After separating and drying the crude product, it was dissolved in benzene–60° naphtha solution and decolorized twice with Norite, and the solution evaporated to dryness *in vacuo*. The residue was recrystallized from absolute alcohol–acetone solution to give 0.2 g. of XVII, m.p. 115.2–115.8°.

b. From XII.—Dehydrogenation of 0.7 g. of XII with

an equivalent amount of roll sulfur was carried out using the above procedure giving 0.3 g. of XVII identical with that obtained from XV.

Anal. Calcd. for $C_{22}H_{18}O_2$: C, 84.07; H, 5.73. Found: C, 84.24; H, 6.02.

MISSOULA, MONTANA

NOTES

Synthesis of Phenanthrenes. VI. 5-Hydroxy-8-keto-4a-methylperhydrophenanthrene

BY RODERICK A. BARNES AND ALBERT H. SHERMAN[1]

RECEIVED JANUARY 2, 1953

Previous work[2-4] has been directed toward the preparation of octahydrophenanthrenes as possible intermediates for the synthesis of steroids. From such intermediates there are two main paths by which further progress toward the steroids might be achieved. The aromatic C ring may be reduced and then the D ring added or the two procedures might be reversed.

The purpose of this paper is to report some results which have been obtained in connection with the first approach. 5,8-Dimethoxy-4a-methyl-1,2,3,4,-4a,9,10,10a-octahydrophenanthrene (I), which has previously been described,[2] was treated with hydrogen bromide to cleave the methoxyl groups. The resulting hydroquinone (II) was rather unstable toward oxygen particularly in basic solution.


I, R = CH₃ III IV
II, R = H

VI ← V
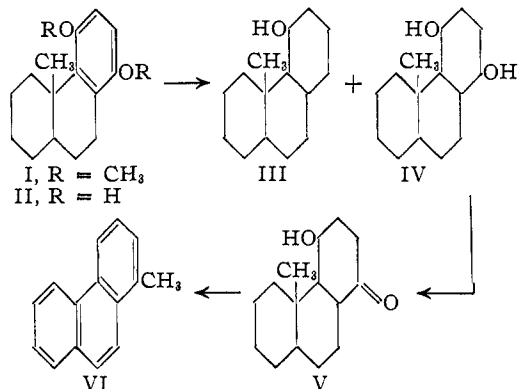
Two reductions of II were carried out; from the first there was isolated one isomer of 5,8-dihydroxy-4a-methylperhydrophenanthrene along with a large amount of unhydrogenated material. The second hydrogenation under more drastic conditions completely reduced the aromatic ring but also caused rather extensive hydrogenolysis. By chromatographic fractionation of the reduction product a single crystalline monohydroxy-4a-methylperhy-

(1) Abstracted from a thesis presented by A. H. Sherman to the Graduate School for the Ph.D. degree, November, 1952.

(2) R. A. Barnes, THIS JOURNAL, **75**, 3004 (1953).

(3) R. A. Barnes and M. D. Konort, *ibid.*, **75**, 303 (1953).

(4) R. A. Barnes, H. P. Hirschler and B. R. Bluestein, *ibid.*, **74**, 4091 (1952).

drophenanthrene (III) and three additional isomers of diol IV were separated.

It is believed that III has the hydroxyl group at the 5-position. This seems likely because the hydrogenolysis requires the close approach of the catalyst surface and the hydroxyl-bearing carbon atom. Such a process would be sterically inhibited at the 5-position by the angular methyl group. Also, when III was oxidized and the resulting ketone treated with methylmagnesium iodide and then dehydrogenated no 4-methylphenanthrene was isolated. It is not surprising that the Grignard reagent would fail to add to the sterically hindered carbonyl group.

The oxidation of diol IV was investigated since most procedures for adding ring D require a keto group at the 8-position. N-Bromosuccinimide in aqueous dioxane oxidized the crude mixture of diols (from second hydrogenation) and after equilibration with base followed by distillation a single ketoalcohol (V) was isolated. It was anticipated that the sterically unhindered hydroxyl group (at the 8-position) would be preferentially oxidized. This was proved by treating V with methylmagnesium iodide and then dehydrogenating the addition product. The formation of 1-methylphenanthrene proved that the keto group of V must have been at carbon 8.

Although the stereochemistry of V has not been established some reasonable assumptions can be made. According to the theoretical considerations previously presented[2] the starting octahydrophenanthrene (II) should have the *cis* configuration of rings A and B.[5] If the results obtained by Cornforth and Robinson[6] in the hydrogenation of a similar *cis*-octahydrophenanthrene can be used as a basis for generalization it seems likely that the hydrogen at carbon 4b is *cis* to the angular methyl group.
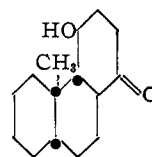
Since V was obtained after equilibration with base the *trans* configuration of rings B and C is most probable. There is as yet no evidence bearing on the configuration of the hydroxyl group of V.

(5) The experimental verification of this prediction is currently in progress.

(6) J. W. Cornforth and R. Robinson, *J. Chem. Soc.*, 1855 (1949).

The fact that only V was isolated when the mixture of diols IVb, c, and d was oxidized suggests that these three compounds may differ only in the configuration of the hydroxyl at carbon 8 and the hydrogen at carbon 8a.

Experimental[7]

5,8-Dihydroxy-4a-methyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (II).—A mixture of 48% hydrobromic acid (100 ml.), acetic acid (165 ml.) and 5,8-dimethoxy-4a-methyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (7.5 g.) was heated at reflux temperature for 7 hours. The reaction mixture was diluted with water and the product extracted with ether. Evaporation of the ether left a greenish solid (6 g.). Recrystallization of 3 g. of this material yielded 1.5 g. (45%) of II which was nearly colorless and melted at 202–204° (capillary). The analytical sample prepared by further recrystallization from benzene melted at 200.1–200.7° (hot stage).

Anal. Calcd. for $C_{15}H_{20}O_2$: C, 77.55; H, 8.68. Found: C, 77.45; H, 8.70.

The ultraviolet spectral curve of II in ethanol had two maxima, one at 295 mμ (log ϵ 3.55), the other at *ca.* 225 mμ could not be determined accurately with our instrument.

An attempt to purify II by dissolving in aqueous alkali led to the formation of a brown tar from which a yellow solid could be isolated. An oxidation of II (0.93 g.) according to the procedure of Smith and Irwin[8] yielded 0.51 g. (55%) of crude quinone, m.p. 53–58°. Sublimation produced golden yellow crystals which melted at 60–62°. This quinone was extremely sensitive to air oxidation and darkened rapidly on standing. The ultraviolet spectral curve had maxima at 250 mμ (log ϵ 3.85) and 295 mμ (log ϵ 3.45).

5,8-Diacetoxy-4a-methyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene.—A mixture of II (0.6 g.), acetic anhydride (2.7 g.) and pyridine (5 ml.) was allowed to stand at room temperature for 40 hours. The reaction mixture was poured into ice-water containing hydrochloric acid (5 ml.) and the product extracted with ether. Evaporation of the ether left a crystalline product (0.5 g., 61%) which melted at 87–93°. The analytical sample was prepared by alternate recrystallization from methanol and ethyl ether–petroleum ether, m.p. 93.5–94.2°.

Anal. Calcd. for $C_{19}H_{24}O_4$: C, 72.13; H, 7.65. Found: C, 72.09; H, 7.73.

Hydrogenation of II. A.—A solution of II (2.1 g.) in dioxane (50 ml.) was hydrogenated for four hours at 2800 p.s.i. and 170–185° using palladium-on-strontium carbonate (2.1 g.) as a catalyst. The catalyst was filtered from the solution and the solvents removed to leave a brown solid residue. Recrystallization of this substance from benzene yielded three crops of unchanged hydroquinone II (0.57 g.) in various stages of purity. The filtrate from these crystallizations was separated by chromatographic fractionation to yield two major components: (1) quinone, m.p. 52–57° formed by air oxidation of II during processing and (2) an isomer of 5,8-dihydroxy-4a-methylperhydrophenanthrene, IVa (0.12 g.) which melted at 193.5–195° after recrystallization from acetone.

Anal. Calcd. for $C_{15}H_{26}O_2$: C, 75.57; H, 11.00. Found: C, 75.43; H, 10.83.

B.—The hydrogenation was repeated using a solution of II (9 g.) in dioxane (115 ml.) and the catalyst (18 g.) at 220–230° and 3450 p.s.i. for 15 hours. An aliquot (1.5 g.) of the liquid hydrogenation product (7.5 g.) was separated by chromatography into four major fractions: (1) a liquid, probably 4a-methylperhydrophenanthrene (0.34 g.); (2) a solid (0.34 g.) which melted at 120.8–121° after recrystallization from hexane; (3) a solid (0.17 g.) which could not be recrystallized to a sharp melting compound and (4) a solid (0.10 g.) which melted at 172–175° after recrystallization from benzene or acetone.

Fraction 2 was a monohydroxy-4a-methylperhydrophenanthrene (III).

Anal. Calcd. for $C_{15}H_{26}O$: C, 81.00; H, 11.78. Found: C, 80.67; H, 11.57.

Fraction 4 was a second isomer (IVb) of 5,8-dihydroxy-4a-methylperhydrophenanthrene.

Anal. Calcd. for $C_{15}H_{26}O_2$: C, 75.57; H, 11.04. Found: C, 75.68; H, 11.04.

Fraction 3 (100 mg.) was rechromatographed; the first fractions eluted (86 mg.) were soluble in methanol while the later fractions (7 mg.) were insoluble in methanol. The methanol-soluble fractions were combined and recrystallized from benzene or ethyl acetate to yield the third isomer (IVc) of 5,8-dihydroxy-4a-methylperhydrophenanthrene, m.p. 152–154°.

Anal. Calcd. for $C_{15}H_{26}O_2$: C, 75.57; H, 11.00. Found: C, 75.18; H, 10.87.

The methanol-insoluble fractions from two different chromatographic separations were combined and recrystallized from methyl ethyl ketone to yield isomer IVd, m.p. 203.5–204.5°.

Anal. Calcd. for $C_{15}H_{26}O_2$: C, 75.57; H, 11.00. Found: C, 75.47; H, 10.63.

The following melting points were observed for mixtures of the isomeric 5,8-dihydroxy-4a-methylperhydrophenanthrenes: IVa (194–195°) and IVd (202–203°), 175–192°; IVa and IVb (172–175°), 140–188°; IVb and IVc (152–154°), 115–151°.

Chromatographic Procedure.—Acid-washed, 80–200 mesh alumina, dried at 180° was used in all separations. The compounds were adsorbed on the column from a benzene solution (or ether–benzene if necessary) and solvents of increasing polarity were used to elute the various fractions (benzene, 2% ether in benzene, 4% ether in benzene, and finally 60% acetone in ether, 1% ethanol in 49.5% acetone–49.5% ether, 2% ethanol in 49% acetone–49% ether). Only fractions composing the major peaks in the chromatographic curve (fraction number plotted against weight of the fraction) were investigated. The solvents for elution of the various pure substances are listed: III, 20–40% ether in benzene; IVa, 8–30% acetone in ether; IVb, 2% ethanol in 49% acetone–49% ether; IVc and IVd, 15–30% acetone in ether.

Attempted Structure Proof for III.—A solution of III (464 mg.) in acetic acid (5 ml.) was oxidized by the dropwise addition at 0° of a solution of chromic anhydride (155 mg.) in water (0.5 ml.) and acetic acid (5 ml.). The reaction mixture was kept at 5° for 11 hours and at 30° for three hours. After processing there was obtained a pale yellow oil which did not crystallize. A few drops of this product were allowed to react with 2,4-dinitrophenylhydrazine to yield orange needles which melted at 210–213°. The major portion of the crude ketone (385 mg.) was added to a cold solution of methylmagnesium iodide prepared from methyl iodide (2.3 g.), magnesium (0.4 g.) and ether (10 ml.). After standing overnight at room temperature the reaction mixture was treated with ice and hydrochloric acid and the product extracted with ether. Evaporation of the ether left an oil (0.40 g.) which was directly dehydrogenated using 17% palladium-on-charcoal (0.08 g.) with diphenylamine (2.0 g.) as a solvent. About 50% of the theoretical amount of hydrogen was evolved. The dehydrogenated product was chromatographed but no crystalline phenanthrene was obtained.[9]

Oxidation of IV with N-Bromosuccinimide. A.—A portion (3 g.) of the crude product from the second hydrogenation was oxidized with N-bromosuccinimide (2.4 g.) in dioxane (22 ml.) and water (3 ml.) according to the procedure of Fieser and Rajagopalan.[10] The crude oxidation product was refluxed for 30 minutes with a 1% solution of potassium hydroxide in methanol (50 ml.). The reaction mixture was diluted with water and the product extracted with ether. A brown oil (2.78 g.) remained after evaporation of the ether. This product was separated by Girard reagent T[11] (5 g.) into a non-ketonic fraction (1.57 g.) and a ketonic fraction (1.16 g.). Evaporative distillation at 0.2 mm. of the ketonic fraction produced three fractions: (1) 0.16 g. (86–95°);

(7) All melting points were determined using a Kofler hot stage. Analyses are by W. Manser, Zurich, Switzerland, and J. F. Alicino, Metuchen, New Jersey.

(8) L. I. Smith and W. B. Irwin, THIS JOURNAL, **63**, 1036 (1941).

(9) If the Grignard reagent only enolized the ketone, then subsequent dehydrogenation may have formed some 4-phenanthrol. However, the solvents used to remove any phenanthrene hydrocarbons would not be expected to elute a phenol from the column of alumina.

(10) L. F. Fieser and S. Rajagopalan, THIS JOURNAL, **71**, 3938 (1949).

(11) A. Girard and G. Sandulesco, *Helv. Chim. Acta*, **19**, 1095 (1936).

(2) 0.44 g. (95–110°) and (3) 0.20 g. (110–115°). Fraction 3 (ketoalcohol V) solidified on standing and after recrystallization from benzene–hexane melted at 177–180°.

Anal. Calcd. for $C_{15}H_{24}O_2$: C, 76.22; H, 10.24. Found: C, 76.34; H, 10.39.

The infrared spectra of all three fractions had a strong carbonyl band at 5.85 μ. Only fraction 3 absorbed appreciably in the hydroxyl region (peaks at 2.75 and 2.85 μ).

B.—Diol IVb (409 mg.), m.p. 172–175°, was oxidized as in part A. The crude product (375 mg.) crystallized and after several recrystallizations melted at 183–185°. The filtrates from the recrystallizations containing most of the oxidation product (324 mg.) were treated with potassium hydroxide in methanol as in part A to yield V, m.p. 177–180° identical with the previous preparation. The melting point of a mixture of V and the crystalline product,[12] m.p. 183–185°, was 155–185°.

Structure Proof for V.—A solution of V (787 mg.) in ether (40 ml.) was added to methylmagnesium iodide prepared from methyl iodide (9.4 g.), magnesium (1.6 g.) and ether (50 ml.). The reaction mixture was processed as in the attempted structure proof of III. The product (756 mg.) crystallized on standing but was directly dehydrogenated without further purification. The first dehydrogenation with 5% palladium-on-charcoal and no solvent was incomplete. A portion (366 mg.) of the partially dehydrogenated mixture was dehydrogenated as in the previous case using freshly prepared palladium-on-charcoal (17%) and diphenylamine (2 g.) as a solvent. The main crystalline fraction of the dehydrogenation product (48 mg.) was recrystallized from ethanol to yield 1-methylphenanthrene which melted at 121–122°. The melting point of a mixture of this sample with authentic 1-methylphenanthrene (m.p. 118–119°)[13] was 118–120° (capillary). The picrate of this compound crystallized from ethanol as orange needles which melted at 136–139° (reported[13] 136–136.5°).

(12) This is believed to be an isomer of V in which rings B and C are *cis.*

(13) Kindly furnished by Prof. R. C. Elderfield from the collection of the late Prof. W. E. Bachmann; W. E. Bachmann and A. L. Wilds, THIS JOURNAL, **60**, 624 (1938).
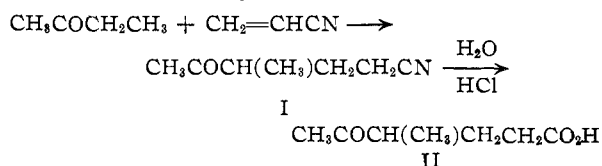
SCHOOL OF CHEMISTRY
RUTGERS UNIVERSITY
NEW BRUNSWICK, N. J.

Monocyanoethylation of Certain Ketones

BY HENRY E. BAUMGARTEN AND ROBERT L. EIFERT

Other investigations in this Laboratory have required the preparation of relatively large quantities of γ-acetylvaleric acid (II) or of its derivatives. Trial of previously reported[1,2] procedures for the synthesis of II revealed that these procedures were lengthy, utilized costly starting materials and resulted in low over-all yields. Indeed, the most attractive procedure for the synthesis of II appeared to be the monocyanoethylation of methyl ethyl ketone to give γ-acetylvaleronitrile (I) followed by acid hydrolysis to II. However, as

$$CH_3COCH_2CH_3 + CH_2=CHCN \longrightarrow$$

$$CH_3COCH(CH_3)CH_2CH_2CN \xrightarrow[HCl]{H_2O}$$

I

$$CH_3COCH(CH_3)CH_2CH_2CO_2H$$

II

pointed out by Yoho and Levine,[3] numerous investigators have found that cyanoethylation of simple ketones leads to the formation of poly-

(1) F. March, *Ann. chim.*, [7] **26**, 295 (1902).

(2) F. Lions, *J. Proc. Roy. Soc., i . S. Wales,* **771**, 192 (1938).

(3) C. W. Yoho and R. Levine, THIS JOURNAL, **74**, 5597 (1952).

cyanoethylated derivatives as the main reaction products or to very low yields of the monocyanoethylated derivatives in those few cases in which monocyanoethylation has been observed. In fact, the best yield of I thus far reported was 6% (obtained by Barkley and Levine[4] from the reaction of methyl ethyl ketone anion with β-chloropropionitrile).

As far as we have been able to determine, most of the previously reported cyanoethylation reactions have been run with the stoichiometric quantities of both reactants (*e.g.*, equimolar quantities for attempted monocyanoethylations) although it seems reasonable that the use of a large excess of ketone over acrylonitrile might lead to a larger yield of the monocyanoethylated derivative. In support of this thesis we found that, when a 10 to 1 molar ratio of methyl ethyl ketone to acrylonitrile was used (with benzyltrimethylammonium hydroxide as catalyst), the yield of I was 24–30%.[5] The hydrolysis of I with concentrated hydrochloric acid gave II in 91% yield. Although the over-all yield of II is not high by the usual standards, the relative low cost of the starting materials (the unused methyl ethyl ketone may be recovered and reused) recommends this procedure over those previously employed for the preparation of II.

Cyclohexanone has been reported[6] to react with a molecular equivalent of acrylonitrile to give a 10% yield of the monocyanoethyl derivative. With a 5 to 1 ratio of ketone to acrylonitrile, cyclohexanone gave a yield of 47% of the monocyanoethyl derivative. Acetone has been reported to give an 8% yield of the monocyanoethyl derivative when either a 1 to 1 ratio[7] or a 2 to 1 ratio[8] of ketone to acrylonitrile was used, although in the former instance the product was not isolated in the pure state. With a 10 to 1 ratio of ketone to acrylonitrile, acetone gave an 18% yield of the monocyanoethyl derivative.

Experimental

γ-Acetylvaleronitrile (I).—In a typical experiment a mixture of 2160 g. (30 moles) of methyl ethyl ketone and 5 ml. of a 40% aqueous solution of benzyltrimethylammonium hydroxide was cooled to 5° in a 5-l. three-necked flask fitted with a stirrer, dropping funnel, thermometer and reflux condenser. To the cooled and well-stirred mixture 159 g. (3 moles) of acrylonitrile was added at such a rate that the temperature did not rise above 10° (about 15 minutes was required). Stirring was continued for five minutes after addition was completed and the mixture was neutralized with dilute hydrochloric acid to congo red. The excess methyl ethyl ketone (and acrylonitrile, if any) was removed by distillation at atmospheric pressure through a 15-in. Vigreux column. The residue was fractionated under reduced pressure and the fraction boiling at 110–120° (15 mm.) was taken leaving a considerable quantity of higher boiling product in the stillpot. The recovered methyl ethyl ketone was dried over potassium carbonate for reuse in similar reactions. Occasionally subsequent reactions were a little harder to control due to the presence of some unreacted acrylonitrile in the recovered methyl ethyl ketone. The product from three runs was fractionated through the same Vigreux column, giving 330 g. (29.4%) of γ-acetyl-

(4) L. B. Barkley and R. Levine, *ibid.*, **72**, 3699 (1950).

(5) The remainder of the acrylonitrile appeared as the dicyanoethyl derivative, yield *ca.* 70%.

(6) H. A. Bruson and T. W. Riener, THIS JOURNAL, **64**, 2850 (1942).

(7) O. W. Shannon, U. S. Patent 2,381,371; *C. A.*, **40**, 350 (1946).

(8) A. P. Terent'ev and S. M. Gurvich, *Vestnik Moskov. Univ.*, **5**, No. 5, Ser. Fix.-Mat. i Estest. Nauk No. 3, 47 (1950); *C. A.*, **45**, 7005 (1951).