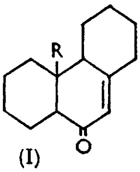
472. *The Condensation of 1-Acetylcyclohexene with 2-Methylcyclohexanone.*

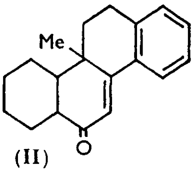
By Edward R. Clark.

1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 12 : 13 : 14-Dodecahydro-1-methyl-9-oxophenanthrene (V; R = H, R′ = Me) has been obtained by condensing 2-methylcyclohexanone with 1-acetylcyclohexene. The isomeric products formed by dimerisation of 1-acetylcyclohexene are shown to be 12-acetylperhydro-9-oxophenanthrene (IX) and perhydro-9-hydroxy-9 : 12-(2′-oxoethylene)phenanthrene (XI).

Rapson and Robinson[1] prepared the hydrophenanthrene (I; R = H) by condensing 1-acetylcyclohexene with cyclohexanone, but failed to obtain the angular methyl substituted hydrochrysene (II) from 1-acetylcyclohexene and 2-methyl-1-tetralone. Huber[2] claimed to have obtained 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 10 : 11 : 12 : 13-dodecahydro-12-methyl-10-oxophenanthrene (I; R = Me) from 1-acetyl-2-methylcyclohexene and cyclohexanone by using potassium isopropoxide as the condensing agent. The product had a molecular extinction coefficient in ethereal solution of only *ca.* 2000 at 238 mμ. It did, however, yield phenanthrene, though in unspecified yield, on dehydrogenation by selenium.



(I)



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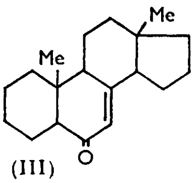

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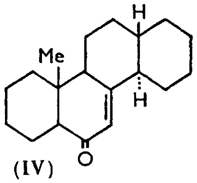

(IV)

Then, in analogy with Huber's work, structures (III) and (IV) were assigned respectively to the products of condensation of 1-acetyl-2-methylcyclohexene with perhydro-8-methylindan-4-one[3] and *trans*-1-decalone.[4]

The condensations of 1-acetyl-2-methylcyclohexene with cyclohexanone in presence of potassium t-butoxide,[5] and with *trans*-1-decalone[6] in presence of potassium t-butoxide and aluminium t-butoxide, have been further investigated, the conclusion in both cases being that ring closure did not take place. Braude and Wheeler[7] found that tricyclic ketones as well as bicyclic products, were formed when they repeated Turner and Voitle's experiment;

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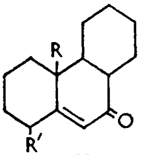
[1] Rapson and Robinson, *J.*, 1935, 1285.
[2] Huber, *Ber.*, 1938, **71**, 725.
[3] Bagchi and Banerjee, *J. Indian Chem. Soc.*, 1946, **23**, 397.
[4] Dimroth, *Angew. Chem.*, 1947, **59**, 215.
[5] Turner and Voitle, *J. Amer. Chem. Soc.*, 1950, **72**, 4166.
[6] Johnson, Szmuszkovicz, and Miller, *ibid.*, p. 3726.
[7] Braude and Wheeler, *J.*, 1955, 329.

they pointed out, however, that 1-acetyl-2-methylcyclohexene undergoes rapid prototropic isomerisation under the influence of metal alkoxides and that consequently the tricyclic material may consist of a mixture of prototropic and skeletal isomers of (I; R = Me). Their failure to obtain solid carbonyl derivatives and the light-absorption characteristics of their product were stated to be consistent with the formation of such a mixture.



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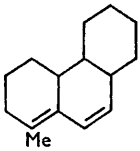
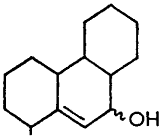
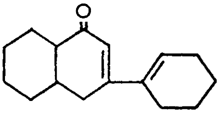


(VI)



(VII)



(VIII)

Despite Rapson and Robinson's failure to condense 1-acetylcyclohexene with 2-methyl-1-tetralone the condensation between acetylcyclohexene and 2-methylcyclohexanone has been investigated as a possible route to hydrophenanthrenes having an angular methyl substituent. 2-Methylcyclohexene-1 : 3-dione failed to condense with acetylcyclohexene in the presence of sodium methoxide in ether or sodium ethoxide in alcohol.

Condensation of 2-methylcyclohexanone with 1-acetylcyclohexene can theoretically yield two isomers. Michael addition involving position 2 of the 2-methylcyclohexanone, followed by aldol condensation, would yield 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 12 : 13 : 14-dodecahydro-12-methyl-9-oxophenanthrene (V; R = Me, R′ = H), while Michael addition involving position 6, followed by aldol condensation would yield the isomeric 1-methyl compound (V; R = H, R′ = Me). du Feu and Robinson,[8] however, showed that 4-chlorobutan-2-one and 4-diethylaminobutan-2-one methiodide condense with 2-methylcyclohexanone at position 2, to yield 1 : 2 : 3 : 5 : 6 : 7 : 8 : 9-octahydro-9-methyl-3-oxonaphthalene. Since the Mannich base methiodide is a source, *in situ*, of methyl vinyl ketone, there was reason to believe that 1-acetylcyclohexene would condense similarly to yield the angular methylated phenanthrene (V; R = Me, R′ = H). Use of sodamide as condensing agent gave a solid and two oily fractions. The lower-boiling oil, in alcoholic solution, showed maximum absorption at 240 mμ ($E^{1\%}_{1\,\text{cm.}}$ 480), in accord with its formulation as an αβ-unsaturated ketone. After several weeks in the refrigerator a crystalline isomer separated, which had infrared bands at 1667 and 1616 cm.$^{-1}$, characteristic of the αβ-unsaturated ketone group. A band at 871 cm.$^{-1}$ is analogous to that found in Δ^5-7-keto-steroids.[9] Reduction with lithium aluminium hydride, but not with sodium borohydride, yielded the corresponding allylic alcohol. The crude product from the borohydride reduction, in cyclohexane solution, showed a peak of absorption at 239 mμ (the original αβ-unsaturated ketone had $\lambda_{\text{max.}}$ 231 mμ in cyclohexane), suggesting that it was the hetero-annular diene (VI) and not the angular methylated isomer which would be expected[10] to have $\lambda_{\text{max.}}$ 234 mμ. Selenium dehydrogenation yielded 1-methylphenanthrene, in accord with this formulation. The crystalline αβ-unsaturated ketone is therefore 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 12 : 13 : 14-dodecahydro-1-methyl-9-oxophenanthrene (V; R = H, R′ = Me), and the product of reduction with lithium aluminium hydride is the alcohol (VII).

Recrystallisation of the solid fraction obtained on distillation yielded two compounds, m. p. 85—85·5° (A) and 131—132·5° (B) respectively. A further quantity of substance (B) separated from the higher-boiling oil. Compound (A) [$\lambda_{\text{max.}}$ 284 mμ (ε 23,000) in ethanol] proved to be the dienone (VIII) previously isolated by Jones and Koch[11] from the products of self-condensation of 1-acetylcyclohexene. Two further crystalline compounds, m. p. 130° and 205° respectively, were obtained by Jones and Koch, who suggested

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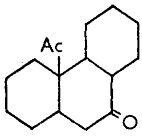
[8] du Feu and Robinson, *J.*, 1937, 53.

[9] Dobriner, Katzenellenbogen, and Jones, " Infra-red Absorption Spectra of Steroids," Interscience Publishers Inc., New York, 1953, p. xiv.

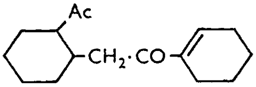
[10] Gillam and Stern, " Electronic Absorption Spectroscopy, Arnold, London, 1957, p. 232.

[11] Jones and Koch, *J.*, 1942, 393.

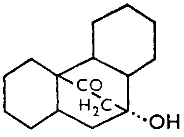
that they were stereoisomers of the diketone (IX) [Rapson and Robinson [1] had previously suggested the structure (X)]. Compound B gave a monoxime, m. p. 258—269°, while Jones and Koch reported 250° (decomp.) and 251° for the melting points of the monoximes derived from the supposed stereoisomers (IX). The infrared spectrum of compound B



(IX)



(X)



(XI)

showed bands at 3460 (OH), and 1701 cm.$^{-1}$ (C=O), and that of its oxime bands at 3401 (CO–H), 3226 (NO–H), and 1664 cm.$^{-1}$ (C=N), demonstrating that compound B is a hydroxy-ketone. The absence of absorption at 1360—1370 cm.$^{-1}$, and the failure to eliminate water when the substance is heated with sodium methoxide in benzene, support the structure (XI) for substance B.

The self-condensation of 1-acetylcyclohexene was carried out under the conditions described by Jones and Koch,[11] and the supposed saturated diketones were isolated. The lower-melting material was identical with compound B. The infrared spectrum of the higher-melting isomer showed, besides the band at 1695 cm.$^{-1}$ (C=O), a triple peak at 1370, 1361, 1352 cm.$^{-1}$, which is absent from the spectrum of the hydroxy-ketone (XI), and is attributed to the methyl ketone structure. The oxime showed absorption bands at 3215 (NO–H), 1695 (C=O), and 1667 cm.$^{-1}$ (C=N), supporting the diketonic structure (IX) for this isomer.

EXPERIMENTAL

Condensation of 1-*Acetylcyclohexene and* 2-*Methylcyclohexanone.*—2-Methylcyclohexanone (24·5 g.) in dry benzene (50 c.c.) was added, with stirring, to a heated suspension of sodamide (from 5·75 g. of sodium) in dry benzene (250 c.c.), in an atmosphere of nitrogen. Heating was continued until no more ammonia was given off. The resulting suspension was cooled in ice, and 1-acetylcyclohexene (31 g.) in dry benzene (50 c.c.) added with stirring which was continued at room temperature for 2 days and then on the steam-bath for 1 hr. The cooled mixture was poured into iced water, the benzene layer separated, and the aqueous layer extracted with benzene. The combined benzene solution and extracts were washed with dilute sulphuric acid and water, and dried (Na_2SO_4). Distillation yielded three fractions: (*a*) (5 g.), b. p. 103—106°/0·05 mm., $\lambda_{\max.}$ 240 mμ ($E^{1\%}_{1\,\text{cm.}}$ 480) in ethanol (Found: C, 81·95; H, 10·2%), (*b*) (6·75 g.), b. p. 133—135°/0·05 mm., $\lambda_{\max.}$ 241 ($E^{1\%}_{1\,\text{cm.}}$ 190), 285 mμ ($E^{1\%}_{1\,\text{cm.}}$ 220), (*c*) an oil which mostly solidified in the receiver, b. p. 137—140/0·05 mm. (8·15 g.).

Fraction (*a*) partly crystallised at 0° during several weeks. Repeated recrystallisation from light petroleum (b. p. 60—80°) gave prisms of 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 12 : 13 : 14-*dodecahydro*-1-*methyl*-9-*oxophenanthrene* (0·75 g.), m. p. 80·5—81·5°, $\lambda_{\max.}$ 239 mμ (ε 13,780) in ethanol (Found: C, 82·3; H, 10·3. $C_{15}H_{22}O$ requires C, 82·6; H, 10·1%), $\nu_{\max.}$ (Nujol mull) 1667s, 1616w cm.$^{-1}$.

Fraction (*b*) also crystallised partly at 0°. Recrystallisation from light petroleum (b. p. 100—120°) gave needles of *perhydro*-9-*hydroxy*-9 : 12-(2′-*oxoethylene*)*phenanthrene* (0·95 g.), m. p. 131—132·5° (Found: C, 77·6; H, 10·1. $C_{16}H_{24}O_2$ requires C, 77·5; H, 9·7%), $\nu_{\max.}$ (Nujol mull): 3460m, 1701s cm.$^{-1}$. This yielded an *oxime*, m. p. 258—259° (decomp.) (Found: C, 72·85; H, 9·5; N, 5·36. $C_{16}H_{25}O_2N$ requires C, 73·1; H, 9·52; N, 5·33%), $\nu_{\max.}$ (Nujol mull) 3401m, 3226m, 1664w cm.$^{-1}$.

The solid material from fraction (*c*) recrystallised from 80% methanol, yielding 3-cyclohex-1′-enyl-1 : 4 : 5 : 6 : 7 : 8 : 9 : 10-octahydro-1-oxonaphthalene (0·7 g.), m. p. 85—85·5°, $\lambda_{\max.}$ 284 mμ (ε 23,000) in ethanol (Found: C, 83·2; H, 9·4. Calc. for $C_{16}H_{22}O$: C, 83·5; H, 9·6%). On microhydrogenation (Pd–C) 11·7 mg. absorbed 2·30 c.c. (2 mols. = 2·24 c.c.). The solid material, obtained on evaporation of the mother-liquors, recrystallised from light petroleum (b. p. 100—120°), yielding perhydro-9-hydroxy-9 : 12-(2′-oxoethylene)phenanthrene (0·87 g.), m. p. and mixed m. p. 130—132°.

1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 12 : 13 : 14-*Dodecahydro*-9-*hydroxy*-1-*methylphenanthrene.*—The corresponding ketone (0·6 g.) was added in dry ether (20 c.c.) during 10 min., with stirring, to

lithium aluminium hydride (0·1 g.) in dry ether (20 c.c.). The mixture was stirred at room temperature for 90 min. and then on the steam-bath for 30 min., the excess of hydride destroyed with wet ether, and dilute sulphuric acid was added. The ethereal layer was separated, the aqueous layer was extracted with ether, and the combined ethereal solution and extracts were washed with water, sodium hydrogen carbonate solution, and water, and dried ($MgSO_4$). Evaporation of the ether gave 0·56 g. of solid. Recrystallisation from ethylene dichloride yielded 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 12 : 13 : 14-*dodecahydro*-9-*hydroxy*-1-*methylphenanthrene*, m. p. 113—113·5° (Found: C, 81·4; H, 10·6. $C_{15}H_{24}O$ requires C, 81·8; H, 10·9%), $\nu_{max.}$ (Nujol mull) 3268—3344s, 1669w cm.$^{-1}$.

Conversion of the Ketone (V; R = H, R′ = Me) *into* 1-*Methylphenanthrene.*—Sodium borohydride (0·19 g.), dissolved in water (2 c.c.) and methanol (15 c.c.), was added to the ketone (0·218 g.) in ether (5 c.c.) and methanol (25 c.c.), and the mixture stirred at room temperature for 4 hr.; then a further 50 mg. of sodium borohydride were added. Stirring was continued at room temperature overnight and then for 2 hr. on the steam-bath. Ether was added to the cooled solution followed by excess of 0·5N-hydrochloric acid. The aqueous layer was separated and extracted with ether, and the combined ethereal solutions were washed with 0·5N-hydrochloric acid and water, and dried ($MgSO_4$). Evaporation of the ether gave 0·205 g. of a semi-solid material, $\lambda_{max.}$ 239 mμ ($E^{1\%}_{1\,cm.}$ 76) in cyclohexane. The infrared spectrum for a carbon tetrachloride solution demonstrated the absence of OH and C=O groups. The crude reduction product (0·196 g.) was heated with selenium at 220—230° for 1 hr., the temperature then raised to 330° during 1 hr. and kept thereat for 16 hr. The crystalline material (70 mg.) which had sublimed into the bottom of the air-condenser was recrystallised from 96% ethyl alcohol, yielding 1-methylphenanthrene, m. p. 120·5—121° (picrate, m. p. 137—137·5°).

Self-condensation of 1-*Acetylcyclohexene.*—1-Acetylcyclohexene (22 g.) was treated with sodamide under the conditions described by Jones and Koch,[11] yielding (*a*) 12-acetylperhydro-9-oxophenanthrene (0·7 g.), m. p. 205—206° (Found: C, 77·5; H, 9·6. Calc. for $C_{16}H_{24}O_2$: C, 77·4; H, 9·7%), $\nu_{max.}$ (hexachlorobutadiene mull) 1692s, 1370m, 1361m, 1352m [oxime, m. p. 251—253° (decomp.) (Found: C, 72·7; H, 9·35; N, 5·45. Calc. for $C_{16}H_{25}O_2N$: C, 73·1; H, 9·52; N, 5·3%), $\nu_{max.}$ (Nujol mull) 3215m, 1695s, 1667w cm.$^{-1}$] and (*b*) perhydro-9-hydroxy-9 : 12-(2′-oxoethylene)phenanthrene (4·25 g.), m. p. and mixed m. p. 131—132·5° (Found: C, 77·35; H, 9·6%) [oxime, m. p. 258—259° (decomp.) (Found: C, 72·95; H, 9·5; N, 5·65%)].

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