dation of 1-ketotetrahydrophenanthrene[28] showed no depression (m.p. 129.5–130.5°).

Anal. Calcd. for $C_{14}H_{14}O_8$: C, 54.2; H, 4.5. Found: C, 54.0; H, 4.9.

Summary

The synthesis of 1,4-cholestadienone-3 (I) and its rearrangement to the isomeric 1-methyl phenolic compound (IIa), first reported by Inhoffen and co-workers, has been confirmed and substantial improvements made in certain of the experimental procedures.

MADISON 6, WISCONSIN RECEIVED JANUARY 2, 1946

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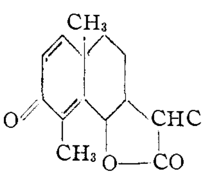
[28] Johnson and Goldman, THIS JOURNAL, **66**, 1034 (1944).

[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

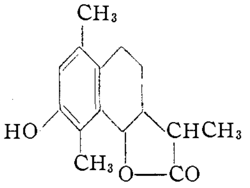
The Dienone–Phenol Rearrangement Applied to Chrysene Derivatives. The Synthesis of 3-Hydroxy-1-methylchrysene and Related Compounds[1]

BY A. L. WILDS AND CARL DJERASSI[2,3]

In an accompanying communication, the rearrangement by acid of 1,4-cholestadienone-3 to 3-hydroxy-1-methyl-10-norcholestatriene-1,3,5 is considered.[4,5] This reaction, which may be termed the dienone-phenol rearrangement, is analogous to the well-known rearrangement of santonin (I) to desmotroposantonin (II),[6] and also bears a formal resemblance to the rearrangement of quinols[7] and of semibenzenes[8] to the corresponding aromatic structures.



I



II

Although the course of the dienone–phenol rearrangement has been fairly well established, it has not been fully confirmed as far as we are aware, by means of an example in which the structures of both the dienone and the phenol were proved by synthesis. The recent claim of a synthesis of santonin (I) by Paranjape, Phalnikar, Bhide and Nargund[9a] must be discounted for the present, since the total asymmetric synthesis of *l*-santonin and related compounds is claimed,[9b] without the use of any optically active reagents.[10]

We therefore decided to synthesize the dienone VI, and subject it to rearrangement. This dienone was selected because it seemed probable that most of the intermediates in its preparation would be solids, thus facilitating development of the steps of the synthesis. Moreover, the structure of the rearrangement product VIIa might be established through dehydrogenation to 3-hydroxy-1-methylchrysene (VIIIa) and synthesis of the latter by a method similar to that used earlier for 3-hydroxychrysene.[11] For preparing the dienone VI, we employed the ingenious method reported by Paranjape, *et al.*,[9a] for the synthesis of compounds with the santonin-type structure, although with significant modifications in the experimental procedures.

1-Keto-1,2,3,4-tetrahydrophenanthrene was condensed with ethyl formate and sodium methoxide, by the procedure of Johnson and Shelberg,[12] to give the 2-hydroxymethylene derivative III in 96% yield. Preliminary experiments on the methylation of this hydroxymethylene ketone resulted in mixtures of the C- and O-methyl derivatives, and revealed that the C-methylated product was quite sensitive to cleavage with loss of the formyl group. A search of the literature for similar alkylations failed to reveal instances in which a C-methylated formyl ketone of established purity had been described. Sen and Mondal[13] found in the case of 2-hydroxymethylenecyclohexanone that some C-alkylation must have occurred, using sodium in benzene or sodium ethoxide in alcohol along with the alkyl halide, since they were able to isolate the semicarbazones of the corresponding 2-alkylcyclohexanones after cleavage of the product. However, they were unable to isolate pure intermediates,[14] and the relative importance of C- and O-alkylation or of cleavage cannot be determined from their work. Pure products were not isolated by Paranjape, *et al.*,[9] in their syntheses. The recent work by Cornforth, *et al.*,[10] did result in an analytically pure, methylated 2-formylcyclohexanone, although the

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[1] From part of the Ph.D. thesis of Carl Djerassi.

[2] Wisconsin Alumni Research Foundation Research Assistant, 1943–1945.

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[4] Wilds and Djerassi, THIS JOURNAL, **68**, 1712 (1946); see formulas I ⟶ IIa for this reaction.

[5] Inhoffen and Huang-Minlon, *Naturwissenschaften*, **26**, 756 (1938); Inhoffen and Zühlsdorff, *Ber.*, **74**, 604 (1941).

[6] See Clemo, Haworth and Walton, *J. Chem. Soc.*, 1110 (1930).

[7] Bamberger and Rising, *Ber.*, **33**, 3636 (1900); Bamberger and Brady, *ibid.*, **33**, 3642 (1900).

[8] v. Auwers and Ziegler, *Ann.*, **425**, 217 (1921).

[9] (a) Paranjape, Phalnikar, Bhide and Nargund, *Current Sci.*, **12**, 150 (1943); *Rasayanam*, **1**, 233 (1943); (b) *Nature*, **153**, 141 (1944).

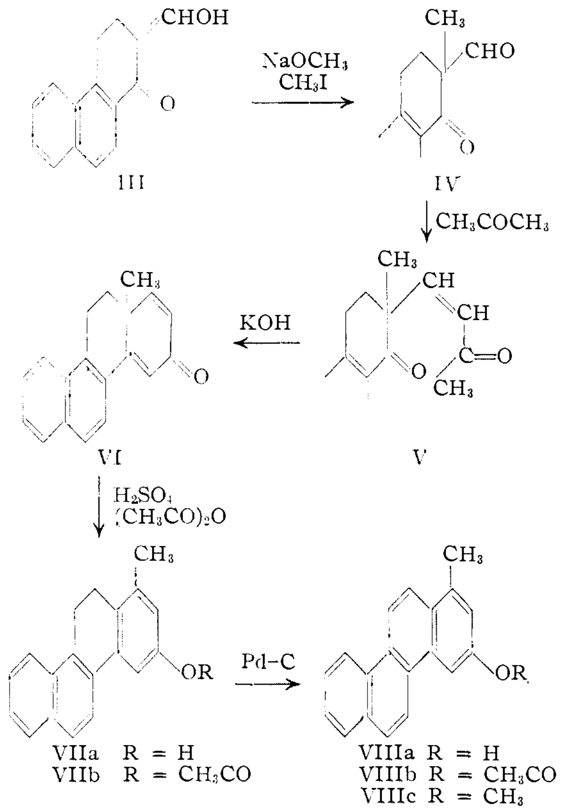
[10] For unsuccessful attempts to repeat the asymmetric synthesis of 2-formyl-2-methylcyclohexanone, also reported, see Cornforth, Cornforth and Dewar, *Nature*, **153**, 317 (1944), and O'Gorman, THIS JOURNAL, **66**, 1041 (1944).

[11] Wilds and Shunk, *ibid.*, **65**, 469 (1943).

[12] Johnson and Shelberg, *ibid.*, **67**, 1750 (1945).

[13] Sen and Mondal, *J. Indian Chem. Soc.*, **5**, 609 (1928).

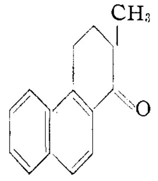
[14] *Cf.* also Robinson and Walker, *J. Chem. Soc.*, 1532 (1935).



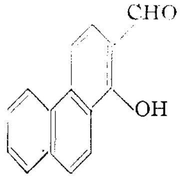
possibility of it containing some of the O-methyl derivative was not excluded.

A number of different conditions were tried in the methylation of the present hydroxymethylene ketone III, which was particularly suitable for study since the C-methyl derivative IV is a crystalline solid. Conditions were developed using the sodio derivative of III in benzene which led to 66% of the desired product IV (or 78–90% if corrected for recovered starting material). Its structure was established as the C-derivative by cleavage of the pure, crystalline material to 2-methyl-1-ketotetrahydrophenanthrene (IX). In some of the unsuccessful methylation experiments, particularly one carried out in isopropyl alcohol at room temperature, part of the material was converted to 1-hydroxy-2-phenanthraldehyde (X), presumably through oxidation by air, as suggested recently by Cook and Thomson,[15] who encountered the compound as a by-product in the condensation of III with acetamidine.

In view of the sensitivity of IV to cleavage, the condensation of this material with acetone was first tried using aluminum *t*-butoxide, which has been shown by Wayne and Adkins[16] to be an effective catalyst for the mesityl oxide and aldol types of condensation. However, this reagent also effected cleavage to the methyl ketone IX. A stronger base such as sodium ethoxide[9a] was entirely unsuitable. Piperidine with a slight excess



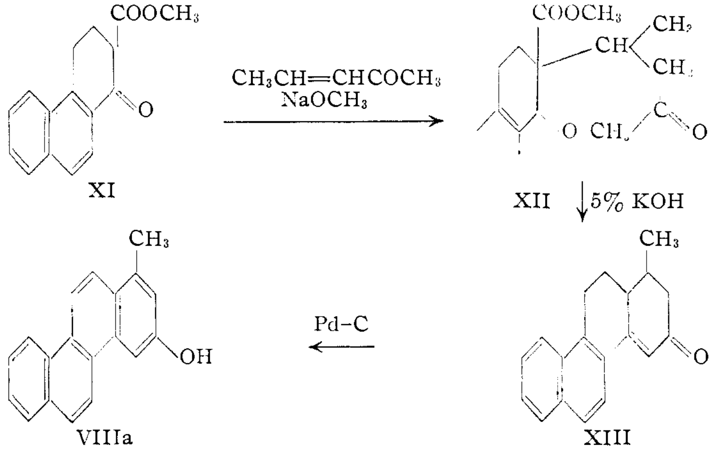
IX



X

of acetic acid[17] proved to be the best of the catalysts tried. Although it was not possible to isolate the diketone V, cyclization of the crude mixture with alcoholic potassium hydroxide led to the crystalline dienone VI in 37–40% yields from IV.

The rearrangement of the dienone VI proceeded smoothly at room temperature when the material was treated with a small amount of sulfuric acid in acetic anhydride solution, giving an acetate which was easily cleaved by alcoholic hydrochloric acid to the corresponding phenol. By analogy with the previous rearrangements,[5,6] the phenol should correspond to formula VIIa, and the acetate to VIIb. When the acetate was dehydrogenated with palladium-charcoal catalyst, the fully aromatic acetate VIIIb was obtained, and from this the corresponding phenol and methyl ether. These were found to be identical with 3-hydroxy-1-methylchrysene (VIIIa) and its derivatives, which were prepared by the independent synthesis discussed below.



In the earlier synthesis of 3-hydroxychrysene,[11] the keto ester XI was first condensed with the methiodide of the Mannich base derived from acetone, formaldehyde and diethylamine. This reaction presumably involved the intermediate formation of 3-buten-2-one followed by a Michael addition. For the present synthesis of the 1-methyl derivative, 3-penten-2-one was used for

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(15) Cook and Thomson, *J. Chem. Soc.*, 395 (1945).

(16) Wayne and Adkins, THIS JOURNAL, **62**, 3401 (1940).

(17) Kuhn, Badstübner and Grundmann, *Ber.*, **69**, 98 (1936).

condensation with the keto ester XI in the presence of a small amount of sodium methoxide. When the crystalline product XII was heated with 5% potassium hydroxide solution, it underwent cyclization with loss of the carbomethoxyl group to give the unsaturated ketone XIII in 59% yield. Unlike the related compound lacking the methyl group, XII also underwent some reversal of the Michael addition during the process, since 1-ketotetrahydrophenanthrene, the cleavage product of XI, also was formed in about 25% yield. The ultraviolet absorption spectrum of the unsaturated ketone XIII, to be reported later in connection with a study of the spectra of this type of ketone, indicated the double bond to be conjugated as shown in XIII.

Dehydrogenation of the ketone XIII to 3-hydroxy-1-methylchrysene VIIIa was effected by heating with palladium-charcoal in a high-boiling solvent—the general method developed by Mosettig and Duvall.[18] With xylene as the solvent, the yield was only 31%, due to incomplete reaction of the ketone even after three days at reflux.[19] With *p*-cymene, heating for the same length of time, the yield of the phenolic derivative VIIIa was 67%, and was raised to 77% by retreatment of the material in the filtrate.

The identity of the samples of the phenol VIIIa and its derivatives VIIIb and VIIIc, prepared by this synthesis, with those obtained by dehydrogenation of the product (VIIb) of the rearrangement of VI, together with the synthesis of the latter, provides clear-cut evidence for the course of the dienone-phenol rearrangement for this example. This lends further support for the structures assigned to the products obtained by rearrangement of other dienones.[4,5,6]

Experimental[20]

Synthesis and Aromatization of 3-Keto-12a-methyl-3,11,12,12a-tetrahydrochrysene

2-Hydroxymethylene-1-keto-1,2,3,4-tetrahydrophenanthrene (III).—Using a modification of the procedure of Johnson and Shelberg,[12] a suspension of alcohol-free sodium methoxide (prepared from 1.28 g. of sodium and 40 cc. of absolute methanol, dried at 130° and 25 mm. for one-half hour and cooled under nitrogen) in 100 cc. of dry, thiophene-free benzene and 4.5 cc. of dry ethyl formate was cooled and treated with a solution of 5.4 g. of 1-keto-tetrahydrophenanthrene[21] in 50 cc. of benzene. After fifteen minutes at room temperature under nitrogen, the mixture was refluxed for thirty minutes, cooled, treated with water and extracted thoroughly with 5% sodium hydroxide. The product obtained by acidifying, filtering and drying was practically pure; yield 5.95 g. (96%), m. p. 85–85.5° (reported for the pure material m. p. 82–83°[12]; 86 ± 2°[22]; 84–85°[15]).

2-Methyl-2-formyl-1-keto-1,2,3,4-tetrahydrophenanthrene (IV).—To the alcohol-free sodium methoxide prepared in a ground-joint, three-necked flask from 0.49 g. of clean sodium and 30 cc. of anhydrous methanol, and dried at 130° at 25 mm., was added 4.68 g. of the hydroxymethylene ketone III in 100 cc. of dry benzene. The suspension of yellow sodium enolate which formed was stirred at reflux under nitrogen for twenty minutes, 40 cc. of benzene was added and 40 cc. distilled to remove the last traces of methanol. (Failure to remove this diminished the yield by as much as 30%.) The mixture was cooled and 30 cc. of methyl iodide and 40 cc. of benzene were added. The mixture was refluxed and stirred for seventy hours (or forty-six hours for runs one-half this size). During this period an additional 30 cc. of methyl iodide was added in 25 cc. of benzene.[23] At the end of the heating period water and salt were added and the product was extracted twice with ether. The organic layers were washed with 5% potassium hydroxide, from which on acidification 0.70–1.21 g. (15–26%) of the starting hydroxymethylene ketone was recovered; m. p. and mixed m. p. 80–82.5°.

After washing the combined ether extract with water, drying, evaporating and triturating the residue with petroleum ether, 3.3 g. (66% yield) of the methylated product was isolated. The melting point varied in different runs from 96–99° to as high as 103–105°. From the mother liquors an additional 0.11 g. (2%) of material, m. p. 93–99°, could be isolated. Recrystallization of the low melting products (m. p. 94–100°) from petroleum ether containing a few drops of acetone gave 84% recovery of material of m. p. 103.5–106° and an additional 6.5% of m. p. 90–97°.

The material gave no color with alcoholic ferric chloride, even on standing for twenty hours (this test was found to detect the O-methyl ether when it was present). The analytical sample crystallized as small, colorless blades from petroleum ether, m. p. 107–109°. A solution of 18.6 mg. of the material in 2 cc. of chloroform showed no detectable optical activity (0.00 ± 0.01°).

Anal. Calcd. for $C_{16}H_{14}O_2$: C, 80.7; H, 5.9. Found: C, 80.2; H, 5.9.

Variations in the Methylation Procedure.—A number of experiments were carried out to establish the optimum conditions for C-methylation described above. Although runs in boiling toluene gave yields similar to those in benzene, a single run in ether gave none of the desired product and 60% of the starting material could be recovered. Failure to use stirring in the benzene runs reduced the yield by 25%. When the runs were too concentrated (for example 10 cc. of benzene per gram of III) 65% of the starting material was recovered after seventy hours.

The deleterious effect of methanol was noted above. Before this was realized some unsuccessful runs were carried out with methanol and an excess of sodium. This resulted on the one hand in the formation of some of the O-ether,[24] and on the other hand in cleavage of the C-methylated product to 1-keto-2-methyltetrahydrophenanthrene (see below). In addition small amounts of two new by-products were isolated. The first (about 1.5% yield) was a neutral, yellow substance, m. p. 320° (dec.), insoluble in most organic solvents except acetic acid, and not investigated further. The second substance, obtained in 3% yield, was soluble in 5% potassium hydroxide. After recrystallization from dilute alcohol it formed shiny, golden yellow blades, m. p. 127–128°, which gave a green color with alcoholic ferric chloride. This material was obtained in 17% yield when the reaction was carried out in isopropyl alcohol solution at room temperature (no nitrogen used in this run). It proved to be **1-hydroxy-2-phenanthraldehyde** (X) recently obtained by Cook and Thomson[15] (m. p. 125–127°).

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[18] Mosettig and Duvall, THIS JOURNAL, **59**, 367 (1937).

[19] *Cf.* Cook and Schoental, *J. Chem. Soc.*, 288 (1945).

[20] All melting points below 210° are corrected; melting points above 210° were taken in a copper block and are uncorrected; those marked vac. were taken in sealed capillaries evacuated to about 0.5 mm.

[21] Wilds, THIS JOURNAL, **64**, 1424 (1942).

[22] Meyer and Reichstein, *Pharm. Acta. Helv.*, **19**, 127 (1944).

[23] No attempt was made to economize on methyl iodide since in preliminary runs failure to add more during the long heating period resulted in incomplete reaction.

[24] Determined by acid hydrolysis of the product and isolation of the alkali-soluble hydroxymethylene ketone III.

Anal. Calcd. for $C_{15}H_{10}O_2$: C, 81.1; H, 4.5. Found: C, 80.8; 81.1; H, 4.7; 4.4.

The **oxime**, obtained as needles from petroleum ether-acetone, melted at 189–191° dec. (reported,[15] 188–189°).

An attempt to synthesize the aldehyde from the hydroxymethylene ketone by dehydrogenation with palladium-charcoal in boiling xylene for forty-eight hours gave instead 1-phenanthrol in 77% yield, m. p. and mixed m. p. 156.5–157°. The acetate melted at 134–135.5° (reported,[25] m. p. 135–136°).

Cleavage of IV to 1-Keto-2-methyltetrahydrophenanthrene (IX). (A) **By Acid.**—A solution of 40 mg. of the methylated formyl ketone IV in 3 cc. of ethanol, 1 cc. of water and 0.6 cc. of concentrated hydrochloric acid was refluxed for two and one-half hours. Upon dilution with water, cooling and scratching 31 mg. (88%) of material was obtained, m. p. 69–71°; when mixed with an authentic sample of 1-keto-2-methyltetrahydrophenanthrene,[26] the m. p. was 71–72.5°.

(B) **By Alkaline Reagents.**—When a solution of 80 mg. of IV in 5 cc. of warm alcohol was treated with 1 cc. of 45% potassium hydroxide the mixture became purple. After refluxing for one hour and diluting, 55 mg. (78%) of the colorless methyl ketone was obtained; m. p. 69–70.5°; mixed m. p. 70.5–73°.

When heated for twenty-four hours with alcohol-free sodium methoxide in benzene, the methylated formyl ketone was again cleaved to crude 1-keto-2-methyltetrahydrophenanthrene in 66% yield, m. p. 64–68°. Similar results (80% crude yield) were obtained with aluminum *t*-butoxide in a mixture of acetone and benzene.

3-Keto-12a-methyl-3,11,12,12a-tetrahydrochrysene (VI).—A solution of 800 mg. of the methylated formyl ketone IV in 10 cc. of dry acetone containing 175 mg. of acetic acid and 125 mg. of piperidine (distilled from sodium) was refluxed for fifty-seven to sixty-five hours. After twenty-four hours an additional 130 mg. of acetic acid and 85 mg. of piperidine were added. At the end of the period of heating the acetone was evaporated, the product was extracted with benzene and ether and washed with dilute acid, alkali and water. The yellowish-brown product, presumably the diketone V, could not be crystallized.

This material was cyclized by refluxing with 15 cc. of methanol and 1.5 cc. of 45% potassium hydroxide under nitrogen for five to seven hours. The purple solution was diluted, extracted with benzene and ether, washed and evaporated. The residue was triturated with petroleum ether and filtered to give 493 mg. (57%) of the crude ketone VI, m. p. 129–148°. From the filtrate could be isolated 14 to 20% of crude 1-keto-2-methyltetrahydrophenanthrene. Recrystallization of the product from petroleum ether–acetone (using Norit) gave a total of 324–349 mg. (37–40%) of colorless to light tan material, m. p. 159–162°, which was used in the subsequent reactions.

The analytical sample, prepared by adsorption on alumina, followed by elution with benzene and recrystallization from petroleum ether–acetone, was obtained as stout, colorless prisms of m. p. 167.5–168°.

Anal. Calcd. for $C_{19}H_{16}O$: C, 87.7; H, 6.2. Found: C, 87.3; H, 6.4.

An attempt to use alcoholic sodium ethoxide for the condensation with acetone, similar to the procedure of Paranjape, *et al.*,[9a] gave a dark-colored oil which could not be crystallized and did not yield any crystalline material after treatment with alcoholic potassium hydroxide.

Aromatization to 3-Hydroxy-1-methyl-11,12-dihydrochrysene (VIIa).—To a solution of 500 mg. of the unsaturated ketone VI (m. p. 159–162°) in 20 cc. of acetic anhydride was added a cold solution of 85 mg. of concentrated sulfuric acid in 2 cc. of acetic anhydride. The solution, which turned dark red at once, was allowed to stand at room temperature for four and one-half hours, and then was treated with cold water, swirling until all of the acetic anhydride had hydrolyzed. Filtration yielded 512 mg. (88%) of the **acetate of 3-hydroxy-1-methyl-11,12-dihydrochrysene,** m. p. 112–117°. Recrystallization from alcohol, using Norit, gave glistening plates (80% recovery), m. p. 119–120°. Sometimes a higher polymorphic form melting at 125.5–126.5° was obtained; when the lower melting form was seeded with the latter, it melted at 126–126.5°.

Anal. Calcd. for $C_{21}H_{18}O_2$: C, 83.4; H, 6.0. Found: C, 83.2; H, 5.9.

It was necessary to limit the amount of sulfuric acid used to effect the rearrangement; when this was increased to 100 mg. for 100 mg. of ketone, the yield dropped to 70%, and with 200 mg. of acid, to 48%.

The rearrangement also was effected by heating a solution of 100 mg. of the unsaturated ketone in 5.5 cc. of acetic anhydride with 40 mg. of *p*-toluenesulfonic acid at 75° for five hours; the yield of recrystallized acetate, m. p. 118.5–119°, was 50%.

The free phenol VIIa was obtained by heating 166 mg. of the acetate with 12 cc. of alcohol and 0.6 cc. of concentrated hydrochloric acid under nitrogen for five hours; the total yield of material was 134 mg. (94%), m. p. 193–195°. The analytical sample, prepared by evaporative distillation at 200–250° (0.01 mm.) and recrystallization from petroleum ether–acetone, formed clusters of colorless prisms, m. p. 194–195°. The phenol was insoluble in 5% aqueous potassium hydroxide and gave no color with alcoholic ferric chloride solution.

Anal. Calcd. for $C_{19}H_{16}O$: C, 87.7; H, 6.2. Found: C, 87.4; H, 6.5.

3-Hydroxy-1-methylchrysene (VIIIa) **from the Dihydro Derivative (VIIb).**—A mixture of 250 mg. of the dihydro acetate VIIb and 50 mg. of palladium–charcoal catalyst[27] was heated under nitrogen at 210–240° for ten minutes and at 260–270° for fifteen minutes. Partial deacetylation apparently occurred, judging from the odor of acetic acid. The product was separated from the catalyst using benzene and completely deacetylated by heating with 25 cc. of alcohol and 1.2 cc. of concentrated hydrochloric acid under nitrogen for five hours. Concentration of the solution and dilution with water gave 153 mg. (72%) of the phenol sintering at 263° and melting at 267–271° (vac.), and an additional 37 mg. (17%) m. p. 248–255° (vac.). Recrystallization of a sample from alcohol–benzene raised the m. p. to 269–271° (vac.).[20] This material showed no depression in m. p. when mixed with the sample described below. The phenol did not dissolve in hot 5–10% aqueous potassium hydroxide and gave no color with alcoholic ferric chloride.

The **acetate,** prepared by refluxing the original dehydrogenation mixture with acetic anhydride and recrystallizing from alcohol, was obtained as colorless, glistening plates, m. p. 175–176.5°. A mixture with the sample of acetate described below (m. p. 176–176.5°) melted at 175.5–176.5°.

The **methyl ether,** prepared by alternate treatments with methanolic potassium hydroxide and dimethyl sulfate as described below, was obtained as rosets of prismatic needles, m. p. 178–179. A mixture with the methyl ether described below (m. p. 179–179.5°) showed no depression in m. p.

Synthesis of 3-Keto-1-methyl-1,2,3,11,12,12a-hexahydrochrysene and 3-Hydroxy-1-methylchrysene

3-Penten-2-one.—Following the procedure of Grignard and Fluchaire,[28] except using stirring instead of shaking, a mixture of 506 cc. of acetone, 422 cc. of ether and 200 cc. of 12% sodium hydroxide saturated with salt was treated with 386 cc. of acetaldehyde in 506 cc. of acetone over a five-hour period while the temperature of the mixture was maintained at 10–12°. The 4-hydroxy-2-pentanone was isolated by distillation, collecting the fraction, b. p. 64–75° at 16 mm., n^{21}_D 1.4300; weight 99 g. (14% yield);

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[25] Fieser, THIS JOURNAL, **51**, 2468 (1929).

[26] Wilds and Beck, *ibid.*, **66**, 1690 (1944).

[27] Linstead and Thomas, *J. Chem. Soc.*, 1130 (1940).

[28] Grignard and Fluchaire, *Ann. chim.*, [10] **9**, 10 (1928).

reported b. p. 77–79° at 20 mm.,[29] n^{20}_{D} 1.4299.[30] Considerable higher boiling material also was formed.

Fifty grams of the hydroxy ketone was dehydrated by slow distillation at atmospheric pressure with 0.04 g. of concentrated sulfuric acid,[31] and the fraction boiling at 119–132°, n^{17}_{D} 1.4333 (weight 27 g., 66%) was collected as 3-penten-2-one. After fractionation through a 22-cm. Vigreux column, the material had the b. p. 121–122.5°, n^{20}_{D} 1.4342, d^{20}_{4} 0.8754, M_{D} (found) 25.03, M_{D} (calcd.) 24.84. (Claisen[29] reported the b. p. 122°.) This material was redistilled just prior to use. With the addition of afew crystals of hydroquinone, the pentenone did not deteriorate for several weeks when stored in the refrigerator.

2-(α-Methyl-γ-ketobutyl)-2-carbomethoxy-1-keto-1,2,-3,4-tetrahydrophenanthrene (XII).—To 20 mg. of sodium in 2 cc. of methanol was added 762 mg. of 2-carbomethoxy-1-ketotetrahydrophenanthrene[32] in 12 cc. of dry, thiophene-free benzene. The clear, yellow solution was refluxed under nitrogen for ten minutes and then cooled in ice. It was essential that the sodium enolate did not precipitate from solution, or else the yield was considerably diminished; if the enolate separated it was redissolved by heating, with the addition of a very small amount of methanol, if necessary.

To the cold, clear solution was added 0.6–1.0 cc. of freshly redistilled 3-penten-2-one and the mixture was allowed to stand at room temperature under nitrogen for twenty-four to forty-eight hours. After treatment with water and acetic acid, the product was extracted twice with benzene, the latter washed with water and evaporated. Trituration with petroleum ether gave 843 mg. (83%) of crude material, m. p. 96–102°, which after recrystallization from alcohol gave 601 mg. (59%) of colorless crystals, m. p. 108–110.5°. From the mother liquor was obtained 93 mg. of solid melting at 103–164°; this material appeared to contain some of the cyclized material (probably as the carbomethoxy derivative).

The analytical sample, prepared by adsorption on alumina and elution with benzene–ether, crystallized from alcohol as rosets of thin, colorless, prismatic needles, m. p. 114.5–115°.

Anal. Calcd. for $C_{21}H_{22}O_4$: C, 74.5; H, 6.6. Found: C, 75.0; H, 6.7.

3-Keto-1-methyl-1,2,3,11,12,12a-hexahydrochrysene (XIII).—A suspension of 2 g. of the diketo ester (m. p. 108–110.5°) in 200 cc. of 5% potassium hydroxide was refluxed under nitrogen for forty-six hours. The hot aqueous layer was decanted and the residue dissolved in hot benzene. The aqueous layer was extracted several times with hot benzene, and the combined extract was washed with water until neutral and evaporated. The crystalline residue was triturated with petroleum ether, yielding 1.09 g. (70%) of material sintering at 167° and melting at 176–190°. Evaporation of the filtrate yielded 0.29 g. (25%) of impure 1-ketotetrahydrophenanthrene, m. p. 78–84° (after purification, m. p. and mixed m. p. 93–95°).[33]

Recrystallization of the first crop from ethyl acetate gave 0.81 g. (52%) of colorless crystals of m. p. 194.5–196.5°. An additional 7% obtained by treatment of the filtrate with alcoholic alkali (see below) brought the total yield of satisfactory material to 59%. Purification of a sample by adsorption on alumina and elution with benzene–ether, followed by recrystallization from ethyl acetate gave colorless rectangular plates of m. p. 196–197°.

Anal. Calcd. for $C_{19}H_{18}O$: C, 87.0; H, 6.9. Found: C, 86.9; H 6.9.

Concentration of the original ethyl acetate filtrate yielded a total of 0.21 g. of material, m. p. 173–180°, the analysis of which indicated it to be a mixture of the desired ketone and the 12a-carbomethoxy derivative (Found: C, 83.5; H, 6.4). When 226 mg. of this material was refluxed with 12 cc. of 45% potassium hydroxide and 50 cc. of methanol under nitrogen for seven hours, 114 mg. of the pure ketone XIII, m. p. and mixed m. p. 194.5–196°, was obtained.

Variations made in the method of cyclizing the diketo ester XII were less satisfactory; with 10% aqueous alkali the cleavage to 1-ketotetrahydrophenanthrene was increased to 33%. The use of acetic acid-hydrochloric acid, methanolic sodium methoxide or alcoholic alkali, reagents which were used successfully in a similar case,[11] led to oils or poor yields of impure solid.

3-Hydroxy-1-methylchrysene (VIIIa).—A mixture of 811 mg. of the ketone XIII, 6 cc. of *p*-cymene (redistilled from sodium) and 170 mg. of palladium-charcoal catalyst[27] was refluxed under nitrogen for seventy hours. After cooling, alcohol was added, the hot solution filtered and evaporated. The product was evaporatively distilled at 200–260° (0.02 mm.) and the distillate digested with hot benzene; after cooling 532 mg. (67%) of material sint. 262°, m. p 267–270° (vac.) was obtained. Concentration of the filtrate gave 77 mg. of material melting at 158–162°. This material was recombined with the mother liquor and again heated in 2.5 cc. of boiling *p*-cymene with 60 mg. of palladium–charcoal for forty-eight hours. After working up as before an additional 82 mg. (10%) of the phenol, m. p. 261.5–263° (vac.) was obtained, bringing the total yield to 77%.

Recrystallization of a sample from alcohol-benzene gave small, colorless needles, m. p. 269–271° (vac.).[20]

Anal. Calcd. for $C_{19}H_{14}O$: C, 88.3; H, 5.5. Found: C, 88.0; H, 5.5.

When the dehydrogenation was carried out in boiling xylene the yield of the phenol was only 31%.

The **acetate,** prepared in 96% yield by heating a solution of 180 mg. of the phenol with 8.5 cc. of acetic anhydride under nitrogen for four hours, crystallized from alcohol–ethyl acetate as colorless, glistening plates, m. p. 176–176.5°.

Anal. Calcd. for $C_{21}H_{16}O_2$: C, 84.0; H, 5.4. Found: C, 84.1; H, 5.4.

The **methyl ether** was prepared by treating a warm suspension of 130 mg. of the phenol in 13 cc. of 10% potassium hydroxide and 25 cc. of methanol with five alternate additions of 1.3 cc. of dimethyl sulfate and 1.3 cc. of 45% potassium hydroxide. After warming for an additional ten minutes, the solution was diluted, cooled and filtered; yield 125 mg. (91%), m. p. 173–176° with previous sintering at 167°. After two recrystallizations from alcohol–ethyl acetate, the m. p. of the rosets of small prismatic needles was 179–179.5°.

Anal. Calcd. for $C_{20}H_{16}O$: C, 88.2; H, 5.9. Found: C, 88.6; H, 6.0.

Summary

Further evidence for the course of the acid-catalyzed rearrangement of a cyclic dienone to a phenol, with migration of an angular methyl group, has been provided by synthesizing 3-keto-12a-methyl-3,11,12,12a-tetrahydrochrysene (VI), and rearranging this dienone to 3-hydroxy-1-methyl-11,12-dihydrochrysene (VIIa) with acetic anhydride–sulfuric acid.

The structure of the rearrangement product was proved by dehydrogenation to 3-hydroxy-1-methylchrysene and comparison with material obtained by an independent synthesis.

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(29) Claisen, *Ann.*, **306**, 324 (1899).

(30) McAllister, Bailey and Bouton, This Journal, **62**, 3212 (1940).

(31) Kyriakides, *ibid.*, **36**, 534 (1914).

(32) Bachmann and Wilds, *ibid.*, **62**, 2085 (1940).

(33) With smaller runs (0.5 g.) practically all of this ketone sublimed into the condenser.