791. *Elaboration Products of Eucarvone.**

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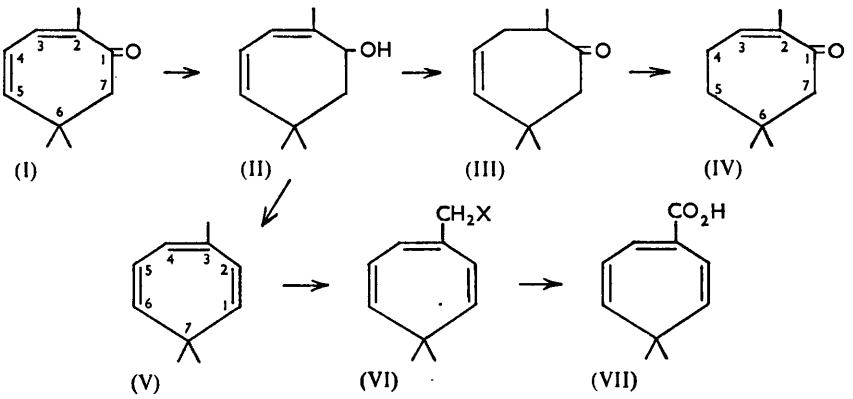
Eucarvone has been converted into thujic acid. Selenium dioxide oxidises eucarvone and α-dihydroeucarvone in an unexpected fashion, producing hydroxy-ketones.

Although eucarvone (I) was one of the first *cyclo*heptane derivatives to be prepared [1] its reactions have not been explored during the recent intensive study of this ring system. This is all the more surprising as its carbon skeleton is identical with that of thujic acid (VII), the interesting *cyclo*heptatriene derivative which occurs together with the thujaplicins in the heart-wood of the Western red cedar (*Thuja plicata* D. Don).[2] Although thujic acid has been synthesised from 4 : 4-dimethyl*cyclo*heptanone [3] the bromination–dehydrobromination procedure employed was not unequivocal from the structural point of view and the yield was small. It was decided, therefore, to attempt a conversion of eucarvone into thujic acid.

Reduction of eucarvone with lithium aluminium hydride gave the expected 2 : 6 : 6-trimethyl*cyclo*hepta-2 : 4-dien-1-ol (II). However, if care was not taken during the



working up, this product isomerised almost completely to α-dihydroeucarvone (III) which had previously been prepared by reduction of eucarvone with sodium and alcohol and oxidation of the monounsaturated alcohol thus produced.[4] [Although (III) was the structure proposed by the earlier workers, it is pertinent to note that the alternative position of the ·CH=CH· grouping is not excluded by the properties of the compound and has certain mechanistic advantages.[5]] This prototropic rearrangement took place in almost quantitative yield when the alcohol (II) was distilled with a trace of sulphuric acid. More drastic acid treatment of both the alcohol (II) and the ketone (III) led to a further rearrangement giving the conjugated ketone, β-dihydroeucarvone (IV). This sensitivity of alcohol (II) towards acidic reagents meant that the use of such reagents to achieve dehydration to the *cyclo*heptatriene (V) met with only limited success. Heating the alcohol with potassium hydrogen sulphate, dipotassium pyrosulphate, or toluene-*p*-sulphonic acid gave a small yield of the hydrocarbon (V) but the major product was α- or β-dihydroeucarvone, depending on the temperature used. Conversion of the alcohol (II) into the corresponding chloro-compound, followed by dehydrochlorination under various

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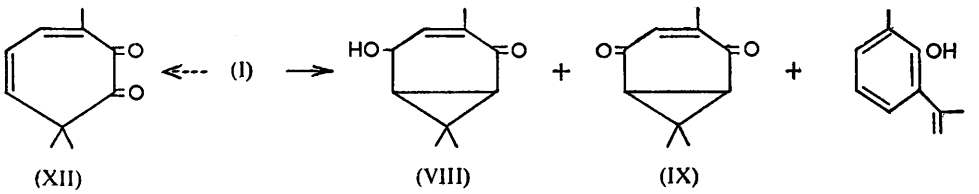
[1] Baeyer, *Ber.*, 1894, **27**, 810; Wallach, *Annalen*, 1905, **339**, 94.
[2] Gripenberg, *Acta Chem. Scand.*, 1949, **3**, 1137.
[3] *Idem, ibid.*, 1951, **5**, 995; 1952, **6**, 854.
[4] For references see Simonsen, "The Terpenes," Vol. II, Cambridge Univ. Press, 1949, pp. 86—94.
[5] We thank Professor D. H. R. Barton, F.R.S., for discussions of this point.

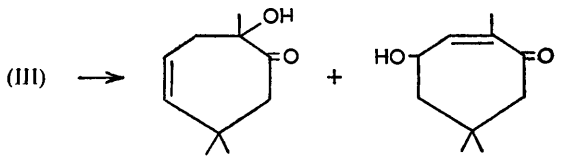
conditions, failed to give this triene (V). Finally a good yield of triene (V) was obtained by the dehydration of the alcohol with boric acid.[6] The structure of the triene (V) was confirmed by its light-absorption properties, by its oxidation to dimethylmalonic acid, and by its hydrogenation to 1 : 1 : 4-trimethyl*cyclo*heptane, identified by comparison with an authentic sample. Treatment of the hydrocarbon (V) with *N*-bromosuccinimide gave the bromo-derivative (VI; X = Br) which was converted into the corresponding acetoxy-compound (VI; X = OAc) by tetraethylammonium acetate, a reagent which accomplishes replacement of an allylic bromine atom without the incursion of an anionotropic rearrangement.[7] Methanolysis of the acetate gave the corresponding alcohol (VI; R = OH) which was then oxidised with chromium trioxide in the cold. Steam-distillation of the crude product gave a small yield of thujic acid (VII), identical with the naturally occurring compound.

In view of the current interest in tropolones it was thought interesting to attempt the oxidation of eucarvone to the α-diketone (XII), in which the *gem.*-dimethyl group blocks enolisation to a true tropolone.

Treatment of eucarvone with the obvious reagent, selenium dioxide, gave as main product a conjugated hydroxy-ketone (VIII); by-products were a conjugated enedione



(XII) (VIII) (IX)



(X) (XI)

(IX), and a mixture of phenols of which 2-methyl-6-*iso*propenylphenol was identified as one component by isolation of its dimer. The key reaction in the determination of the structure of the hydroxy-ketone (VIII) was the production of *cis*-caronic acid on oxidation. A detailed description of the argument in favour of structure (VIII) is not given as this part of the work has been anticipated by a recent publication which gives other examples of reactions of eucarvone involving similar ring-bridging.[8]

As this direct route to the diketone (XII) had failed, an indirect approach was tried, namely, oxidation of α-dihydroeucarvone (III) by selenium dioxide to an α-diketone which should be convertible by dehydrogenation into (XII). It was felt that the " insulation " between the carbonyl group and the double bond in α-dihydroeucarvone would render rearrangements less likely. In practice this reaction gave two isomeric hydroxy-ketones, $C_{10}H_{16}O_2$, readily separable by a remarkably large difference in boiling point. Their structural assignment as (X) and (XI) was shown by the following evidence. The ultraviolet and infrared absorption of the compound (XI) indicated it to be a hydroxylated αβ-unsaturated ketone containing a trisubstituted double bond. Treatment with manganese dioxide converted it into an enedione, thus showing the hydroxyl group to be both secondary and allylic. It was unaffected by periodic acid, but ozonolysis and

[6] Brandenberg and Galat, *J. Amer. Chem. Soc.*, 1950, **72**, 3275.
[7] Owen and Smith, *J.*, 1952, 4035.
[8] Corey, Burke, and Remers, *J. Amer. Chem. Soc.*, 1956, **78**, 174, 180; cf. Campbell, Baldoni, and Campbell, Abs. 119th Meeting of the Amer. Chem. Soc., 1951, p. 6L.

oxidation of the ozonide produced ββ-dimethylglutaric acid. All these reactions are fully compatible with the formulation (XI) and this was confirmed by dehydration of the compound whereby eucarvone was produced in good yield.

The light-absorption properties of the isomer (X) indicated it to be a hydroxylated, non-conjugated ketone containing a disubstituted *cis*-double bond. It was unaffected by manganese dioxide but was quantitatively cleaved by 1 mol. of periodic acid, thus indicating that the hydroxyl and the carbonyl group were vicinal. As the compound was not affected by bismuth oxide,[9] a specific reagent for the oxidation of secondary α-hydroxy-ketones, the presence of a tertiary α-hydroxy-ketone system was suggested. Permanganate oxidation of the compound (X) gave αα-dimethylsuccinic acid. These findings point to the structure (X) for this product (as in the starting α-dihydroeucarvone, a $\Delta^{3:4}$-structure is an alternative possibility). Inspection of this structure suggested that it too should yield eucarvone on dehydration. Although the product of this reaction was isomeric with eucarvone and closely resembled the latter in physical properties, the derivatives of the two ketones were not identical. Further, the tetrahydro-derivative of the new ketone was not tetrahydroeucarvone (2 : 6 : 6-trimethyl*cyclo*heptanone), thus indicating that a skeletal rearrangement had taken place. (An attractive hypothesis to account for these facts is the occurrence of a transannular Nametkin rearrangement to give 3 : 7 : 7-trimethyl*cyclo*hepta-2 : 4-dien-1-one. This possibility was disproved by the non-identity of the tetrahydroketone with 2 : 2 : 6-trimethyl*cyclo*heptanone, authentic derivatives of which were kindly supplied by Dr. O. Jeger.) The structure of this rearrangement product is being investigated. Another unexpected property of this product (X) was its reaction with 2 : 4-dinitrophenylhydrazine; in methanol, ethanol, and acetic acid the corresponding methoxy-, ethoxy-, and acetoxy-2 : 4-dinitrophenylhydrazones were obtained. More surprisingly the ultraviolet absorption of these derivatives showed them to be αβ-unsaturated. The simplest explanation is that, in the acidic medium, the compound (X) undergoes an anionotropic replacement rearrangement to the corresponding substituted hydroxy-ketone derived from (XI).

The above results show that the 7-methylene group in eucarvone and its derivatives is well shielded by the *gem.*-dimethyl group. In a further attempt to attack this protected site, use was made of the finding that *N*-iodosuccinimide reacts with enol acetates to give α-iodo-ketones, whereas other carbon–carbon double bonds are unaffected.[10] Application of this reaction to the enol acetate of eucarvone (prepared by interaction of the ketone and *iso*propenyl acetate) gave no pure compound.

Experimental

Ultraviolet spectra were determined with a Unicam SP500 Spectrophotometer, and infrared spectra with a Perkin–Elmer Model 21 Spectrophotometer. Only the important maxima in the infrared spectra are recorded.

Eucarvone (I).—This was prepared in 65% yield from carvone by Wallach's method.[1] It had b. p. 82—84°/8 mm., n_D^{25} 1·5065, $\lambda_{max.}$ (in MeOH) 300 mμ (log ε 3·82), $\nu_{max.}$ (thin film) 1660 (conjugated C=O), 1387, 1364 (CMe_2), 828 cm.$^{-1}$ (>C=CH−). The 2 : 4-dinitrophenylhydrazone, red plates (from ethanol–ethyl acetate), had m. p. 151—152°, $\lambda_{max.}$ (in $CHCl_3$) 388 mμ (log ε 4·44).

2 : 6 : 6-*Trimethyl*cyclo*hepta*-2 : 4-*dien*-1-*ol* (II).—To a stirred slurry of powdered lithium aluminium hydride (6 g.) in ether (200 ml.) was added, during 30 min., a solution of eucarvone (20 g.) in ether (100 ml.). After a further 10 min. the excess of hydride was destroyed by addition of ethyl acetate, followed by water. The solids were dissolved by adding the minimum amount of ice-cold 5% sulphuric acid. Ether-extraction, washing (sodium hydrogen carbonate solution and water), drying ($MgSO_4$), and distillation gave the *alcohol* (18·5 g., 92%), b. p. 94—97°/10 mm., n_D^{18} 1·4980, $\lambda_{max.}$ (in MeOH) 248·5 mμ (log ε 3·76), (in hexane) 248 mμ (log ε 3·56) [cf. *cyclo*hepta-1 : 3-diene :[11] $\lambda_{max.}$ (in *iso*octane) 248 mμ (log ε 3·87)], $\nu_{max.}$ (thin film) 3375 (OH), 1647 (−CH=CH−), 1380, 1368 (CMe_2), 1032 cm.$^{-1}$ (C−OH) (Found: C, 78·55; H, 10·3. $C_{10}H_{16}O$

[9] Rigby, *J.*, 1951, 793.
[10] Djerassi and Lenk, *J. Amer. Chem. Soc.*, 1953, **75**, 3493.
[11] Pesch and Friess, *ibid.*, 1950, **72**, 5756.

requires C, 78·9; H, 10·6%). The *phenylurethane*, m. p. 110—111°, crystallised from light petroleum (b. p. 60—80°) in needles (Found : N, 5·4. $C_{17}H_{21}O_2N$ requires N, 5·15%).

It is essential in the working-up that the time of contact with acid be kept to a minimum and that the temperature be kept below 5° in order to avoid extensive isomerisation of the product to α-dihydroeucarvone (see below).

Interconversions of the Alcohol (II), *α-Dihydroeucarvone* (III), *and β-Dihydroeucarvone* (IV).—(*a*) The alcohol (II) (2 g.) was distilled in the presence of a trace of sulphuric acid (one drop of a 10% ethanolic solution). Fractionation of the distillate gave α-dihydroeucarvone (III) (1·72 g., 86%), b. p. 74—76°/9 mm., n_D^{17} 1·4686, $\lambda_{max.}$ (in MeOH) 290 mμ (log ε 1·57), $\nu_{max.}$ (thin film) 1708 (non-conjugated C=O), 1370, 1390 (CMe_2), 689 cm.$^{-1}$ (*cis* $-CH=CH-$). The semicarbazone formed needles, m. p. 188—189°, from aqueous ethanol (lit.,[4] m. p. 189—191°). The 2 : 4-*dinitrophenylhydrazone*, prepared by using a solution of 2 : 4-dinitrophenylhydrazine in acetic acid, crystallised from ethanol in yellow prisms, m. p. 120—121°, $\lambda_{max.}$ (in $CHCl_3$) 367 mμ (log ε 4·38) (Found : C, 58·0; H, 6·25; N, 16·9. $C_{16}H_{20}O_4N_4$ requires C, 57·8; H, 6·05; N, 16·85%). If the reagent was used in the more usual medium of ethanolic sulphuric acid the 2 : 4-dinitrophenylhydrazone of β-dihydroeucarvone (see below) was obtained.

(*b*) The alcohol (II) (5 g.) was distilled in the presence of toluene-*p*-sulphonic acid; a considerable quantity of resin remained in the flask. Fractionation of the distillate gave β-dihydroeucarvone (IV) (3·5 g., 70%), b. p. 78—79°/7 mm., n_D^{25} 1·4777, $\lambda_{max.}$ (in MeOH) 239 mμ (log ε 3·79), $\nu_{max.}$ (thin film) 1664 (conjugated C=O), 835 cm.$^{-1}$ (>C=CH−). The semicarbazone formed needles, m. p. 203—204° (decomp.; sealed tube), from aqueous ethanol (lit.,[4] m. p. 202°), and the oxime plates, m. p. 121—122°, from aqueous ethanol (lit.,[4] m. p. 122°). The 2 : 4-*dinitrophenylhydrazone* crystallised from ethyl acetate in orange-red plates, m. p. 194—195°, $\lambda_{max.}$ (in $CHCl_3$) 380·5 mμ (log ε 4·4) (Found : C, 57·7; H, 5·85; N, 16·9%).

(*c*) α-Dihydroeucarvone (10 g.), ethanol (25 ml.), and concentrated sulphuric acid (1 ml.) were heated under reflux for 45 min. The mixture was poured into saturated sodium carbonate solution, and the product isolated by means of ether. Drying ($MgSO_4$) and distillation gave β-dihydroeucarvone (IV) (9·2 g., 92%), b. p. 86—88°/11 mm., n_D^{25} 1·4773, identified further by its derivatives described under (*b*).

7-*Chloro*-1 : 5 : 5-*trimethyl*cyclo*hepta*-1 : 3-*diene*.—To an ice-cold solution of alcohol (II) (5 g.) and dimethylaniline (6 g.) in chloroform (10 ml.), was added during 30 min. with stirring a solution of thionyl chloride (5 g.) in chloroform. After 10 hr. at −10° the mixture was shaken with ice-cold N-hydrochloric acid (50 ml.) and extracted with chloroform. Washing (sodium hydrogen carbonate solution and water), drying ($MgSO_4$), and distillation gave the fragrant *chloro-compound* (3·9 g., 70%), b. p. 78—80°/8 mm., n_D^{18} 1·4992, $\lambda_{max.}$ (in MeOH) 243 mμ (log ε 3·48) (Found : C, 70·05; H, 8·85; Cl, 20·4. $C_{10}H_{15}Cl$ requires C, 70·35; H, 8·85; Cl, 20·8%). The compound gradually polymerised to a dark resin.

3 : 7 : 7-*Trimethyl*cyclo*hepta*-1 : 3 : 5-*triene* (V).—A mixture of the alcohol (II) (20 g.) and boric acid (10 g.) was gradually heated until it became homogeneous; the bath-temperature was then raised rapidly to 350°. The distillate was dissolved in light petroleum (b. p. 40—60°) and dried ($MgSO_4$), and the solvent removed through a column. Fractionation gave the *hydrocarbon* (V) (11 g., 61%) as a mobile liquid, b. p. 62°/20 mm., n_D^{20} 1·4948, $\lambda_{max.}$ (in hexane) 268 mμ (log ε 3·4) (cf. *cyclo*hepta-1 : 3 : 5-triene :[12] $\lambda_{max.}$ 260 mμ), $\nu_{max.}$ (thin film) 1625, 1610 (C=C), 1375, 1360 (CMe_2), 816 (>C=CH−), 664 cm.$^{-1}$ (*cis* $-CH=CH-$). The hydrocarbon gave a deep red colour with tetranitromethane in carbon tetrachloride (Found : C, 89·6; H, 10·7. $C_{10}H_{14}$ requires C, 89·5; H, 10·5%). A higher-boiling fraction from the preparation (4·6 g.), b. p. 82°/12 mm., n_D^{19} 1·4699, proved to be α-dihydroeucarvone, identified by its derivatives described above.

The hydrocarbon (V) (1 g.) and maleic anhydride (0·8 g.) were heated together in a sealed tube for 3 hr. at 100°. The resulting pasty mass was treated with the solvent system light petroleum–benzene–methanol–water in the manner described by Lythgoe *et al.*[13] Drying and evaporation of the combined top layers gave a gum which solidified on being triturated with ethanol. Crystallisation from the same solvent gave the *adduct* as prisms, m. p. 112—114° (Found : C, 71·95; H, 6·4. $C_{14}H_{16}O_3$ requires C, 72·4; H, 6·95%); microhydrogenation showed 2·08 double bonds. Oxidation of the hydrocarbon (V) (1 g.) in benzene solution with aqueous potassium permanganate buffered with carbon dioxide gave dimethylmalonic acid (60 mg.), m. p. and mixed m. p. 189—191° (decomp.; rapid heating); decarboxylation gave *iso*butyric acid, identified as its *S*-benzylthiuronium salt, m. p. and mixed m. p. 141—143°.

[12] Dryden, *J. Amer. Chem. Soc.*, 1954, **76**, 2841.
[13] Anet, Lythgoe, Silk, and Trippett, *J.*, 1953, 320.

1 : 1 : 4-*Trimethylcycloheptane*.—(*a*) Catalytic hydrogenation of eucarvone in ethanol over 10% palladium–charcoal gave a quantitative yield of 2 : 6 : 6-trimethyl*cyclo*heptanone,[4] b. p. 79—80°/12 mm., n_D^{19} 1·4558, $\nu_{max.}$ (thin film) 1700 (C=O), 1383, 1369 cm.$^{-1}$ (CMe_2); the 2 : 4-*dinitrophenylhydrazone*, purified by chromatography in light petroleum on kieselguhr–bentonite,[14] crystallised from light petroleum (b. p. 60—80°) in orange plates, m. p. 137—137·5°, $\lambda_{max.}$ (in $CHCl_3$) 365 mμ (log ε 4·34) (Found: C, 57·7; H, 6·35; N, 16·45. $C_{16}H_{22}O_4N_4$ requires C, 57·45; H, 6·65; N, 16·75%). The saturated ketone (3·5 g.), 60% hydrazine hydrate (5 ml.), sodium hydroxide (2·3 g.), and diethylene glycol (20 ml.) were heated under reflux for 2 hr. (internal temp. 137°). The mixture was then distilled until the internal temperature reached 200° and the distillate was set aside. The residual solution was then heated under reflux for 12 hr., combined with the distillate, diluted with water (100 ml.), and extracted with ether. The combined extracts were washed with 2N-hydrochloric acid and water and dried ($MgSO_4$). Evaporation and distillation gave 1 : 1 : 4-*trimethylcycloheptane* (1·8 g., 59%), b. p. 72—72·5°/35 mm., n_D^{15} 1·4438 (Found: C, 85·45; H, 14·4. $C_{10}H_{20}$ requires C, 85·65; H, 14·35%), $\nu_{max.}$ 2920 (CH stretching), 1462 (CH deformation), 1383, 1364 (CMe_2 deformation), 1182, 814 cm.$^{-1}$ (CMe_2 skeletal).

(*b*) A solution of the trimethyl*cyclo*heptatriene (V) (1·32 g.) in acetic acid (10 ml.) was hydrogenated over platinic oxide (200 mg.); after 3 mols. of hydrogen had been absorbed reaction ceased. The filtered solution was poured into excess of saturated sodium carbonate solution. The organic layer was dried and distilled, to give a product (1·1 g.), b. p. 86°/56 mm., n_D^{25} 1·4412. The infrared spectrum was identical with that of 1 : 1 : 4-trimethyl*cyclo*heptane prepared as in (*a*).

Thujic Acid (VII).—A mixture of the trimethyl*cyclo*heptatriene (1 g.), carbon tetrachloride (10 ml.), chloroform (3 ml.), powdered *N*-bromosuccinimide (1·3 g.), and a trace of benzoyl peroxide was heated under reflux for 20 min., by which time all the solids were floating on the surface of the liquid. The mixture was cooled to 0°, the succinimide (0·7 g., 97%) was filtered off, and the filtrate freed from solvents under reduced pressure. The crude 3-bromomethyl-7 : 7-dimethyl*cyclo*hepta-1 : 3 : 5-triene (VI; X = Br) (1·5 g.) in acetone (10 ml.) was added slowly to a solution of tetraethylammonium acetate (5 g.) in acetone (50 ml.) with cooling to <5°. The orange solution deposited tetraethylammonium bromide overnight. The bromide was filtered off and washed with acetone; the combined filtrates were concentrated under reduced pressure. Addition of water and isolation by means of ether gave 3-acetoxymethyl-7 : 7-dimethyl*cyclo*hepta-1 : 3 : 5-triene (VI; X = OAc) (1·0 g.), b. p. 94—97°/12 mm., n_D^{19} 1·5435. This product was added to methanolic sodium methoxide [from sodium (0·1 g.) and methanol (20 ml.)] and set aside at room temperature for 18 hr. Dilution with water and isolation by means of ether gave 3-hydroxymethyl-7 : 7-dimethyl*cyclo*hepta-1 : 3 : 5-triene (0·35 g.), b. p. 100—102°/12 mm., $n_D^{19\cdot5}$ 1·5200. A solution of this hydroxy-compound in acetone (10 ml.) was treated with a solution of chromium trioxide (0·31 g.) in water (20 ml.), the temperature being kept below 20°. After 1 hr. the mixture was thoroughly extracted with ether and the extracts were shaken with sodium carbonate solution; acidification by dilute sulphuric acid and isolation with ether gave an acidic gum (80 mg.) which crystallised. This product was steam-distilled in nitrogen; the distillate was cooled to 0° and the resulting solid (40 mg.) filtered off and dried. Repeated crystallisation from light petroleum (b. p. 40—60°) gave thujic acid as needles, m. p. 78—80° undepressed on admixture with an authentic sample of the naturally occurring material (m. p. 81—82°). The infrared absorptions of the natural and the synthetic material were almost identical: $\nu_{max.}$ (in CS_2) 2980, 1690, 1415, 1380, 1365, 1285, 1260, 1200, 1095, 1040, 935, 825, 760, 740, 725, 670 cm.$^{-1}$. Isomerisation by heating the synthetic product with concentrated hydrochloric acid for 30 min. gave cumic acid, m. p. 114—116° undepressed on admixture with an authentic specimen (m. p. 114—116°). (The intermediates in the above preparation rapidly polymerised.)

Oxidation of Eucarvone by Selenium Dioxide.—A solution of eucarvone (30 g.) and selenium dioxide (22·2 g.) in ethanol (550 ml.) and water (20 ml.) was heated under reflux for 16 hr. The solution was concentrated to 100 ml., the precipitated selenium filtered off, and the filtrate poured into N-sulphuric acid (1 l.). Extraction with chloroform gave an oil which was heated in benzene (250 ml.) under reflux with silver powder (30 g.); filtration and evaporation gave a viscous, red oil which partially solidified. As direct crystallisation was attended by considerable loss the crude product was freed from high-boiling selenium-containing by-products by flash-distillation under a high vacuum. The distillate (21·3 g.), b. p. 40—180°/0·1 mm., was treated

[14] Elvidge and Whalley, *Chem. and Ind.*, 1955, 589.

with light petroleum (40 ml.; b. p. 40—60°) and set aside at −10°. The crystals thus obtained were crystallised from light petroleum (b. p. 60—80°), to give 3 : 7 : 7-*trimethyl*bicyclo[4 : 1 : 0]-*hept*-3-*en*-5-*ol*-2-*one* (VIII) (4·7 g.) as prisms, m. p. 85—86°, $\lambda_{max.}$ (in MeOH) 229 mμ (log ε 4·04) (Found: C, 72·3% H, 8·4. $C_{10}H_{14}O_2$ requires C, 72·25; H, 8·5%).

The petroleum mother-liquors were extracted with 10N-sodium hydroxide, and the extracts acidified with hydrochloric acid. Isolation by means of ether gave a phenolic fraction (5·9 g.), b. p. 86—87°/10 mm., n_D^{25} 1·5392. A portion of this product was heated with iodine at 60° for 30 min. and steam-distilled. Crystallisation of the solid steam-distillate from light petroleum (b. p. 60—80°) gave prisms, m. p. 68—70°, undepressed by an authentic sample of 2′-hydroxy-2 : 4 : 4 : 8 : 3′-pentamethylflavan (m. p. 69—70°); the acetyl derivatives (m. p. 101—102°) were also identical.[15]

Evaporation and distillation of the petroleum mother-liquors after alkaline extraction gave unchanged eucarvone (1·9 g.), b. p. 80—82°/8 mm., and a higher-boiling fraction, b. p. 115—120°/9 mm. which partially solidified. Crystallisation from light petroleum (b. p. 80—100°) gave massive yellow prisms (1·2 g.), m. p. 91—92°, of 3 : 7 : 7-*trimethyl*bicyclo[4 : 1 : 0]*hept*-3-*ene*-2 : 5-*dione* (IX) [identical with the product obtained by manganese dioxide oxidation of the hydroxy-ketone (VIII)], $\lambda_{max.}$ (in MeOH) 240 mμ (log ε 4·12) (Found: C, 73·6; H, 7·35. $C_{10}H_{12}O_2$ requires C, 73·2; H, 7·35%). The *mono*-2 : 4-*dinitrophenylhydrazone* crystallised from ethanol–benzene in orange-red plates, m. p. 171—173° (Found: N, 16·2. $C_{16}H_{18}O_5N_4$ requires N, 16·25%); the *bis*-2 : 4-*dinitrophenylhydrazone* formed scarlet needles, charring at *ca.* 250° (from nitrobenzene), $\lambda_{max.}$ (in $CHCl_3$) 408 mμ (log ε 4·7) (Found: C, 50·2; H, 3·95; N, 21·25. $C_{22}H_{20}O_8N_8$ requires C, 50·4; H, 3·85; N, 21·35%).

Oxidation of α-Dihydroeucarvone by Selenium Dioxide.—A solution of α-dihydroeucarvone (20 g.) and selenium dioxide (15·2 g.) in ethanol (300 ml.) and water (10 ml.) was heated under reflux for 16 hr. and the crude product isolated and freed from selenium as described in the above cognate preparation. Fractional distillation gave two products. The lower-boiling material (9·5 g.) was in the sequel shown to be 2-*hydroxy*-2 : 6 : 6-*trimethyl*cyclo*hept*-4-*en*-1-*one* (X), b. p. 88—90°/8 mm., n_D^{18} 1·4845, showing no intense absorption above 200 mμ, $\nu_{max.}$ (thin film) 3460 (OH), 1708 (non-conjugated C=O), 1660 (C=C), 1386, 1370 (CMe_2), 1070 (C−OH), 682 cm.$^{-1}$ (*cis* −CH=CH−) (Found: C, 71·95; H, 9·25. $C_{10}H_{16}O_2$ requires C, 71·4; H, 9·6%). Microhydrogenation showed 1·1 double bonds. The *phenylurethane* crystallised from light petroleum (b. p. 80—100°) in stout needles, m. p. 131° (Found: C, 70·9; H, 7·45. $C_{17}H_{21}O_3N$ requires C, 71·05; H, 7·35%). With 2 : 4-dinitrophenylhydrazine the derivatives obtained differed in composition according to the solvent used; methanolic sulphuric acid gave an O-*methyl dinitrophenylhydrazone*, red tablets, m. p. 157—158° (from ethanol–ethyl acetate) (Found: C, 56·2; H, 6·3; N, 15·6. $C_{17}H_{22}O_5N_4$ requires C, 56·35; H, 6·1; N, 15·45%); ethanolic sulphuric acid gave the O-*ethyl analogue*, orange plates m. p. 150° (from ethanol–ethyl acetate), $\lambda_{max.}$ (in $CHCl_3$) 375 mμ (log ε 4·43) (Found: C, 57·55; H, 6·35; N, 14·7. $C_{18}H_{24}O_5N_4$ requires C, 57·45; H, 6·45; N, 14·9%); acetic acid gave the O-*acetyl analogue*, yellow or red plates (polymorphs), m. p. 179—180° (from ethanol–ethyl acetate), $\lambda_{max.}$ (in $CHCl_3$) 371 mμ (log ε 4·45) (Found: C, 55·1; H, 5·85; N, 14·6. $C_{18}H_{22}O_6N_4$ requires C, 55·4; H, 5·7; N, 14·35%).

The higher-boiling fraction (6 g.) proved to be 4-*hydroxy*-2 : 6 : 6-*trimethyl*cyclo*hept*-2-*en*-1-*one* (XI), b. p. 78—81°/0·1 mm., n_D^{18} 1·5004, λ_{max} (in MeOH) 237 mμ (log ε 3·81), $\nu_{max.}$ (thin film) 3420 (OH), 1666 (conjugated C=O), 1368 (CMe_2), 1042 (C−OH), 837 cm.$^{-1}$ (>C=CH−) (Found: C, 71·45; H, 9·25%). Microhydrogenation showed 0·96 double bond. The *phenylurethane* crystallised from light petroleum (b. p. 80—100°) in needles, m. p. 141—141·5° (Found: C, 70·8; H, 7·55%); the 2 : 4-*dinitrophenylhydrazone* formed crimson prisms, m. p. 152° (from ethanol–ethyl acetate), $\lambda_{max.}$ (in $CHCl_3$) 373·5 mμ (log ε 4·41) (Found: C, 55·15; H, 5·75; N, 15·9. $C_{16}H_{20}O_5N_4$ requires C, 55·15; H, 5·75; N, 16·1%).

Oxidations of the Hydroxy-ketones (X) *and* (XI).—(a) *Periodic acid.* Separate samples (90 mg.) of the isomers were treated with aqueous 0·2M-periodic acid together with sufficient methanol to give homogeneity (a blank was performed simultaneously). After 30 hr. at 20° the solutions were treated with saturated sodium hydrogen carbonate solution (2 ml.), 0·2M-sodium arsenite (10 ml.), and 10% potassium iodide solution. After 15 min. the mixture was titrated with iodine solution. The results showed that compound (X) had consumed 0·91 mol. of periodic acid, whereas the isomer (XI) had only used 0·11 mol. A control with benzoin showed a consumption of 0·94 mol.

(b) *Chromium trioxide in acetic acid.* A solution of the compound (XI) (0·5 g.) and chromium

[15] Baker, Curtis, and McOmie, *J.*, 1952, 1774.

trioxide (0·2 g.) in acetic acid (5 ml.) and water (5 ml.) was kept at room temperature for 12 hr. Excess of oxidising agent was destroyed by methanol, and the product isolated with benzene. Distillation gave 2 : 6 : 6-*trimethyl*cyclo*hept*-2-*ene*-1 : 4-*dione* (0·41 g.), b. p. 110—112°/9 mm., $n_D^{18\cdot5}$ 1·4948, $\lambda_{max.}$ (in MeOH) 244 mμ (log ε 3·95), $\nu_{max.}$ (thin film) 1672 (conjugated C=O), 1620 (C=C), 1372 (CMe_2), 834 cm.$^{-1}$ (>C=CH−) (Found : C, 71·8; H, 8·7. $C_{10}H_{14}O_2$ requires C, 72·2; H, 8·5%). The *mono*-2 : 4-*dinitrophenylhydrazone* formed orange needles, m. p. 190—191° (from ethanol–ethyl acetate), $\lambda_{max.}$ (in $CHCl_3$) 374·5 mμ (log ε 4·46) (Found : C, 55·6; H, 5·2; N, 16·0. $C_{16}H_{18}O_5N_4$ requires C, 55·5; H, 5·25; N, 16·2%); the *bis*-2 : 4-*dinitrophenylhydrazone* crystallised from acetic acid in red needles, m. p. 289° (decomp.), $\lambda_{max.}$ (in $CHCl_3$) 397 mμ (log ε 4·71) (Found : C, 49·8; H, 4·3; N, 21·0. $C_{22}H_{22}O_8N_8$ requires C, 50·2; H, 4·2; N, 21·3%).

Oxidation of the isomer (X) by the same procedure, followed by titration with ferrous ammonium sulphate solution, indicated the oxidising agent consumed to be 96% of that required for the fission of a tertiary α-hydroxy-ketone. No pure entity could be obtained from the products.

(c) *Manganese dioxide.* A solution of the compound (XI) (0·2 g.) in light petroleum (b. p. 40—60°) (25 ml.) was shaken with activated manganese dioxide [16] (2 g.) for 4 days. Filtration, evaporation, and distillation gave the diketone described under (b). The isomeric compound (X) was unaffected by this treatment.

(d) *Potassium permanganate.* Carbon dioxide was passed into a stirred suspension of the compound (X) (0·5 g.) in water (5 ml.) while a solution of potassium permanganate (2·5 g.) in water (40 ml.) was added during 1 hr., and the resulting mixture set aside overnight. Acidification and passage of sulphur dioxide, followed by isolation by means of ethyl acetate, gave a solid product which was recrystallised from benzene. It formed prisms (60 mg.), m. p. 139—141° undepressed on admixture with authentic αα-dimethylsuccinic acid. The same product was obtained by a similar oxidation of the isomer (XI).

(e) *Ozone.* Ozonised oxygen (0·6% of O_3) was passed for 4 hr. through a cooled (−30°) solution of compound (XI) (0·19 g.) in ethyl acetate (5 ml.). Any volatile products were collected in a water-trap; its contents gave no iodoform reaction or positive tests for formaldehyde. The solution was then hydrogenated over 10% palladium–charcoal (0·5 g.), the uptake of hydrogen being almost that required by theory. Removal of solvent under reduced pressure gave a solid residue which showed a strong iodoform reaction. This product was heated for 2 hr. with chromium trioxide (0·35 g.) in 50% acetic acid (10 ml.). Isolation by means of benzene and crystallisation from benzene–light petroleum (b. p. 60—80°) gave ββ-dimethylglutaric acid as prismatic needles, m. p. and mixed m. p. 101°.

Dehydration of the Isomers (X) *and* (XI).—(*a*) A mixture of compound (XI) (0·5 g.) and boric acid (0·2 g.) was heated by a free flame until no further distillate could be obtained. Working up as in the above cognate dehydration and distillation gave a product, b. p. 81—82°/8 mm., n_D^{17} 1·5160, which was shown by its light absorption and properties of its derivatives to be eucarvone.

(*b*) A mixture of the isomer (X) (1·5 g.) and boric acid (0·55 g.) was heated and the product worked up as under (*a*). Distillation gave a pale yellow oil (1·02 g., 74%), b. p. 88—89°/11 mm., n_D^{15} 1·5040, λ_{max} (in MeOH) 299 mμ (log ε 3·7), $\nu_{max.}$ (thin film) 1668 (conjugated C=O), 1384, 1360 (CMe_2), 828 (>C=CH−), 676 cm.$^{-1}$ (*cis* −CH=CH−) (Found : C, 79·8; H, 9·5. $C_{10}H_{14}O$ requires C, 79·95; H, 9·4%). The product gave negative iodoform and Schiff's tests. The 2 : 4-*dinitrophenylhydrazone* crystallised from ethanol–ethyl acetate in crimson needles, m. p. 172—173° (depressed 40° by admixture with eucarvone 2 : 4-dinitrophenylhydrazone), $\lambda_{max.}$ (in $CHCl_3$) 396 mμ (log ε 4·45) (Found : C, 58·1; H, 5·9; N, 16·8. $C_{16}H_{18}O_4N_4$ requires C, 58·15; H, 5·5; N, 16·95%). Oxidation of the ketone with chromium trioxide or ozone by the procedures already described gave αα-dimethylsuccinic acid; no formaldehyde was detected. Catalytic hydrogenation of the ketone with 10% palladium–charcoal ceased after 2·0 mols. of hydrogen had been absorbed. The saturated ketone had b. p. 90°/15 mm., n_D^{25} 1·4520, $\nu_{max.}$ (thin film) 1707 (C=O), 1386, 1367 cm.$^{-1}$ (CMe_2). The 2 : 4-*dinitrophenylhydrazone* crystallised from light petroleum (b. p. 80—100°) in orange plates, m. p. 115—118°, $\lambda_{max.}$ (in $CHCl_3$) 364 mμ (log ε 4·34) (Found : C, 57·7; H, 6·2. $C_{16}H_{22}O_4N_4$ requires C, 57·45; H, 6·65%).

Enol Acetate of Eucarvone.—A mixture of eucarvone (25 g.), *iso*propenyl acetate (150 ml.), and toluene-*p*-sulphonic acid (2 g.) was heated under a 12″ Vigreux column at such a rate that slow distillation took place; fresh *iso*propenyl acetate (100 ml.) was added slowly to maintain the total volume above 100 ml. After 15 hr. solid sodium hydrogen carbonate (20 g.) was added and the excess of reagent evaporated off under reduced pressure. The residual dark oil was

[16] Weedon, *Ann. Reports*, 1952, **49**, 142.

taken up in ether, filtered, washed with sodium hydrogen carbonate solution, and dried. Distillation gave the *enol acetate* (28·7 g., 90%), b. p. 110°/10 mm., n_D^{25} 1·4926, $\lambda_{max.}$ (in hexane) 268 mμ (log ε 3·43) (Found : C, 74·95; H, 8·05. $C_{12}H_{16}O_2$ requires C, 74·95; H, 8·4%).

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