factory. Fourth, isopropyllithium is obtainable in 58% yield from isopropyl chloride. The yields of some other RLi compounds prepared in petroleum ether are: 50% ethyllithium from ethyl bromide; 60% *n*-propyllithium from *n*-propyl bromide; 70% *n*-butyllithium from the bromide and 75% from the chloride.

Acknowledgments.—The authors are grateful to R. K. Abbott, G. E. Brown, R. N. Meals, H. A. Pacevitz and F. A. Yeoman for assistance.

Summary

On the basis of a series of new experiments some general principles have been formulated concerning metalation and halogen–metal interconversion reactions.

Preferential halogen–metal interconversions have been effected with some polyhalogen compounds.

Some new information has been provided on the preparation and manipulation of organolithium compounds.

AMES, IOWA
GOODWELL, OKLAHOMA RECEIVED JUNE 15, 1940

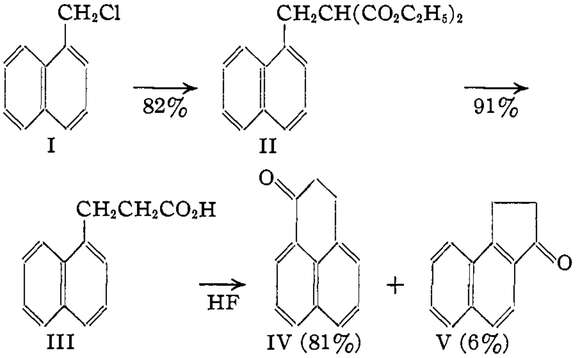
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

Synthetic Experiments Utilizing Perinaphthanone-7

BY LOUIS F. FIESER AND MARSHALL D. GATES, JR.

This investigation was undertaken in the hope of obtaining 1′,9-dimethylene-1,2-benzanthracene by application of the general *o*-halide scheme of synthesis,[1] starting with the condensation of *o*-chlorophenylmagnesium bromide with perinaphthanone-7. Since the work was initiated a similar series of reactions proceeding from acenaphthenone has been applied successfully to the synthesis of 1′,9-methylene-1,2-benzanthracene.[2] As will be shown, a peculiarity specific to the perinaphthane series blocked the present approach to the goal indicated.

Although preparations regarded as consisting essentially of perinaphthanone-7[3] (IV) have been reported by other workers, the purity and identity of these preparations have not been established and some confusion exists concerning the characterization of the acid from which the ketonic material was produced by cyclization. Thus the following melting points are reported for the amide of β-(1-naphthyl)-propionic acid (III): 140°,[4] 85°,[5] 133°,[6] although investigators seem agreed as to the melting point of the acid obtained by the malonic ester synthesis from α-chloro- or bromomethylnaphthalene. We employed α-chloromethylnaphthalene prepared by chloromethylation in acetic acid solution according to Darzens and Lévy,[7] although like Cambron[8] we were unable to duplicate the yield. The reaction is not as easily controlled as in Cambron's procedure,[8,9] but after some experience it was possible to prepare the halide in 51.5% yield (not allowing for much recovered naphthalene). The condensation with malonic ester was improved considerably by using a large excess of the ester, and pure β-(1-naphthyl)-propionic acid was obtained on a large scale in excellent over-all yield. The amide, prepared both from the acid chloride and the crystalline methyl ester,[10] melted at 103–104° and had the expected composition. Mayer and Sieglitz[5] cyclized III by the action of aluminum chloride in ligroin on the acid chloride and obtained in poor yield a yellow ketonic substance melting at about 85–86°, but Cook and Hewett[11] found that material obtained in this way is a mixture and that the yellow color is due to the presence of a significant amount of the



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[1] Fieser and Seligman, THIS JOURNAL, **61**, 136 (1939).

[2] Fieser and Cason, *ibid.*, **62**, 432 (1940).

[3] "7,8-Dihydrophenalone-9" (Ref. 5); for comments on the present nomenclature, see Ref. 12.

[4] Willgerodt, *Ber.*, **21**, 534 (1888).

[5] Mayer and Sieglitz, *ibid.*, **55**, 1835 (1922).

[6] Darzens and Lévy, *Compt. rend.*, **201**, 902 (1935).

[7] Darzens and Lévy, *ibid.*, **202**, 73 (1936).

[8] Cambron, *Can. J. Research*, **17B**, 10 (1939).

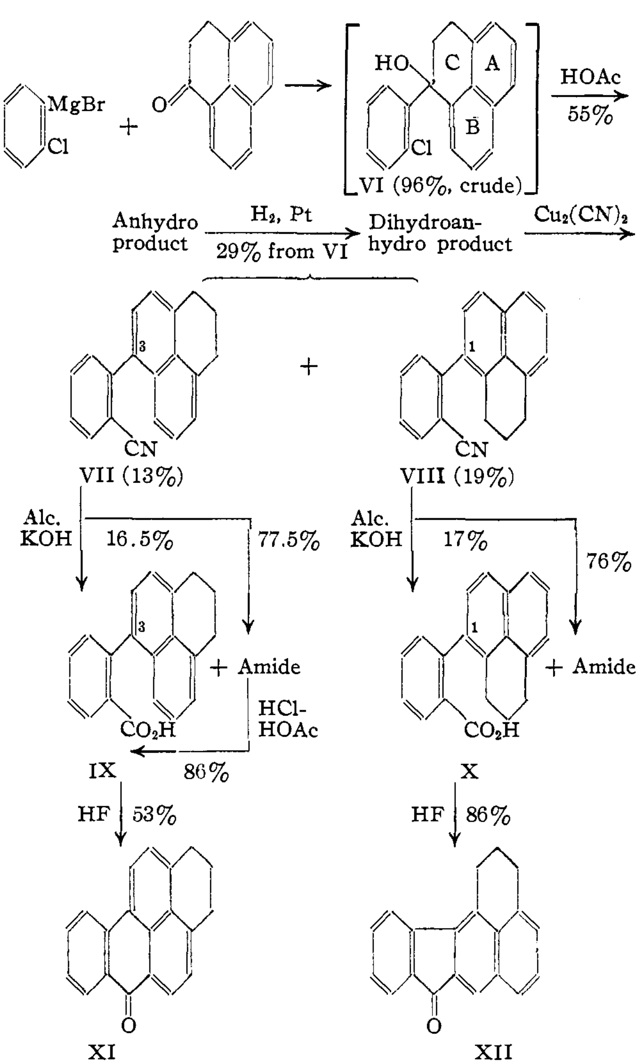
[9] Fieser and Novello, THIS JOURNAL, **62**, 1855 (1940).

[10] Manske and Ledingham, *Can. J. Research*, **17B**, 14 (1939).

[11] Cook and Hewett, *J. Chem. Soc.*, 365 (1934).

dehydrogenation product, perinaphthenone, which they isolated and identified. On heating the acid III with stannic chloride they obtained the same substance along with a small amount of a saturated ketone, m. p. 120–121°, evidently corresponding to one of the alternative structures IV and V. Darzens and Lévy[6] conducted the cyclization of III by the Friedel and Crafts procedure in nitrobenzene solution and obtained in good yield a yellow substance melting at 86°.

We studied the cyclization under various conditions and, in conformity with the observation of Cook and Hewett,[11] ascertained that interaction of the acid chloride with either aluminum or stannic chloride invariably gives yellow material containing perinaphthenone. The removal of this substance from the crude product, obtained for example according to Darzens and Lévy,[6] is tedious and the yield of residual material is low. Fortunately the interfering dehydrogenation reaction can be avoided almost completely by cyclizing free β-(1-naphthyl)-propionic acid with hydrogen fluoride. The crude product was pale yellow and the chief constituent was easily isolated in a pure and colorless condition by adsorbing the yellow impurity and a ketonic by-product on alumina. The main material was obtained in 81% yield and identified as perinaphthanone-7 (IV) by Clemmensen reduction to the known perinaphthane.[12] The purified, colorless ketone melts at 82.6–83.2°. The higher melting, yellow preparations of the earlier workers,[5,6] while evidently impure, gave oximes corresponding fairly closely to ours and probably contained considerable amounts of IV. The by-product which is adsorbed on alumina more strongly than IV was isolated in a pure, colorless condition and found to correspond closely in melting point (120.6–121.4°) and in the m. p. of the oxime with Cook and Hewett's[11] ketone. This substance may therefore be assigned the alternate structure of 4,5-benzhydrindone-1 (V).



In the synthesis proper, perinaphthanone-7 was allowed to react with the Grignard reagent from *o*-chlorobromobenzene. The carbinol of the expected formula VI could not be obtained in a crystalline condition, and although a purified viscous oil was obtained in nearly theoretical yield the results of the subsequent operations indicated that this contained only about 40% of the desired carbinol VI. An entirely similar situation was encountered in the condensation of the same Grignard reagent with acenaphthenone,[2] where the characterization of the crude carbinol was facilitated by the formation of a crystalline product of dehydration. In the present instance dehydration of the crude carbinol was accomplished satisfactorily by short boiling with acetic acid but the product, even after careful purification by chromatographic adsorption, was an oil. By preliminary processing in acetic acid with zinc dust the unsaturated material was obtained in a form capable of being hydrogenated in the presence of Adams catalyst, and from the reaction product there was obtained, with the aid of further adsorption technique, a saturated oil

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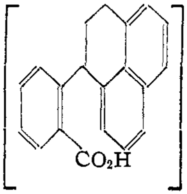
(12) Fieser and Hershberg, This Journal, 60, 1658 (1938).

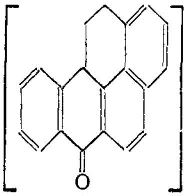
having very nearly the composition of the expected chloro compound. No crystalline material could be isolated, however.

On replacement of halogen with the nitrile group a solid was obtained which could be separated by systematic fractionation into two pure isomeric nitriles and a third crystallizate of constant melting point which proved to be a eutectic mixture of these two substances. Although acid hydrolysis of the nitriles was unpromising, hydrolysis was effected very smoothly by refluxing with alcoholic potassium hydroxide, each isomer yielding the amide as the chief product along with a smaller amount of the corresponding acid. The amide from the lower melting nitrile was hydrolyzed to the acid in excellent yield by refluxing in acetic–hydrochloric acid solution.

The isolation of two series of compounds where one was expected indicates the occurrence of an anomalous reaction at some stage of the operations, and since the anhydro and dihydroanhydro products were oils, in contrast to the corresponding compounds of the acenaphthene series,[2] this most likely is in the dehydration of the carbinol. The absorption spectra of the isomeric acids were determined by Dr. R. N. Jones, but there was little difference between the two and the results provided no very significant indication concerning the structures. Conclusive evidence on this point, however, was obtained by the following observations. On cyclization with liquid hydrogen fluoride at room temperature, one acid was converted into a beautifully crystalline substance identical with the recently synthesized 2,1′-trimethylene-1′,9-benzanthrone-10[12] (XI), and the acid is therefore 3-(*o*-carboxyphenyl)-perinaphthane (IX). Evidently an isomerization has occurred involving a migration of the double bonds from one of the originally aromatic rings (A in formula VI) to the alicyclic ring (C). A similar migration from the alternate benzenoid ring (B) would give rise to the isomeric acid X, and the second acid isolated might have either this structure or that (XIII) corresponding to a preservation of the original bond structure



XIII



XIV

Cyclization of the acid in question with hydrogen fluoride gave a bright yellow product having more the character of a fluorenone (XII) than an anthrone (XIV), and a conclusive distinction between these alternate structures was obtained spectrographically in determinations made by Dr. R. N. Jones. The spectrum of the reaction product (Fig. 1) bears no resemblance to that of 1,2-benz-10-anthrone,[13] which was examined as a model of XIV, but corresponds closely in form with the spectrum of the parent 2,3-benzfluorenone,[14] with a bathochromic shift of about 8 mμ attributable to the alkyl substitution. The ketone is therefore 4,4′-trimethylene-2,3-benzfluorenone (XII) and the acid from which it is derived is 1-(*o*-carboxyphenyl)-perinaphthane (X).

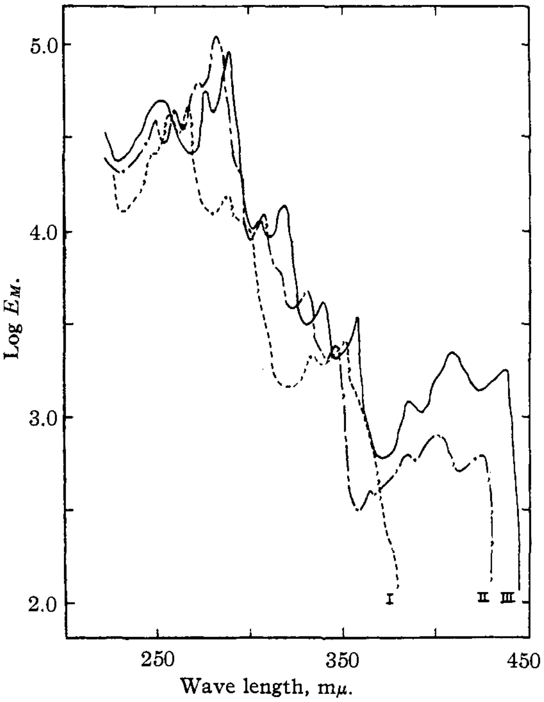


Fig. 1.—Absorption spectra in hexane: Curve I, 1,2-benz-10-anthrone (in hexane containing a trace of ethanol), maxima in mμ (log E_M values): 249 (4.43), 257 (4.62), 267 (4.67), 289 (4.18), [301] (4.01), 334 (3.32), 351 (3.41). Curve II, 2,3-benzfluorenone, maxima: 250 (4.58), 260.5 (4.64), 273 (4.81), 282 (5.05), [294] (4.33), 308 (4.08), [315] (3.80), 331 (3.67), 346 (3.39), 365 (2.60), 385 (2.80), 401 (2.91), 425 (2.80). Curve III, 4,4′-trimethylene-2,3-benzfluorenone (XII), maxima: 252.5 (4.71), 277 (4.73), 289 (4.98), 306 (4.02), 319 (4.14), 339 (3.60), 357 (3.50), [379] (2.90), 385 (3.08), 409.5 (3.33), 437 (3.25).

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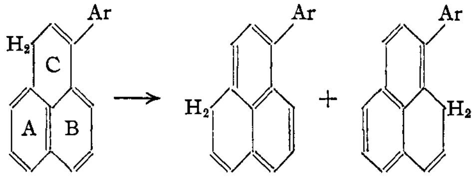
[13] Prepared by the method of Fieser and Hershberg, THIS JOURNAL, 61, 1272 (1939); m. p. 178–179.5°, corr.

[14] Prepared according to Thiele and Wanscheidt, *Ann.*, 376, 269 (1910); m. p. 164.2–164.8°, corr.

Thus the crystalline nitriles isolated, VII and VIII, are both products of rearrangement and the normal product was not encountered. This normal product would contain a naphthalenoid system which is isolated from the phenyl nucleus present in the molecule, whereas in the two rearrangement products both aromatic centers are conjugated. The tendency to assume this condition of conjugation doubtless provides the driving force for the rearrangement. It seems likely that the isomerization occurs at the dehydration step, for a bond migration in the anhydro product would require merely the α,γ-wandering of a single hydrogen atom.



This apparently is the first instance of isomerization in the perinaphthane series of the type discussed by Robinson.[15]

Experimental Part[16]

α-Chloromethylnaphthalene.—After several trials of the method of Darzens and Lévy[7] the following procedure was adopted as being more satisfactory than that described. Dry hydrogen chloride was passed into a suspension of 43 g. of trioxymethylene in 512 g. of acetic acid until 58 g. had been absorbed and 128 g. of naphthalene was added to the resulting, slightly warm solution. The flask was stoppered and heated at 60° (temperature of contents) until the first sign of the separation of the initially clear solution into two phases. The heating period required to reach this point varied in different runs from twenty to sixty-five hours. Whereas Darzens and Lévy consider the appearance of a second phase to represent the beginning of the chloromethylation reaction, it was our experience that this corresponds to the onset of polymerization, for when heating was continued beyond this point a large amount of resinous polymer was invariably left as a residue on distillation. Furthermore, a mixture of α-chloromethylnaphthalene, acetic acid and water in the proportions corresponding to the conditions of the reaction was found to be perfectly homogeneous. Consequently when the separation was first observed the mixture was poured into 2 liters of water and the precipitated oil was taken up in ether. After washing with water, with 5% sodium carbonate solution until neutral, and again with water, the solution was dried over sodium sulfate and the product distilled. After collecting a fore-run of 24 g. of naphthalene, the yield of α-chloromethylnaphthalene, b. p. 118–122° at 2 mm., was 91 g. (63% allowing for the naphthalene recovered, 51.5% based on the total employed[17]). The halide was used without further purification.

Diethyl α-Naphthylmethyl Malonate.—A cooled solution prepared by adding 45.5 g. of sodium in small pieces with stirring under reflux to 890 g. of absolute alcohol (distilled from magnesium methylate) was treated slowly with stirring with 525 g. of freshly distilled malonic ester, followed by 205 g. of α-chloromethylnaphthalene (gradual warming). After a final four-hour period of refluxing and stirring, the mixture was diluted with 100 cc. of water and neutralized with hydrochloric acid. The product, collected by separation of the layers and ether extraction and washed with soda and dilute acid, was dried and fractionated. After collecting 248 g. of malonic ester at the water pump (b. p. 85–94° at 14 mm.), the oil was transferred to a smaller flask, a small fore-run was separated, and the naphthylmethyl malonate was distilled as a pale lemon-yellow, viscous oil, b. p. 167–171° at 1.5–2 mm.; yield 284.5 g. (82%).

β-(1-Naphthyl)-propionic Acid.—A mixture of 330 g. of the above ester, 50 cc. of methanol, and a solution of 240 g. of sodium hydroxide in 1 l. of water was refluxed for three hours with the further addition during this period of 200 cc. of water containing 40 g. of sodium hydroxide. After adding 600 cc. of hot water to dissolve the sodium salt which had separated, the solution was brought just to the neutral point with hydrochloric acid and filtered from precipitated silica. On heating nearly to boiling and adding 200 cc. of concentrated hydrochloric acid to the vigorously stirred solution the malonic acid was precipitated in a granular, easily collected form. The colorless α-naphthylmethylmalonic acid, dried at 60° and 35 mm., weighed 264.8 g. (99%).

The total malonic acid was heated in a 3-liter flask in a bath maintained at 175°. Evolution of carbon dioxide commenced at an inner temperature of 140° and increased rapidly as the material melted and attained a temperature of 160°. The reaction was over in about thirty minutes, and after five minutes longer the melt was allowed to cool while rotating the flask to give a loose cake. Crystallization from benzene containing a little methanol gave a first crop of 179 g. of glistening white needles, m. p. 156–156.7°, corr. A second crop (29.8 g.) on crystallization from benzene and then from benzene–acetone afforded 20.5 g., m. p. 156–156.6°, corr., making the total yield of pure β-(1-naphthyl)-propionic acid 199.5 g. (92%). Darzens and Lévy[6] report the m. p. 156°.

The **methyl ester**, prepared by Fischer esterification, distilled at 126–128° (1 mm.) as a colorless oil and on two crystallizations from dilute methanol formed glistening plates, m. p. 35–36.5° (Manske and Ledingham,[10] 36°).

The **amide** was prepared (1) by allowing the methyl ester to stand with concentrated aqueous ammonia for five days, during which time the material liquefied and then changed to a solid and (2) by adding the acid chloride dropwise to aqueous ammonia solution. Both samples after two crystallizations from benzene–hexane formed fine, colorless needles, m. p. 103–104°, corr., and a mixture showed no depression.

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[15] Klyne and Robinson, *J. Chem. Soc.*, 1992 (1938).

[16] Melting points marked * were uncorrected for stem exposure.

[17] This yield is considerably better than reported recently by Ruggli and Burchardt, *Helv. Chim. Acta*, **23**, 443 (1940), who apparently used the procedure essentially as described by Darzens and Lévy.[7]

Anal. Calcd. for $C_{13}H_{13}ON$: C, 78.34; H, 6.58. Found: C, 78.24; H, 6.66.

Perinaphthanone-7 (IV).—A mixture of 46 g. of β-(1-naphthyl)-propionic acid and 140 g. of anhydrous hydrogen fluoride was allowed to stand in a platinum container at room temperature for two and one-half hours and poured onto 400 g. of ice. The organic material separated as a thick oil which set to a light yellow solid on stirring; this was collected and washed and taken into ether–benzene. On extraction with 5% sodium carbonate solution there was recovered 3.9 g. of usable starting acid, m. p. 152–154 °*. The ether–benzene solution was concentrated to remove the ether, diluted with hexane and passed through a 30 × 200 mm. column of activated alumina. The tower was washed with benzene–hexane and finally with benzene, with retention of most of the yellow impurity. After concentrating the filtrate this deposited on cooling 26.2 g. of faintly yellow, massive prisms of IV, m. p. 78.5–81 °. A second crop consisted chiefly of massive prisms but contained also clusters of needles, which when separated mechanically afforded 0.65 g. of the crude isomer V, m. p. 109–115 °. The remainder of the crystallizate after passage in benzene–hexane solution through a fresh alumina tower, upon crystallization afforded 2.5 g. of nearly colorless prisms, m. p. 80.5–82 °, and then 2.3 g. of faintly yellow crystals, m. p. 79–81 °. The total yield of satisfactory perinaphthanone-7 was 31.0 g. (81% based on the acid utilized). A sample purified further by adsorption and by several recrystallizations from benzene–hexane formed colorless prisms, m. p. 82.6–83.2 °, corr.

The **oxime** crystallized from alcohol as flat, faintly yellow needles, m. p. 127–128 °, corr. (compare 124–125 °,[5] 126 °[6]). The **semicarbazone** formed pale yellow plates from dilute alcohol; when introduced to a bath at 220° it melted at 232–233 °, corr., with extensive decomposition.

Anal. Calcd. for $C_{14}H_{13}ON_3$: C, 70.26; H, 5.48. Found: C, 70.12; H, 5.67.

4,5-Benzhydrindone-1 (V).—The alumina adsorption columns used in the above separation were eluted with methanol as long as the filtrate showed a yellow color. The methanol was evaporated and the residue taken up in benzene–hexane (1:1) and passed through a fresh tower of alumina. Upon elution with the same solvent mixture and concentration of the filtrate there was obtained 0.83 g. of light yellow needles, m. p. 103–114°, and elution with benzene and benzene containing a trace of methanol afforded after crystallization 0.91 g. of orange needles, m. p. 111–116.5°. With the inclusion of the mechanically separated crystals mentioned above, the total crude ketone amounting to 2.39 g. (6.3%) was crystallized three times from benzene–hexane and gave 0.93 g. of colorless needles of the benzhydrindone, m. p. 120.6–121.4°, corr. The oxime was obtained from ethyl acetate as colorless, small, flat blades, m. p. 229–231 °, corr., with decomposition (Cook and Hewett,[11] 226–227 °).

Perinaphthane.—One gram of perinaphthanone-7 was reduced by the Clemmensen–Martin procedure[18] (refluxing for thirty hours). The collected product distilled as a light yellow oil which solidified in the receiver, and three crystallizations from dilute methanol (Norit) afforded colorless plates, m. p. 63.5–65 °, showing no depression with authentic perinaphthane.[12] The **trinitrobenzene derivative**[12] formed saffron-bronze needles from dilute alcohol, m. p. 158–159 °, corr.

Perinaphthanone-7 and o-Chlorophenylmagnesium Bromide.—In a typical run the light brown Grignard reagent prepared under nitrogen from 13.2 g. of o-chlorobromobenzene, 1.67 g. of magnesium and 300 cc. of ether was treated slowly with stirring with 10 g. of perinaphthanone in 75 cc. of ether. After warming under reflux for four and one-half hours the mixture was decomposed with 100 cc. of 25% ammonium chloride solution and the ethereal layer was washed with 5% alkali until this no longer became pink, with water and with saturated sodium chloride solution. After filtering through sodium sulfate and evaporating, the residual oil was subjected to steam distillation to remove volatile material and the remaining crude carbinol VI was collected and dried in ether and obtained as a very viscous, light brown glass. The substance could not be caused to crystallize; it did not reduce permanganate in acetone. The yield (15.5 g.) was close to the theoretical amount (16.2 g.), but the material apparently was not homogeneous, for dehydration by a variety of methods in no case yielded more than 40% of unsaturated material, as determined by hydrogen absorption.

Dehydration of the Crude Carbinol VI and Hydrogenation.—Among a number of methods of dehydration tried, boiling with acetic acid seemed the most satisfactory. It was found, however, that on attempted hydrogenation of the resulting product it acquired a bright emerald-green color and was not easily hydrogenated. On treatment with zinc as described below no discoloration occurred and absorption of hydrogen proceeded normally. Thus 19.1 g. of crude carbinol was heated under reflux with 75 cc. of glacial acetic acid for thirty minutes, when the solution had acquired a deep wine-red color. A 2-g. portion of zinc dust was added and the mixture was shaken well and again heated to boiling. The zinc was removed by filtration and washed with ether, the filtrate was diluted with 200 cc. of water and the ethereal layer was washed with water, dilute alkali, and saturated salt solution, and concentrated. Hexane was added, causing the separation of gum, and the ether was removed by evaporation. The solution was decanted through a column of alumina and Super-Cel (1:1) and the residual gum was leached thoroughly with warm hexane, which was likewise decanted through the column. The tower was finally washed with 500 cc. of hexane and the pale yellow filtrate evaporated, eventually in vacuum. The residue consisted of 9.8 g. (55%) of a light yellow, very viscous oil. This gave a strong Baeyer test. The material was readily soluble in petroleum ether and sparingly soluble in methanol; it could not be induced to crystallize.

After distillation at 4 mm. (85% recovery) the material was hydrogenated in acetic acid solution (50 cc.) in the presence of 480 mg. of Adams catalyst, added in several portions. The hydrogen absorption (425 cc.) amounted to only 63% of that based upon the weight of starting material but corresponded closely to the theoretical amount calculated from the yield of saturated product isolated (416 cc.). On collecting the product by diluting the filtered solution with water and extracting with ether it was ob-

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(18) Martin, THIS JOURNAL, **58**, 1438 (1936).

served that the aqueous solution contained no halide ion. A solution of the material in hexane containing a little benzene was passed through alumina-Super-Cel and the column was washed with the same solvent. A yellowish-green fluorescent zone passed into the filtrate, and on recovering the solute and passing it in pure hexane through a fresh tower the yellowish material remained on the adsorbent, and after washing with hexane the colorless, blue fluorescent solution afforded 5.13 g. (28.6% from the carbinol) of nearly colorless, slightly fluorescent, viscous oil. The substance, probably a mixture of the isomeric chlorides corresponding to VII and VIII, was entirely stable to permanganate in acetone, readily soluble in petroleum ether, and sparingly soluble in methanol. Various expedients failed to induce crystallization. No solid derivative could be obtained from picric acid or trinitrobenzene in benzene-hexane. A sample, distilled at 178–180° at 1 mm., was completely colorless and showed a bluish fluorescence; the composition is close to that expected for the mixture of isomers.

Anal. Calcd. for $C_{19}H_{15}Cl$: C, 81.86; H, 5.42. Found: C, 82.54; H, 5.49.

1- and 3-(*o*-Cyanophenyl)-perinaphthane (VII and VIII).—A mixture of 13.7 g. of the saturated chloro compound, 4.66 g. of cuprous cyanide, 1 cc. of acetonitrile, and 13 cc. of anhydrous pyridine was heated in a sealed tube at 230–240° for forty-eight hours. The collected neutral organic material consisted of a brownish-green oil. This was dissolved in benzene–hexane (1:1) and passed through a tower of alumina, which was then eluted with benzene-hexane (70:30), leaving a nearly black band on the column. The greenish fluorescent filtrate after clarification with Norit and concentration was diluted with hexane to incipient crystallization and allowed to cool. A yellowish crystallizate resulted, melting at 101–117° and weighing 8.0 g., and no further solid could be obtained from the mother liquor.

No significant separation was noted on crystallization of the solid from benzene–hexane or from alcohol–ethyl acetate, but by systematic fractional crystallization from glacial acetic acid the material was separated into the following three fractions of the same composition (analyses are given below): (a) **1-(*o*-Cyanophenyl)-perinaphthane** (VIII), 2.43 g. (18.6%), clusters of blade-like needles, m. p. 144.7–145.4°, corr. (b) **3-(*o*-Cyanophenyl)-perinaphthane** (VII), 1.77 g. (13.4%), small round clumps of colorless needles, m. p. 122.5–123.8°, corr. (c) **Eutectic mixture** of **VII and VIII**, 2.41 g. (18.3%), blade-like needles, m. p. 104.3–106.3°, corr. This on hydrolysis gave a mixture of two amides identified as those derived from VII and VIII.

Anal. Calcd. for $C_{20}H_{15}N$: C, 89.18; H, 5.61. Found: (a) C, 89.24; H, 5.63. (b) C, 89.02; H, 5.66. (c) C, 88.99; H, 5.60.

1-(*o*-Carbamidophenyl) and 1-(*o*-Carboxyphenyl)-perinaphthane.—Acid hydrolysis of the nitrile VIII by the procedure of Newman and Orchin,[19] or by heating the substance with concentrated hydrochloric acid and dioxane at temperatures up to 220°, gave little promise, but alkaline hydrolysis conducted as follows gave excellent results. A mixture of 1.78 g. of the nitrile, a solution of 15 g. of potassium hydroxide in 100 cc. of 95% alcohol, and 10 cc. of water was heated under reflux with the addition of 30 cc. more water after the nitrile had gone into solution. Refluxing was continued for thirty-nine hours and the clear solution was then poured into a beaker and diluted with an equal volume of water. On cooling, a flocculent yellow precipitate of the amide separated, m. p. 166–170°*, and this was combined with a small additional quantity obtained by benzene–ether extraction of the alkaline filtrate. Crystallization from benzene afforded in two crops 1.45 g. (76%) of amide in the form of transparent, colorless prisms, m. p. 169–171°*. A recrystallized sample melted at 173–174.5°, corr.

Anal. Calcd. for $C_{20}H_{17}ON$: C, 83.59; H, 5.96. Found: C, 83.77; H, 6.09.

To obtain the acid, the above alkaline filtrate was concentrated until 60 cc. of distillate (mostly alcohol) had been removed. Since the solution began to foam badly at this point it was acidified while hot and then made slightly basic. On distilling off 60 cc. more solvent the colloidal silica agglomerated and was easily removed by filtration. Careful acidification of the hot filtrate yielded a flocculent white precipitate of **1-(*o*-carboxyphenyl)-perinaphthane.** This was extracted with ether after cooling, the solvent was displaced with benzene, and hexane was added. A first crop of crystals consisted of tan prisms (0.31 g.), m. p. 168.5–169.5°,* and a second crop (0.03 g.) melted only slightly lower; yield 17%. Two recrystallizations from benzene–hexane gave nearly colorless prisms adhering to the walls of the flask, m. p. 173.7–174.7°, corr.

Anal. Calcd. for $C_{20}H_{16}O_2$: C, 83.31; H, 5.59. Found: C, 83.44; H, 5.56.

3-(*o*-Carbamidophenyl) and 3-(*o*-Carboxyphenyl)-perinaphthane.—Hydrolysis of 1.57 g. of the nitrile VII, conducted precisely as described for the isomer, afforded 1.30 g. (77.5%) of the amide as fine, colorless needles, m. p. 188–190°*. A sample twice recrystallized from benzene melted at 194.2–196.5°, corr.

Anal. Calcd. for $C_{20}H_{17}ON$: C, 83.59; H, 5.96. Found: C, 83.47; H, 6.00.

The **acid** was obtained as clusters of nearly colorless needles, m. p. 181–182.5°*, in yield of 0.28 g. (16.5%). A twice recrystallized sample (benzene–ligroin) was colorless and melted only slightly higher; m. p. 187.9–188.5°, corr.

Anal. Calcd. for $C_{20}H_{16}O_2$: C, 83.31; H, 5.59. Found: C, 83.31; H, 5.66.

Hydrolysis of Eutectic (c).—Hydrolysis of 2.66 g. of this material as above gave an amide fraction m. p. 149–178°. Systematic fractionation from benzene afforded 1.05 g. of amide of the 3-series, m. p. 187.5–189.5°*, which gave no depression when mixed with the derivative from VII, and 0.16 g. of the 1-isomer, m. p. 168–170°* (mixed m. p. with amide from VIII). The separation of the lower melting isomer was difficult and attended with considerable losses, and the acid fraction was not examined.

Hydrolysis of 3-(*o*-Carbamidophenyl)-perinaphthane.—Conversion of the amide to the acid by means of isoamyl nitrite in acetic acid was attempted without success, but acid hydrolysis was quite satisfactory. This was done by refluxing 2.58 g. of amide with 150 cc. of concentrated hydrochloric acid and 50 cc. of acetic acid. The solid soon

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[19] Newman and Orchin, THIS JOURNAL, 61, 244 (1939).

dissolved to give a light yellow solution and within an hour the acidic product began to separate as an oil which subsequently solidified. After refluxing for thirty-four hours the mixture was diluted with water and extracted with ether. The product was then extracted into alkali and the solution was made nearly neutral, clarified with Norit (hot), and strongly acidified (Congo Red). The 3-(*o*-carboxyphenyl)-perinaphthane separated as an oil which changed to a granular solid on short boiling. Crystallization of the dried product (2.38 g.) from benzene–hexane, with recrystallization of the second crop, gave a total of 2.14 g. of satisfactory material, m. p. 181–182.5°*. The neutral fraction in the ether afforded 0.10 g. of nearly pure amide, whence the yield of acid was 86%.

2,1′-Trimethylene-1,9-benzanthrone (XI).—In a small platinum crucible 180 mg. of 3-(*o*-carboxyphenyl)-perinaphthane was covered with 5 cc. of anhydrous hydrogen fluoride. In a little over an hour the reagent had evaporated leaving a bright orange solid residue. This was crystallized from benzene–acetone, giving 90 mg. (53%) of flat, diamond-shaped orange leaves, m. p. 216–217.5°, corr. On a second crystallization the sample (62 mg.) melted at 217.2–218.4°, corr., and did not depress the m. p. (216.4–218°, corr.) of an authentic sample.[12]

4,4′-Trimethylene-2,3-benzfluorenone (XII).—One hundred milligrams of 1-(*o*-carboxyphenyl)-perinaphthane was cyclized with hydrogen fluoride (8 g.) as above, the residue left on evaporation of the reagent being a bright yellow solid. This was washed in benzene solution with bicarbonate, but no uncyclized material was present. After concentrating and adding hexane there crystallized 81 mg. (86.5%) of bright yellow prismatic blades, m. p. 196.5–197.5°*. The sample recrystallized for analysis exhibited polymorphism. When heated slowly it softened slightly at 187° and melted at 201–203°, corr. When heated rapidly it melted at 187–189°, corr., and when a sample was introduced to a bath at 190° it melted immediately to a clear liquid and then resolidified, remelting at 201–203°, corr.

Anal. Calcd. for $C_{20}H_{14}O$: C, 88.85; H, 5.23. Found: C, 88.77; H, 5.28.

Summary

A satisfactory method has been developed for the preparation of pure perinaphthanone-7 which consists in cyclization of β-(1-naphthyl)-propionic acid with hydrogen fluoride and separation of the main product (81%) from a trace of 4,5-benzhydrindone-1 (6%) by chromatographic adsorption and crystallization. On condensing perinaphthanone-7 with *o*-chlorophenylmagnesium bromide and applying the successive steps of dehydration, hydrogenation, conversion through the nitrile to the acid, and ring closure, the end products obtained are 2,1′-trimethylene-1′,9-benzanthrone-10 and 4,4′-trimethylene-2,3-benzfluorenone, in place of the expected 1′,9-dimethylene-1,2-benzanthracene. This is due to a rearrangement in the perinaphthane system, probably occurring in the course of dehydrating the carbinol, with the reformation of the naphthalenoid unit in both possible arrangements embodying conjugation with the substituent aryl radical.

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On the Constitution of α-Spinasterol

BY ERHARD FERNHOLZ AND WILLIAM L. RUIGH

α-Spinasterol has been isolated from spinach leaves, senega root, and alfalfa leaves and seeds. Since these plants are botanically unrelated, this sterol will in all probability eventually be found to be of rather widespread occurrence.

Larsen showed that α-spinasterol is an isomer of stigmasterol since saturation of its two double bonds led to the formation of stigmastanol.[1] With the nature of the carbon skeleton and the position of the hydroxyl group thus established, only the location of the two double bonds remained to be determined. Larsen and Heyl[2] reported that ozonization did not yield a volatile aldehyde, and thus concluded that there was no double bond in the side-chain. Our own results contradict their findings. We have obtained from α-spinasterol ethylisopropylacetaldehyde identical with the aldehyde from stigmasterol[3] in a yield of 22%, and have, therefore, demonstrated that one of the double bonds is between C-22 and C-23 in the side-chain. Of the two double bonds only one, that in the side-chain, is hydrogenated in neutral solvents. The hydrogenation stops after the formation of α-spinastenol, and in order to obtain complete saturation it is necessary first to isomerize α-spinastenol into β-spinastenol by means of acid.[2] This is strictly comparable to the case of α-dihydroergosterol, with which we compared

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[1] C. D. Larsen, THIS JOURNAL, **60**, 2431 (1938).

[2] Larsen and Heyl, *ibid.*, **56**, 2663 (1934).

[3] A. Guiteras, *Z. physiol. Chem.*, **214**, 89 (1933).