

A STEREOSPECIFIC SYNTHESIS OF (\pm)-FERRUGINOL*

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Abstract—A stereospecific synthesis of (\pm)-ferruginol following the Robinson "ring extension" method has been described. The infra-red spectra of the benzoates of the synthetic and natural ferruginol are found to be identical.

THE phenolic diterpene, ferruginol, comprises the major part of the resin of the Miro tree (*Podocarpus ferruginea*) endemic to New Zealand and was first isolated by Brandt and Newbauer.¹ The structure of ferruginol (X), was established with certainty^{1,2} and its partial syntheses were achieved from podocarpic acid and dehydroabietic acid.³ From a study of thermodynamic dissociation constant data, Barton and Schmeidler⁴ had concluded that the A/C ring junction in the diterpenoids is *trans*, and this was confirmed by the first total synthesis of (\pm)-ferruginol by King *et al.*⁵ However, the synthetic route followed by King *et al.* is not stereospecific, because the important intermediate 1:1-dimethyl-4a-methyl-6-methoxy-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VI) was obtained as a mixture of stereoisomers, from which the natural *trans* isomer was obtained in low yield by a laborious process. It is therefore desirable to develop a stereospecific synthetic route whereby the *trans* isomer could be obtained predominantly. We have now achieved this objective and synthesised 1:1-dimethyl-4a-methyl-6-methoxy-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VI), following the Robinson "ring extension" method⁶ and transformed compound (VI) to (\pm)-ferruginol.

1-Methyl-7-methoxy-3:4-dihydronaphthalene⁷ (I) was oxidised in acetic acid solution with red lead oxide⁸ and the crude diacetate rearranged in dilute alcoholic sulphuric acid to 1-methyl-7-methoxytetralone-2 (II) in 70 per cent yield. Condensation of the β -tetralone (II) with 4-diethylaminobutanone-2-methiodide,⁹ or with methyl vinyl ketone afforded, 6-methoxy-2-keto-4a-methyl-2:3:4:4a:9:10:hexahydrophenanthrene (III), as a very viscous oil, which ultimately crystallised with difficulty to give rhomboid prisms, m.p. 72°. Of the two methods, the Robinson-Mannich base procedure gave superior yields of the ketone (III) (60 per cent) to the methyl vinyl ketone procedure (45 per cent). The ketone (III) gave a deep red

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² W. P. Campbell and D. Todd *J. Amer. Chem. Soc.* 62, 1287 (1940).

³ W. P. Campbell and D. Todd, *J. Amer. Chem. Soc.* 64, 928 (1942).

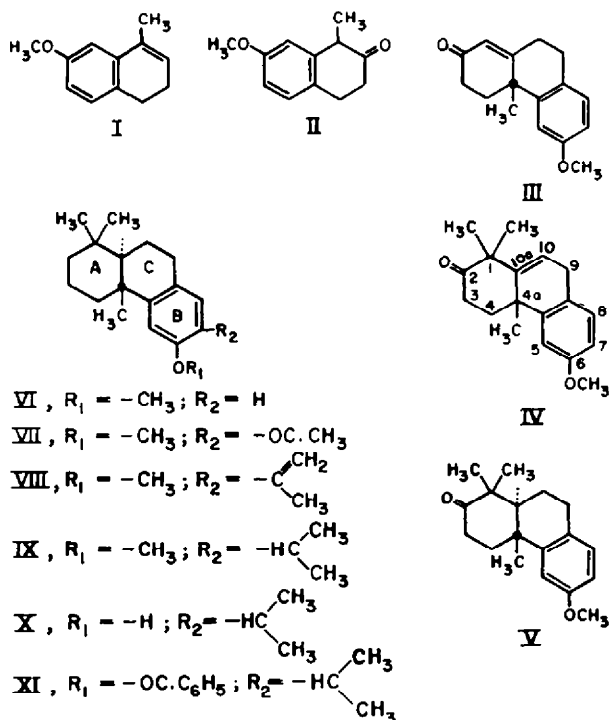
⁴ D. H. R. Barton and G. A. Schmeidler, *J. Chem. Soc.* 1197 (1948).

⁵ F. E. King, T. J. King and J. G. Toplis, *Chem. & Ind.* 108, (1954); *J. Chem. Soc.* 573 (1957).

⁶ E. C. du Feu, F. J. McQuillin and R. Robinson, *J. Chem. Soc.* 53 (1937).

⁷ P. C. Mitter and S. De, *J. Indian Chem. Soc.* 16, 35 (1939).

⁸ W. F. Newhall, S. A. Harris, F. W. Holly, E. L. Johnston, J. W. Richter, E. Walton, A. N. Wilson and K. Folkers, *J. Amer. Chem. Soc.* 77, 5646 (1955).



2:4-dinitrophenylhydrazone, which exists in two different forms, depending upon the solvent from which it was crystallised. When crystallised from acetic acid, it was obtained as rectangular plates, m.p. 242° (dec.), whereas if crystallised from ethyl acetate it was obtained as prisms, m.p. 200° . A *gem*-dimethyl group was then introduced in one step⁹ by allowing the ketone (III) to react with methyl iodide in the presence of potassium *tert*-butoxide in *tert*-butyl alcohol solution, to give 1:1-dimethyl-2-keto-6-methoxy-4*a*-methyl-1:2:3:4:4*a*:9-hexahydrophenanthrene (IV) as a viscous oil. A clear separation of the dimethylated product (IV) from the unreacted ketone (III) could not be achieved by fractional distillation in high vacuum as evidenced by the infra-red spectra data. However, the pure dimethylated product (IV) could be separated from the unreacted product through its crystalline 2:4-dinitrophenylhydrazone by fractional crystallisation from ethyl acetate, and then regenerating the ketone according to the method of Demaecker and Martin,¹⁰ in 55 per cent yield. All efforts to obtain the ketone (IV) in a crystalline form were unsuccessful. The compound (IV) on hydrogenation with 10% palladium-charcoal in acetic acid afforded *trans*-1:1-dimethyl-2-keto-6-methoxy-4*a*-methyl-1:2:3:4:4*a*:9:10:10*a*-octahydrophenanthrene (V). The *trans* configuration is assigned to this compound by a consideration of the following facts:

(1) It is well known that hydrogenation of Δ^5 -steroids invariably leads to the *trans* configuration at the A/B ring junction and compound (IV) is similar in structure to a Δ^5 -steroid.

⁹ R. B. Woodward, A. A. Patchett, D. H. R. Barton, D. A. J. Ives and R. B. Kelly, *J. Amer. Chem. Soc.* **76**, 2852 (1954); *J. Chem. Soc.* 1131 (1957).

¹⁰ J. Demaecker and R. H. Martin, *Nature, Lond.* **173**, 266 (1954).

(2) During the hydrogenation of the compound (IV) the absorption of the catalyst on the α -face of the C-10:10a is not sterically hindered, whereas the β -face is highly hindered by the C-1 β -axial methyl and C-4a angular methyl groups. Consequently the A/C ring junction in compound (V) will be *trans*.

(3) Further, recent work¹¹ on hydrogenation of compounds having similar structure (IV) definitely established that the hydrogenated product will have the *trans* configuration.

The keto group in compound (V) was reduced by Clemmensen's method to give *trans*-1:1-dimethyl-4a-methyl-6-methoxy-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VI) in 75 per cent yield.

An *isopropyl* group was then introduced at the 7- position of the *trans*-octahydrophenanthrene (VI) by a procedure similar to that described by King *et al.* Compound (VI) was subjected to reaction with acetyl chloride in nitrobenzene in presence of aluminium chloride to yield *trans*-1:1-dimethyl-4a-methyl-6-methoxy-7-acetyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VII) in excellent yield. This compound gave the semicarbazone of m.p. 222–223°, already shown to be *trans*,⁵ in 80 per cent yield as the only isomer. This further supports the *trans* structure assigned to compound (VI). Compound (VII) was subjected to Grignard reaction with methylmagnesium iodide to give the carbinol, which upon dehydration with acetic anhydride gave *trans*-1:1-dimethyl-4a-methyl-6-methoxy-7-*isopropenyl*-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VIII). This was smoothly hydrogenated in alcoholic solution over platinum oxide catalyst to yield *trans*-1:1-dimethyl-4a-methyl-6-methoxy-7-*isopropyl*-1:2:3:4:4a:9:10:10a-octahydrophenanthrene, (\pm)-ferruginyl methyl ether (IX). This was then demethylated by heating with pyridine hydrochloride at 160° in an atmosphere of nitrogen to give (\pm)-ferruginol as a resin, which gave a crystalline benzoate, m.p. 132°, and was in good agreement with that described by King *et al.*⁵ Further, confirmation of the structure of the synthetic product was obtained by the identity of the infra-red spectra of the synthetic and natural ferruginyl benzoates.

EXPERIMENTAL*

7-Methoxytetralone-1. This compound was prepared according to the modified procedure described by Krishna Rao and Sukh Dev.¹²

1-Methyl-7-methoxy-3:4-dihydronaphthalene (I). *6-Methoxytetralone-1* was subjected to Grignard reaction with methylmagnesium iodide according to the procedure worked out by Mitter and De.⁷

1-Methyl-7-methoxytetralone-2 (II). A mixture of 36.7 g of *1-methyl-7-methoxy-3:4-dihydronaphthalene*, 0.4 g of sodium acetate, 250 ml of glacial acetic acid and 40.5 ml of acetic anhydride was heated to 55°. The addition of 143 g of red lead oxide was performed with stirring at such a rate that the temperature of the reaction mixture was maintained at 57–59°. After the addition was complete, about 150 ml of acetic acid was removed under reduced pressure, and the residue was diluted with water and extracted with ether. The ether extract was washed with water, 10%

* All melting points and boiling points are uncorrected.

¹¹ G. Stork and W. J. Schwlenberg, *J. Amer. Chem. Soc.* **78**, 250 (1956); J. D. Cocker and T. G. Halsall, *Chem. & Ind.* 1275 (1956); J. L. Beton, T. G. Halsall, E. R. H. Jones and P. C. Phillips, *J. Chem. Soc.* 735 (1957); H. J. Ringold and G. Rosenkranz, *J. Org. Chem.* **22**, 602 (1957); F. Sondheimer and D. Elad, *J. Amer. Chem. Soc.* **79**, 5542 (1957).

¹² G. S. Krishna Rao and Sukh Dev, *J. Indian Chem. Soc.* **34**, 255 (1957).

sodium bicarbonate solution and then with water and dried over anhydrous sodium sulphate. The solvent was removed and 51 g of the crude residue of the diacetate was subjected to hydrolysis without further purification.

A mixture of 51 g of the above diacetate in 80 ml of ethanol, 115 ml of water and 21.5 ml of concentrated sulphuric acid was heated under reflux for 2 hr on a water bath. The mixture was then diluted with large volume of water and extracted with ether. The extract was washed with water and dried over anhydrous sodium sulphate. The solvent was removed and the residue was distilled under vacuum using a 6 in. fractionating column. 1-Methyl-7-methoxytetralone-2 (II), distilled at 125–126°/0.8 mm, n_D^{25} 1.5538, as a colourless liquid; yield 19.1 g (70 per cent) (Found: C, 76.1; H, 7.4. Calc. for $C_{12}H_{14}O_2$: C, 75.8; H, 7.4 per cent).

Semicarbazone of 1-methyl-7-methoxytetralone-2. To a mixture of 1.5 g of semicarbazide hydrochloride and 1.5 g of fused sodium acetate in 10 ml of aqueous alcohol, 0.8 g of the β -tetralone was added, and within a few minutes the semicarbazone separated out in the cold. This was filtered off and crystallised from alcohol to give colourless prisms, m.p. 191–192° (Found: N, 17.2. Calc. for $C_{13}H_{17}O_2N_3$: N, 17.0 per cent).

2-Keto-6-methoxy-4a-methyl-2:3:4:4a:9:10-hexahydrophenanthrene (III). Using a *diethylaminobutaneone 2-methiodide*. To 13.17 g (15.5 ml) of diethylaminobutaneone-2 cooled in ice, 13.12 g (5.8 ml) of methyl iodide was added with constant swirling and in small portions, and swirling continued for $\frac{1}{2}$ hr after addition of methyl iodide, when the methiodide was obtained in a crystalline form. A solution of 17.5 g of β -tetralone in 85 ml of thiophene-free dry benzene was added to the methiodide in an atmosphere of dry nitrogen. A solution of 5.7 g of potassium in 85 ml of absolute alcohol was added with swirling to the mixture cooled in ice. After $\frac{1}{2}$ hr the methiodide has disappeared and a fine precipitate of potassium iodide separated. The contents were left in ice for 1 hr, and then the mixture was gently boiled for $\frac{1}{2}$ hr. An excess of 2 N sulphuric acid was added, the reaction product was diluted with water and the benzene layer was separated. The aqueous layer was extracted twice with ether and the combined ether–benzene extracts were washed with water and dried over anhydrous sodium sulphate. The solvents were removed and the residue on distillation gave 2-keto-6-methoxy-4a-methyl-2:3:4:4a:9:10-hexahydrophenanthrene, b.p. 115–120° (bath temperature)/0.004 mm, as a very viscous liquid; yield 19 g. This was dissolved in 20 ml of ether and kept at 0°. After 1 week the product slowly crystallised and it was kept at 0° for 24 hr and filtered off (13.5 g, 60 per cent), m.p. 69°. The analytical sample was crystallised twice from light petroleum (boiling range 40–60°), m.p. 73° (Found: C, 79.3; H, 7.5. Calc. for $C_{16}H_{28}O_2$: C, 79.1; H, 7.6 per cent).

2:4-Dinitrophenylhydrazone of (III). A sample of 0.5 g of the ketone was treated with an alcoholic solution of 2:4-dinitrophenylhydrazine sulphate, and the crystalline 2:4-dinitrophenylhydrazone thus formed was filtered off. After two crystallisations from acetic acid, the m.p. 241–242° was constant; shining deep red rectangular plates were obtained. (Found: C, 62.9; H, 5.5; N, 12.8. Calc. for $C_{13}H_{17}O_2N_3$: C, 62.6; H, 5.3; N, 13.3 per cent).

The crude 2:4-dinitrophenylhydrazone was twice crystallised from ethyl acetate to the constant m.p. 200°; shining deep red prisms were obtained. (Found: C, 62.6; H, 5.4. Calc. for $C_{13}H_{17}O_2N_3$: C, 62.6; H, 5.3 per cent).

2-Keto-6-methoxy-4a-methyl-2:3:4:4a:9:10-hexahydrophenanthrene (III) using *methyl vinyl ketone*. A solution of 9.35 g of 1-methyl-7-methoxytetralone-2 in 40 ml of alcohol was treated under nitrogen with a solution of 6.3 ml of 40% benzyltrimethylammonium hydroxide solution in 40 ml of alcohol, and the mixture was cooled to 0°. A solution of 4 ml of 85% methyl vinyl ketone in 40 ml of alcohol was added with stirring during $\frac{1}{2}$ hr. The stirring was continued for 1 hr at 0°, and the solution was then refluxed for $\frac{1}{2}$ hr. The reaction mixture was cooled and acidified with 2 N sulphuric acid, and diluted with water and extracted with ether. The ether extract was washed with water, sodium bicarbonate solution and finally with water until neutral. After drying over anhydrous sodium sulphate, the solvent was removed and the residue was distilled as above. The product was dissolved in 5 ml of ether and kept at 0°, when 5.4 g (45 per cent) of 2-keto-6-methoxy-4a-methyl-2:3:4:4a:9:10-hexahydrophenanthrene crystallised as light-yellow prisms, m.p. 70°. The mixed melting point with the product obtained by the previous method showed no depression.

1:1-Dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9-hexahydrophenanthrene (IV). To a solution of 5.9 g of potassium in 200 ml of *tert.*-butyl alcohol was added 12 g of 2-keto-6-methoxy-4a-methyl-2:3:4:4a:9:10-hexahydrophenanthrene, and the mixture was mechanically stirred until the solid dissolved. The solution was cooled in ice and 42.6 g of methyl iodide was added. The mixture was stirred at room temperature for 2 hr, when potassium iodide separated, and after refluxing for $\frac{1}{2}$ hr most of the solvent was removed under reduced pressure. The residue was treated with water and the product was extracted with ether and after removal of the solvent, 13 g of the crude product was purified through its 2:4-dinitrophenylhydrazone as described below:

Preparation of the pure 2:4-dinitrophenylhydrazone of (IV). A mixture of 9.5 g of 2:4-dinitrophenylhydrazine, 500 ml of alcohol and 20 ml of concentrated hydrochloric acid was heated under reflux on a water bath. When all the solid had dissolved, the solution was filtered and cooled to room temperature. To the solution 13 g of the crude ketone in 200 ml of alcohol was added, and the mixture was stirred. The 2:4-dinitrophenylhydrazone was filtered off and washed with a little cold alcohol, and, after drying, the product weighed 19 g and was crystallised from ethyl acetate. The first crop of 13 g melted at 212°, and the subsequent fractions consisted of a mixture of 2:4-dinitrophenylhydrazones of the original ketone and the methylated product, and could not be purified. The analytical sample was crystallised once more from ethyl acetate and the m.p. 213° was constant; orange red prisms were obtained. (Found: C, 64.0; H, 5.9. Calc. for $C_{24}H_{26}O_5N_4$: C, 64.0; H, 5.8 per cent).

The 2:4-dinitrophenylhydrazone of 1:1-dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9-hexahydrophenanthrene crystallised from glacial acetic acid with a molecule of solvent, m.p. 238–240° (dec.) (Found: N, 11.1. Calc for $C_{24}H_{26}O_5N_4$: CH_3COOH : N, 11.0 per cent).

Regeneration of the ketone (V) from its 2:4-dinitrophenyl-drazone. A solution of 12 g of the 2:4-dinitrophenylhydrazone in 1500 ml of acetone and 50 ml of concentrated hydrochloric acid was refluxed for 1 hr under nitrogen on a steam-bath. It was cooled and a solution of 60 g of stannous chloride in 250 ml of concentrated hydrochloric acid and 330 ml of water was added and refluxed for 2 hr. The acetone was removed under reduced pressure, and the residue was diluted with 1 l. of water and extracted with benzene, and the extract was washed with N hydrochloric acid until

the washings were colourless and then with water until neutral. The benzene was removed and the residue was slowly distilled from an air-bath kept at 120–125°/0.004 mm. 1:1-Dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9-hexahydrophenanthrene (IV) was obtained as a viscous oil; yield 7.45 g (55 per cent) (Found: C, 79.9; H, 8.2. Calc. for $C_{18}H_{22}O_2$: C, 79.9; H, 8.2 per cent).

All attempts to crystallise the oil were unsuccessful.

trans-1:1-Dimethyl-2-keto-5-methoxy-4a-methyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (V). A solution of 7.4 g of 1:1-dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9-hexahydrophenanthrene in 100 ml of glacial acetic acid was hydrogenated in the presence of 0.5 g of 10% palladium on charcoal at room temperature. After the calculated amount of hydrogen had been absorbed, the solution was filtered and the acetic acid was removed under reduced pressure. The residue was dissolved in benzene and washed with water, sodium bicarbonate solution and again with water. The solvent was removed and the product was distilled in vacuum. *trans*-1:1-Dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene distilled at 180–184°/0.8 mm, as a colourless viscous oil; yield 7.2 g (Found: C, 79.8; H, 8.9. Calc. for $C_{18}H_{24}O_2$: C, 79.4; H, 8.9 per cent).

2:4-Dinitrophenylhydrazone of (V). The 2:4-dinitrophenylhydrazone of 1:1-dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene was prepared in the usual manner and crystallised from ethyl acetate. The analytical sample after two crystallisations from ethyl acetate melted at 198–199° (Found: N, 12.3. Calc. for $C_{24}H_{28}O_5N_4$: N, 12.3 per cent).

trans-1:1-Dimethyl-4a-methyl-6-methoxy-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VI). Seven grams of *trans*-1:1-dimethyl-2-keto-6-methoxy-4a-methyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene and 60 ml of diluted hydrochloric acid (1:1) were added to amalgamated zinc, prepared by treating 50 g of reagent-quality zinc for 15 min with a solution of 5 g of mercuric chloride, 4 ml of concentrated hydrochloric acid and 60 ml of water, and heated under reflux for 40 hr in an oil-bath at 135°. During refluxing at intervals of 6 hr concentrated hydrochloric acid (5 ml) was added. The contents were decanted from the zinc, and the organic matter was dissolved in ether, and the ether solution was washed with water, 5% sodium hydroxide solution (to remove any demethylated product) and finally with water until neutral. After removal of the solvent, the residue was distilled over sodium. *trans*-1:1-Dimethyl-4a-methyl-6-methoxy-1:2:3:4:4a:9:10:10a-octahydrophenanthrene distilled at 145–147°/0.8 mm, as a colourless mobile oil; yield 5 g (75 per cent), n_D^{20} 1.5465. (lit.⁶ b.p. 122–124°/0.2 mm, n_D^{20} 1.5478) (Found: C, 83.8; H, 10.2. Calc. for $C_{18}H_{28}O$: C, 83.7; H, 10.1 per cent).

trans-1:1-Dimethyl-4a-methyl-6-methoxy-7-acetyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VII). To a solution of 5 g of *trans*-1:1-dimethyl-4a-methyl-6-methoxy-1:2:3:4:4a:9:10:10a-octahydrophenanthrene and 3 ml of acetyl chloride in 50 ml of nitrobenzene at 5–8°, 6 g of finely powdered anhydrous aluminium chloride was added in small portions and the contents were left at 10° for 75 hr with occasional shaking. The reaction mixture was decomposed with 50 ml of concentrated hydrochloric acid and the nitrobenzene was removed by steam distillation. The residue was extracted with ether, and the extract was washed with water till neutral and dried over sodium sulphate. The residue after removal of the ether was distilled in vacuum and *trans*-1:1-dimethyl-4a-methyl-6-methoxy-7-acetyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene

(5 g), b.p. 185–190°/0.2 mm, was obtained as a viscous oil (Found: C, 80.1; H, 9.2. Calc. for $C_{20}H_{28}O_2$: C, 80.0; H, 9.4 per cent).

Semicarbazone of (VII). To a solution of 1 g of semicarbazide hydrochloride and 1 g of fused sodium acetate in 6 ml of alcohol, 0.3 g of the ketone (VII) was added and the mixture was heated on a water bath for $\frac{1}{2}$ hr and kept at 10° for 2 days. The precipitated semicarbazone was filtered off (0.3 g, 80 per cent yield), m.p. 219–220°. The analytical sample was crystallised from methanol, m.p. 222–223° (King *et al.*⁵ give 222–223°) (Found: C, 70.8; H, 8.4. Calc. for $C_{21}H_{31}O_2N_3$: C, 70.6; H, 8.7 per cent).

trans-1:1-Dimethyl-4a-methyl-6-methoxy-7-isopropenyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (VII). A solution of 3.4 g of *trans-1:1-dimethyl-4a-methyl-6-methoxy-7-acetyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene* in 80 ml of dry ether was added with stirring to a solution of methylmagnesium iodide prepared from 1.8 g of magnesium and 4 ml of methyl iodide in 100 ml of dry ether. The contents were stirred at room temperature for 4 hr and then gently refluxed for $\frac{1}{2}$ hr. The reaction mixture was then decomposed with saturated ammonium chloride solution and the ether layer was separated. The aqueous layer was extracted twice with ether, and the combined ether extracts were washed with water, 5% sodium thiosulphate solution and again with water, and dried over sodium sulphate. The residue after evaporating the ether, 3.4 g, was dehydrated by refluxing for 2 hr with 40 ml of acetic anhydride. The excess of acetic anhydride was removed under reduced pressure and the residue was dissolved in ether, and the extract was washed with 5% sodium hydroxide solution and then with water until neutral. The product obtained after removal of the ether on distillation gave 2.9 g (86 per cent) of *trans-1:1-dimethyl-4a-methyl-6-methoxy-7-isopropenylphenanthrene*, b.p. 152–155°/0.5 mm, as a light-yellow coloured viscous oil (Found: C, 84.0; H, 9.7. Calc. for $C_{21}H_{30}O$: C, 84.5; H, 10.1 per cent).

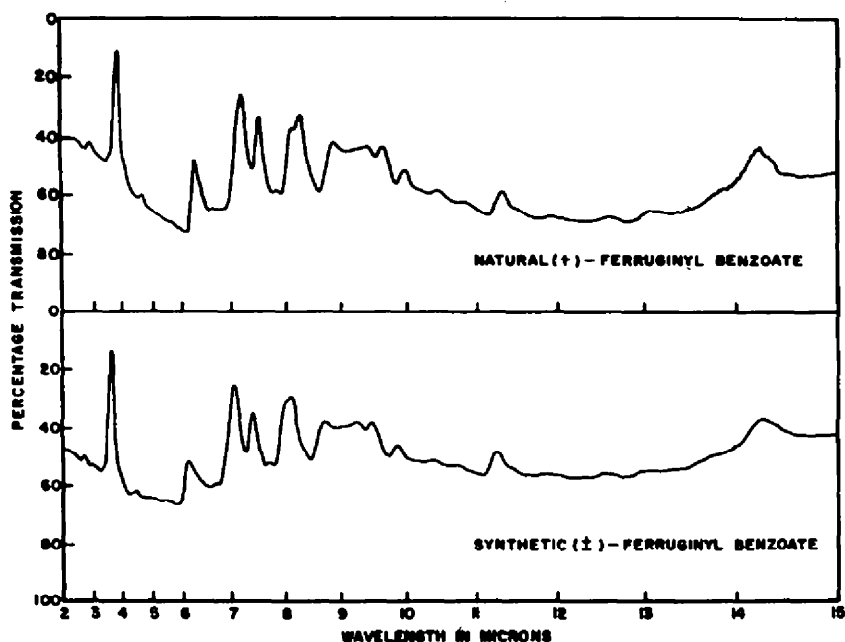
trans-1:1-Dimethyl-4a-methyl-6-methoxy-7-isopropyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene (IX). A solution of 2.7 g of *trans-1:1-dimethyl-4a-methyl-6-methoxy-7-isopropenyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene* in 150 ml of ethanol was hydrogenated in presence of 0.25 g of platinum oxide catalyst at room temperature. After the calculated amount of hydrogen was absorbed the solution was filtered from the catalyst and the alcohol was removed under reduced pressure. The residue on distillation gave 2.6 g of *trans-1:1-dimethyl-4a-methyl-6-methoxy-7-isopropyl-1:2:3:4:4a:9:10:10a-octahydrophenanthrene [(±)-ferruginyl methyl ether]*, b.p. 150–155°/0.8 mm, as a gum having a bluish violet fluorescence (Found: C, 84.1; H, 10.4. Calc. for $C_{21}H_{32}O$: C, 83.9; H, 10.7 per cent).

(±)-Ferruginol (X). A mixture of 1.5 g of (IX) and 10 g of pyridine hydrochloride was heated for 5 hr, at 158–160° in an atmosphere of dry nitrogen. Water was added and the product was extracted with ether. The extract was washed with water and dried over anhydrous sodium sulphate. The solvent was removed and the residue was distilled under high vacuum (bath temperature 140–145°/0.5 mm) to give *(±)-ferruginol* as a pale-yellow resin (Found: C, 83.3; H, 10.4. Calc. for $C_{20}H_{30}O$. C, 83.8; H, 10.6 per cent).

(±)-Ferruginyl benzoate (XI). To a solution of 1.2 g of *(±)-ferruginol (X)* in 10 ml of pyridine, 1 ml of benzoyl chloride was added and the mixture was allowed to stand at room temperature for 2 days. The pyridine was then removed under reduced pressure and the residue was dissolved in ether. The solution was washed with dilute

hydrochloric acid, water, saturated sodium bicarbonate solution and finally with water, and dried over sodium sulphate. The ether was evaporated and the residue was chromatographed on 200 g of neutral alumina of activity II (length of alumina column 30 cm). The fractions eluted with light petroleum (boiling range 40–60°)–benzene (1:1) gave a total of 0.89 g of crystalline material (from methanol), m.p. 118–120°. Two additional crystallisations from ethanol gave analytically pure (\pm)-ferruginyl benzoate, m.p. 132° (King *et al.*⁶ reported 130–130.5°) (Found: C, 83.0 H, 8.8. Calc. for $C_{27}H_{34}O_2$: C, 83.1; H, 8.8 per cent).

The infra-red spectra of the synthetic and natural ferruginyl benzoates were found to be identical in all respects.



The infra-red spectra were recorded in a Nujol mull on a Grubb Parson D.B. 1 type spectrophotometer.

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