cedure as above, gave 15 g. (80%) of product melting at 93.0–94.0° upon two recrystallizations from benzene.

Method B. The imide-chloride prepared in an identical manner as above from 2.1 g. of phosphorus pentachloride and 3.5 g. of 4,4′-dibromobenzanilide also melted at 93.0–94.0°, when recrystallized twice from benzene. This was not depressed on mixing with the material from the Beckmann rearrangement of the ketoxime; yield 2.7 g., 72%.

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[CONTRIBUTION FROM THE DIVISION OF ONCOLOGY, THE CHICAGO MEDICAL SCHOOL]

K Region Fission and Addition Products of 7,12-Dimethylbenz[a]anthracene[1]

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The K region (5,6-positions) of 7,12-dimethylbenz[a]anthracene was cleaved by treating the appropriate dihydrodiol with sodium periodate. The resultant dialdehyde was converted to several oxygenated products as well as 5,6-dihydro-7,12-dimethylbenz[a]anthracene. This latter compound was also obtained in good yield by the hydrogenation of the parent polynuclear hydrocarbon using palladium on strontium carbonate as catalyst.[3]

The carcinogenic property of the polynuclear hydrocarbon 7,12-dimethylbenz[a]anthracene, I, has been extensively investigated.[4] This hydrocarbon has been found to be extremely potent as a skin carcinogen.[5–9] Nevertheless, very little has been reported on the metabolism of this hydrocarbon. An important factor contributing to this lack of information is the paucity of chemical studies which began with methyl-substituted polynuclear hydrocarbons in general and 7,12-dimethylbenz[a]anthracene in particular.

For some time,[10] as indicated by several reviews[11,12,13] it has been speculated that a biochemical process which occurred at the K region[14] of a polynuclear hydrocarbon was significant to carcinogenesis. Metabolism at the K region of the carcinogen dibenz[a,h]anthracene was established when the dibasic acid resulting from fission at this region was characterized as a metabolite.[15] Consequently, a variety of alteration products which involved either fission or addition to the K region of 7,12-dimethylbenz[a]anthracene have been prepared.

When starting with unsubstituted polynuclear hydrocarbons, the customary route to K region fission products has been the addition of osmium tetroxide followed by hydrolysis to the dihydrodiol.[16] Oxidation with a dichromate salt[15,17] or chromic acid[18] converted the dihydrodiol to an *ortho* quinone. The *ortho* quinone was cleaved to a dibasic acid with peracetic acid.[15,17] This route was unsuccessful when applied to 7,12-dimethylbenz[a]anthracene. Although the dihydrodiol, II, of the substituted hydrocarbon was available through the action of osmium tetroxide on 7,12-dimethylbenz[a]anthracene,[16] the oxidative step to the *ortho* quinone was fruitless.

An alternative route to K region fission products of 7,12-dimethylbenz[a]anthracene was developed. The dihydrodiol, II, when treated with sodium periodate gave the dialdehyde, III, in quantitative yield.[19] An attempt to use alkaline silver oxide for the oxidation of the dialdehyde, II, to the corresponding dibasic acid failed. An acidic product was isolated with difficulty from the reaction mixture. This product, on the basis of elemental analysis, corresponded to an alcohol acid and presumably was IV. The lactonization of IV would be in keep-

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(3) An abstract of some of this work appeared in *Proc. Am. Assoc. Cancer Research* **3**, 25 (1959).

(4) P. Shubik and J. L. Hartwell, *Survey of Compounds Which Have Been Tested for Carcinogenic Activity*, Supplement I, United States Government Printing Office, Washington, 1957, p. 153.

(5) W. E. Bachman, E. L. Kennaway, and N. M. Kennaway, *Yale J. Biol. and Med.*, **11**, 97 (1938).

(6) M. Klein, *Cancer Research*, **16**, 123 (1956).

(7) V. Darchun and H. I. Hadler, *Cancer Research*, **16**, 316 (1956).

(8) H. I. Hadler, V. Darchun, and K. Lee, *J. Nat. Cancer Inst.* **23**, 1383 (1959).

(9) G. Della Porta, H. Rappaport, U. Saffiotti, and P. Shubik, *A. M. A. Archiv. Path.*, **61**, 305 (1956).

(10) O. Schmidt, *Naturwissenchaften* **29**, 146 (1941).

(11) C. A. Coulson, *Adv. in Cancer Research*, **I**, 1 (1953).

(12) G. M. Badger, *Adv. in Cancer Research*, **2**, 73 (1954).

(13) A. Pullman and B. Pullman, *Adv. in Cancer Research*, **3**, 117 (1955).

(14) The possession of a phenanthrene moiety has been accepted as a required structural feature for carcinogenic activity in a polynuclear hydrocarbon. The 9,10-double bond of the phenanthrene moiety has been termed the K region of the polynuclear hydrocarbon. This region is susceptible to 1,2-addition reactions. In 7,12-dimethylbenz[a]anthracene the 5,6-positions are the K region.

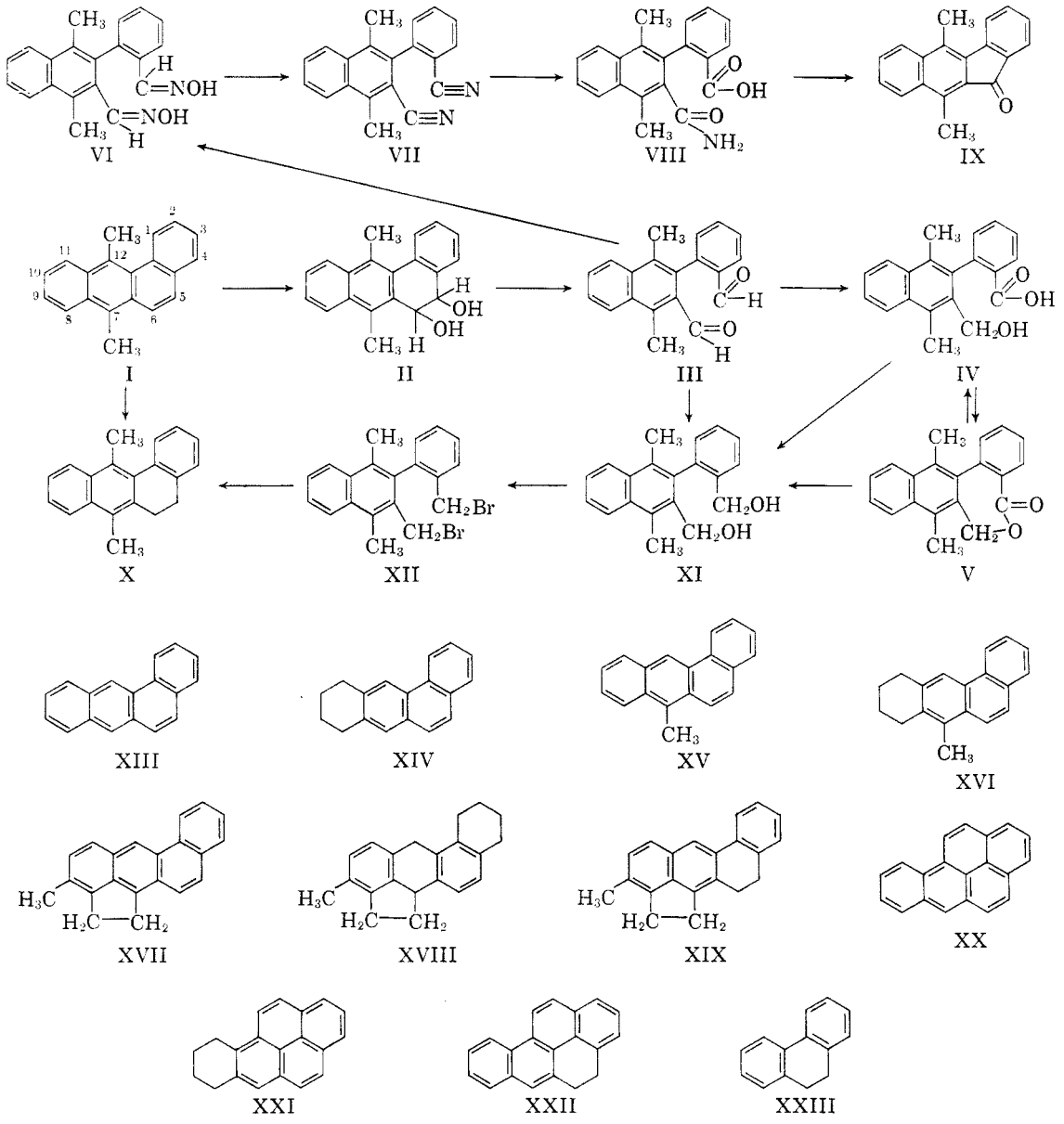
(15) P. M. Bhargava, H. I. Hadler, and C. Heidelberger, *J. Am. Chem. Soc.*, **77**, 2877 (1955).

(16) J. W. Cook and R. Schoental, *J. Chem. Soc.*, 170 (1948).

(17) E. F. M. Stephenson, *J. Chem. Soc.*, 2620 (1949).

(18) C. J. Collins, J. G. Burr, Jr., and D. N. Hess, *J. Am. Chem. Soc.*, **73**, 5176 (1951).

(19) Collins, Burr and Hess[18] reported that the K region dihydrodiol of the unsubstituted polynuclear hydrocarbon, benz[a]anthracene, was not cleaved by lead tetraacetate.



ing with the difficulty encountered in the isolation of IV. Evidently an intramolecular Cannizzaro reaction was brought about by the alkalinity of the silver oxide reagent. The conversion of III to IV by strong alkali alone, confirmed the occurrence of the intramolecular Cannizzaro reaction. The isolation of the alcohol acid IV was feasible when precautions were taken to minimize lactonization. The alcohol acid was easily lactonized to V with catalytic amounts of *p*-toluenesulphonic acid.

The excellent recovery of single isomers (III to IV and III to V in 82% and 93% yield respectively) indicated that the Cannizzaro reaction was under appreciable steric control. In the first step of the postulated mechanism of the Cannizzaro reaction the hydroxyl anion attacks the aldehydo group which eventually ends up as the carboxyl group in the final product.[20] Thus, structure IV has been written with the carboxyl group in the position corresponding to the most exposed aldehydo group in III. The ready saponification of the lactone V to the acid IV supported the structures assigned to IV and V. It was of interest that although the intramolecular spatial relationship between the two aldehydo groups in III was influenced by the serious restricted rotation about the biphenyl bond in III, the intramolecular reaction proceeded with ease. The possibility of steric acceleration was not investigated.

Although one of the aldehydo groups in III was hindered by two *ortho* substituents and a buttressing[21] *meta* group, the dioxime, VI, was readily formed. Dehydration of VI with acetic anhydride

(20) E. R. Alexander, Principles of Ionic Organic Reactions, John Wiley and Sons, Inc., New York, N. Y., 1950, p. 168.

(21) M. Rieger and F. H. Westheimer, *J. Am. Chem. Soc.*, **72**, 19 (1950).

yielded the dinitrile, VII. Vigorous saponification of VII did not proceed past the monoamide stage of the dibasic acid. The residual acid amide group was assigned to the most hindered position in VIII. When the acid amide, VIII, was treated with 100% phosphoric acid, a reagent recommended for the hydrolysis of hindered acid amides,[22] there was obtained a neutral yellow moderately volatile solid. The analysis of this product agreed with that of the fluorenone IX. A possible sequence yielding this product would be hydrolysis, decarboxylation, and intramolecular acylation.

Two routes were considered for the synthesis of the dihydro K region derivative, X. One route was that developed by Hall and Turner[23,24,25] for the synthesis of 9,10-dihydrophenanthrene in order to circumvent the hydrogenation of phenanthrene. The other route was direct hydrogenation of 7,12-dimethylbenz[a]anthracene. Both routes proved to be successful.

Hall and Turner[23,24] cyclized 2,2′-di(bromomethyl)-diphenyl with phenyllithium to obtain 9,10-dihydrophenanthrene. In order to apply this synthetic method, the dialcohol, XI, was obtained by the action of lithium aluminum hydride on any one of the ring fission products III, IV, or V. Treatment of the dialcohol, XI, with 48% hydrobromic acid in acetic acid gave the appropriate bisbromomethyl compound, XII. When XII was cyclized with phenyllithium, the desired dihydro K region product, X, resulted. Both the dihydrodiol, II, and the dihydrocompound X, had the same chromophore as shown by their ultraviolet absorption spectra. There was a bathochromic shift of the spectral bands in II and X relative to XI. This was explained by the higher energy of the ground states of II and X relative to XI because of the strain imposed by the 5,6-bond in II and X on the hindered biphenyl system.

The usual procedure for the partial hydrogenation of polynuclear hydrocarbons at room temperature and pressure has been to use a platinum catalyst in an acidic medium and to interrupt the reaction before hydrogen absorption was complete. Under these conditions, the major product isolated from the reduction mixture characteristically had a saturated terminal ring, irrespective of whether the parent polynuclear hydrocarbon was substituted or unsubstituted. On occasion a small amount of K region hydrogenated product was also isolated.

Fieser and Hershberg[26] isolated 8,9,10,11-tetrahydrobenz[a]anthracene, XIV, in 77% yield after allowing benz[a]anthracene, XIII, to absorb two moles of hydrogen in the presence of Adams catalyst, ferrous chloride, and hydrochloric acid. The substituted polynuclear hydrocarbon 7-methylbenz[a]anthracene, XV, gave after absorbing two moles of hydrogen (in the presence of Adams catalyst and a trace of hydrochloric acid) 8,9,10,11-tetrahydro-7-methylbenz[a]anthracene, XVI, in 59% yield.[26] These same authors also studied the hydrogenation of 3-methylcholanthrene,[27] XVII. They found that after the absorption of four moles of hydrogen (in the presence of acetic acid and Adams catalyst containing some palladium), the hexahydroproduct, XVIII, was obtained in 40% yield and the dihydro K region product XIX, was obtained in 20% yield. More starting material was recovered when lesser amounts of hydrogen were absorbed; however, the ratio of XVIII to XIX remained unchanged. From these data Fieser and Hershberg concluded that two independent concurrent courses for the hydrogenation of 3-methylcholanthrene existed.

Lijinsky and Zechmeister[28] hydrogenated the unsubstituted polynuclear hydrocarbon benzo[a]pyrene, XX, with two moles of hydrogen (in the presence of Adams catalyst and acetic acid) and isolated the tetrahydro product, XXI, in 37% yield and the K region dihydro product XXII,[29] in 11% yield.

The literature cited above suggested that although the interrupted hydrogenation of 7,12-dimethylbenz[a]anthracene, I, in the presence of platinum and acid might yield some K region dihydro product, X, it was advisable to investigate other conditions. Also, it had been known for some time that phenanthrene itself in the presence of copper chromium oxide catalyst was hydrogenated at elevated temperature and pressure to yield the K region dihydro product, XXIII.[30,31] When palladium on strontium carbonate, precipitated under alkaline conditions, was chosen as the hydrogenation catalyst a good yield (73%) of purified material of 5,6-dihydro-7,12-dimethylbenz[a]anthracene, X, was obtained from the parent polynuclear hydrocarbon, I, at room temperature and pressure. The uptake of hydrogen stopped after 1.2 moles were absorbed.

Several considerations pointed to the selection of palladium on strontium carbonate for the exclusive hydrogenation of the K region of 7,12-dimethylbenz[a]anthracene. The double bond in

(22) G. Berger and S. C. J. Olivier, *Rec. Trav. Chim.*, **46**, 600 (1927).

(23) D. M. Hall and E. E. Turner, *Nature* **163**, 537 (1949).

(24) D. M. Hall, M. S. Leslie, and E. E. Turner, *J. Chem. Soc.*, 711 (1950).

(25) G. M. Badger, P. R. Jefferies, and R. W. L. Kimber, *J. Chem. Soc.*, 1837 (1957).

(26) L. F. Fieser and E. B. Hershberg, *J. Am. Chem. Soc.*, **59**, 2502 (1937).

(27) L. F. Fieser and E. B. Hershberg, *J. Am. Chem. Soc.*, **60**, 941 (1938).

(28) W. Lijinsky and L. Zechmeister, *J. Am. Chem. Soc.*, **75**, 5495 (1953).

(29) The structure assignment was tentative.

(30) D. D. Philips, *Org. Syntheses*, **24**, 31 (1954).

(31) A. Burger and E. Mosettig, *J. Am. Chem. Soc.*, **58**, 1861 (1936).

question was the most olefinic and least aromatic in the parent compound.[32] Acidic conditions brought about either by the method used to prepare the catalyst or by the addition of acid to the hydrogenation medium would be expected to promote hydrogenation of aromatic rings[33] (on an empirical basis), as illustrated above[26,27,28] with XIII, XV, XVII, and XX. In a neutral or alkaline medium the geometry of the olefinic substrate being hydrogenated would exert its maximal steric influence on the incoming *cis* hydrogen.[34] In an acidic medium the probability of the intervention of a different hydrogenation mechanism or of additional polar factors would be increased.[34] The hydrogenation of the K region was slower than that of an aromatic ring (inferred from the results of Fieser and Hershberg[26] discussed above) and hydrogenation by the slower of the possible hydrogenation mechanisms was favored by the absence of acid.[34] Thus, to obtain the results of a single mechanism under the most homogeneous steric influence due to the geometry of the substrate, to limit the hydrogenation of the aromatic rings, and to select the slower of the possible mechanisms of hydrogenation, the chosen catalyst was precipitated under alkaline conditions and no acid was added to the hydrogenation medium. The K region of a polynuclear hydrocarbon also might be considered analogous to a styrene bond. Palladium on strontium carbonate (prepared differently from the catalyst used in these experiments) had been used successfully for the hydrogenation of another hindered styrene type double bond.[35]

EXPERIMENTAL[36]

3,4-Dihydroxy-3,4-dihydro-7,12-dimethylbenz[a]anthracene, II. The generalized procedure of Cook and Schoental[16] was followed. A solution of 2 g. (0.00786 mole) of osmium tetroxide in 40 ml. of dry benzene was added at room temperature, under nitrogen, over a 10-min. period to a stirred solution of 2.0146 g. (0.00786 mole) of 7,12-dimethylbenz[a]anthracene (the commercial product was eluted from Florisil with cyclohexane and crystallized from cyclohexane), m.p. 122.5–123.3° in 60 ml. of dry benzene containing 1 ml. of dry pyridine. The stirring was stopped and 2 days later the benzene was removed *in vacuo*. The dark residue was dissolved *completely* in about 200 ml. of methylene chloride and shaken for 2 hr. with 200 ml. of 5*N* sodium hydroxide and 60 ml. of 1*M* D-mannitol. The two layers were separated and the shaking repeated with a fresh aqueous solution (if necessary) until there was no more pink color in the methylene chloride layer. The organic layer was washed with water, dried with sodium sulfate, and evaporated. The residue was crystallized from benzene-cyclohexane and gave 1.786 g. (78%) of a colorless solid, m.p. 172.5–173.5° (lit.[16] m.p. 171–172°).

Florisil was used for chromatographic purification. The starting hydrocarbon, I, was eluted with cyclohexane and the dihydrodiol, II, was eluted either with 10% acetone-90% benzene or with chloroform.

λ_{max} ($\log_{10}\epsilon$); 219.5 (4.371); 260.5 (4.625); 269 (4.673); 303 (3.886); λ_{min} ($\log_{10}\epsilon$); 234 (4.083); 264.5 (4.585); 284 (3.642).

1,4-Dimethyl-2-phenylnaphthalene-3,2'-dicarboxaldehyde, III. To a solution of 1.408 g. (0.00484 mole) of dihydrodiol, II, m.p. 174–175.7° dissolved in a mixture of 1300 ml. of methanol and 250 ml. of water there was added at room temperature a solution of 4.15 g. (0.0194 mole) of sodium periodate dissolved in 70 ml. of water and 350 ml. of methanol. After 2 days the reaction mixture was concentrated *in vacuo* or atmospheric pressure to one third of its original volume. The organic material was taken up in benzene washed successively with water, 5% sodium bicarbonate, water, brine, and dried with sodium sulfate. After evaporating the solvent, there remained a quantitative yield of a pale yellow solid m.p. 136.3–138°. Repeated crystallization from ethanol-methanol gave a colorless solid, m.p. 137–137.5°.

Anal. Calcd. for $C_{20}H_{16}O_2$ (288.33): C, 83.31; H, 5.59. Found: C, 83.20; H, 5.57.

The dialdehyde, III, was eluted from Florisil with 0.5% acetone-99.5% benzene.

λ_{max} ($\log_{10}\epsilon$); 221 (4.554); 255 (4.588); 260 (4.607); 297 (3.809); 358 (3.482): λ_{min} ($\log_{10}\epsilon$); 235 (4.346); 326 (3.253).

1,4-Dimethyl-3-hydroxymethyl-2-phenylnaphthalene-2'-carboxylic acid IV. A. *Using alkaline silver oxide.* To a fresh suspension prepared from 0.34 g. (0.002 mole) of silver nitrate dissolved in 10 ml. of water and 0.4 g. (0.01 mole) of sodium hydroxide in 4 ml. of water, a solution of 0.144 g. (0.0005 mole) of the dialdehyde, III, m.p. 138–138.5 in 10 ml. of dioxane and 40 ml. ethanol was shaken at room temperature overnight. The black precipitate was filtered and then washed well with water, ethanol, water, and alkali. The green filtrate was reduced *in vacuo* to 25 ml. and 100 ml. of water added. The alkaline solution was washed with benzene and acidified with 0.5*N* nitric acid. The organic material was taken up in chloroform, washed with water, and dried with sodium sulfate. The solvent was evaporated to give 0.127 g. of a semisolid. Repeated crystallization from acetone-cyclohexane gave 0.012 g. of a solid, m.p. 165–165.2 (m.).

Anal. Calcd. for $C_{20}H_{18}O_3$ (306.34): C, 78.41; H, 5.92. Neut. equiv., 306. Found C, 78.73; H, 6.12. Neut. equiv., 301.

The alcohol acid IV required 100% ethyl acetate for elution from silica.

λ_{max} ($\log_{10}\epsilon$); 236.5 (4.912); 286 (3.875); 330 (2.844); λ_{min} ($\log_{10}\epsilon$); 263 (3.651): 227 (2.733).

B. *Using only alkali.* To an ice cold solution of 1.00 g. (0.00437 mole) of dialdehyde, III, m.p. 138.6–138.9°, dissolved in 200 ml. of methanol there was added slowly with cooling an ice cold solution of 235 g. (4.37 moles) of potassium hydroxide dissolved in 200 ml. of water and 200 ml. of methanol. The next day the volume was reduced by two thirds *in vacuo*. Water was added to dissolve the solid and the aqueous solution was washed with benzene. The

(32) G. M. Badger, *The Structures and Reactions of the Aromatic Compounds*, University Press, Cambridge, Great Britain, 1954, p. 160.

(33) H. Adkins and R. L. Shriner, in *Organic Chemistry, an Advanced Treatise*, H. Gilman, editor-in-chief, John Wiley and Sons, New York 2nd ed., 1943, p. 817.

(34) H. I. Hadler, *Experientia*, 11, 175 (1955).

(35) W. S. Johnson, E. R. Rogier, J. Szmuskovicz, H. I. Hadler, J. Ackerman, B. K. Bhattacharyya, B. M. Bloom, L. Stalman, R. A. Clement, B. Bannister, and H. Wynberg, *J. Am. Chem. Soc.* 78, 6289 (1956). See foot-note 39 of this reference.

(36) Melting points were corrected and taken on a hot stage when followed by (m). Ultraviolet absorption spectra were determined on a Beckman spectrophotometer model DK1; 95% alcohol was employed as the solvent. Microanalyses were carried out by Drs. G. Weiler and F. B. Strauss, Oxford, England, and Microtech Laboratory, Skokie, Ill.; U.S.A. evaporations were conducted on a steam bath under a stream of nitrogen. Chromatographic purification procedures have been included because of the interest in the biological testing of some of these compounds and to aid metabolic studies.

alkaline solution was added in portions to an extraction funnel containing hydrochloric acid, ice chips and chloroform. Thus, on shaking acidification and extraction were carried out simultaneously.

The chloroform extract was washed with water and dried with sodium sulfate. After evaporation of the solvent there was obtained a quantitative yield of solid, m.p. 149.5–154.5°. One crystallization from acetone-cyclohexane gave 0.875 g. (82%) of colorless needles, m.p. 163–165°, identical (mixed m.p.) with the acid produced by method A.

C. *From the lactone*, V. To a stainless steel flask containing 5.6 g. (0.1 mole) of potassium hydroxide dissolved in 5 ml. of water and 5 ml. of methanol there was added a solution of 0.058 g. (0.0002 mole) of lactone V, m.p. 174–175° (see below) in 10 ml. of methanol. The mixture was heated in an atmosphere of nitrogen at reflux for 2 hr. The volume was reduced by one third by evaporation and the acidic material isolated by method B described above. There was obtained 0.050 g. (82%) of white needles, m.p. 157.5–159.5°.

Methyl ester. A solution of 0.153 g. (0.0005 mole) of alcohol acid, IV, m.p. 159–160°, in 10 ml. of ethyl acetate was added to a cold ethereal solution of diazomethane. The solvents were evaporated the next day and the residue taken up in benzene, washed successively with saturated sodium bicarbonate water, and dried with sodium sulfate. On evaporation a quantitative yield of solid, m.p. 130–140°, was obtained. One crystallization from benzene-cyclohexane gave 0.140 g. (87%) of solid, m.p. 141.5–142.5°. After repeated crystallization from benzene-cyclohexane the melting point was 142.5–143.5°.

Anal. Calcd. for $C_{21}H_{20}O_3$ (320.37): C, 78.72; H, 6.29. Found: C, 78.75; H, 6.36.

The methyl ester of IV was eluted from Florisil with 2% acetone–98% benzene.

λ_{max} ($\log_{10}\epsilon$); 236 (4.591); 285 (3.597); 330 (2.520); λ_{min} ($\log_{10}\epsilon$); 263 (3.382); 327 (2.415).

1,4-Dimethyl-3-hydroxymethyl-2-phenylnaphthalene-2'-carboxylic acid, ϵ lactone, V. The crude acidic product of IV, was obtained from 0.144 g. (0.005 mole) of dialdehyde, III, m.p. 138–138.5°, using procedure B. The crude product was dissolved in 200 ml. of dry benzene, a crystal of *p*-toluenesulphonic acid was added and the solution heated at reflux with a water separator for several days. The benzene solution was washed successively with water, saturated sodium bicarbonate, and water, and dried with sodium sulfate. After evaporating the solvent there was obtained 0.134 g. (93%) of colorless solid, m.p. 171–173°. After elution from silica with a mixture of 10% ethyl acetate and 90% benzene and repeated crystallization from benzene-cyclohexane, there were obtained colorless crystals, m.p. 178.5–179°.

Anal. Calcd. for $C_{20}H_{16}O_2$ (288.34): C, 83.31; H, 5.59. Found: C, 83.43; H, 5.55.

The lactone V was eluted from Florisil with 1% acetone–99% benzene.

λ_{max} ($\log_{10}\epsilon$) 225.2 (4.579); 252 (4.687); 303 (3.659); λ_{min} ($\log_{10}\epsilon$) 234 (4.509); 285 (3.590).

1,4-Dimethyl-2-phenylnaphtalhene-3,2'-dicarboxaldehyde dioxime, VI. A solution of 0.029 g. (0.0001 mole) of dialdehyde, III, 0.027 g. (0.0004 mole) of hydroxylamine hydrochloride, 2 ml. of dry pyridine, and 2 ml. of absolute ethanol were heated at reflux for 2 hr. The solvents were evaporated *in vacuo*. The residue was taken up in benzene, washed with water, dried with sodium sulfate, and the solvent evaporated to give a quantitative yield of solid, m.p. 195.5–198.5° (m). The melting point was 197.5–199° after repeated crystallization from acetone-cyclohexane.

Anal. Calcd. for $C_{20}H_{18}N_2O_2$ (318.36): C, 75.45; H, 5.69. Found: C, 75.43; H, 5.64.

1,4-Dimethyl-2-phenylnaphthalene-3,2'-dicarbonitrile, VII. A solution of 0.840 g. (0.00263 mole) of dioxime, VI, m.p. 199–201° (m), and 30 ml. of acetic anhydride was heated at reflux for 1 hr. Two hundred milliliters of water was added and 15 min. later the organic material was taken up in benzene and washed successively with water, saturated sodium bicarbonate and water, and dried with sodium sulfate. The solvent was evaporated and the residue (quantitative yield, m.p. 235–235.5°) was crystallized from ethyl acetate–cyclohexane to give 0.689 g. (92%), m.p. 235–235.5°. After repeated crystallization the melting point was 237–238°.

Anal. Calcd. for $C_{20}H_{14}N_2$ (282.33): C, 85.08; H, 5.00. Found: C, 84.65; H, 5.23.

1,4-Dimethyl-3-carbamyl-2-phenylnaphthalene-2'-carboxylic acid, VIII. A solution of 0.141 g. (0.0005 mole) of dinitrile, VII, m.p. 235–235.5° in 30 ml. of ethylene glycol monomethyl ether containing 5 g. of potassium hydroxide was heated at reflux for 18 hr. in a stainless steel flask fitted with a reflux condenser. After cooling, 90 ml. of water were added and the neutral material extracted with benzene. The alkaline solution was acidified with ice cold hydrochloric acid and the organic material taken up in ethyl acetate. The extract was washed with water, dried with sodium sulfate, and the solvent evaporated. The residue was dissolved in benzene and placed on a column of silica. After washing the column with benzene and ethyl acetate–benzene, a pale yellow solid was eluted with ethyl acetate in quantitative yield, m.p. 220–221°, then 237–240°. Several crystallizations from ethyl acetate–cyclohexane and from acetone-cyclohexane gave a colorless solid with a double m.p. *viz.*, 232.5–233° and 240.5–241°, with a crystal transformation at 220°.

Anal. Calcd. for $C_{20}H_{17}O_3N$ (319.35): C, 74.90, H, 5.46; N, 4.39. Found: C, 74.80, 74.85; H, 5.60, 5.43; N, 4.40, 4.46.

When VIII was heated at reflux for 24 hr. with ethylene glycol containing potassium hydroxide, the starting material was recovered unchanged.

1,4-Dimethyl-2,3-benz-9-fluorenone, IX. The procedure suggested by Berger and Olivier[22] for the hydrolysis of hindered amides was used. A solution of 1.42 g. (0.01 mole) of phosphorus pentoxide in 3.3 g. (0.02 mole) of 85% phosphoric acid was added to 0.064 g. (0.0002 mole) of the amide, VIII. The homogeneous mixture was heated, under nitrogen in an oil bath kept at 180° for 90 min. Some yellow solid appeared on the condenser. After cooling the mixture was diluted with 125 ml. of water containing 0.5 ml. of concd. hydrochloric acid. The organic material was taken up in ethyl acetate, and washed in succession with water, ice cold 0.5*N* sodium hydroxide, and water. After evaporating the solvent there was obtained a quantitative yield of yellow solid, m.p. 118–120°. Crystallization from cyclohexane and acetone-cyclohexane and sublimation at 220° at 15 mm. gave yellow needles, m.p. 122–123.5° (m.).

Anal. Calcd. for $C_{19}H_{14}O$ (258.30): C, 88.34; H, 5.46. Found: C, 88.68; H, 5.45.

The fluorenone was eluted from Florisil with 1% acetone 99% benzene.

1,4-Dimethyl-2',3-dihydroxymethyl-2-phenylnaphthalene, XI. To a solution of 0.085 g. (0.0003 mole) of lactone, V, m.p. 168–171°, in 25 ml. of dry ether there was added 4 ml. (0.0006 mole) of lithium aluminum hydride dissolved in tetrahydrofuran. The mixture was heated gently at reflux for 30 min., cooled, and ethyl acetate cautiously added. After the addition of 25 ml. of saturated sodium potassium tartrate solution, the ether layer was separated, washed successively with saturated sodium bicarbonate, then water, and dried with sodium sulfate. The solvent was evaporated to give 0.082 g. (94%) of a colorless solid m.p. 137–149°. Repeated crystallization from benzene-cyclohexane containing a trace of pyridine gave colorless crystals, m.p. 157–157.5°, with a transition point at 146–147°.

Anal. Calcd. for $C_{20}H_{20}O_2$ (292.36): C, 82.15; H, 6.89 Found: C, 82.22; H, 6.89.

The dialcohol, XI, was eluted from Florisil with 8% acetone–92% benzene. λ_{max} ($\log_{10}\epsilon$); 237 (4.988); 286 (3.865); 293 (3.888) λ_{min} ($\log_{10}\epsilon$); 260 (3.618).

By means of this procedure III and IV were each converted to XI.

1,4-Dimethyl-2',3-dibromomethyl-2-phenylnaphthalene, XII. To a solution of 0.594 g. (0.002 mole) of dialcohol, XII, m.p. 156–157.5°, in 40 ml. of acetic acid there was added 12.5 ml. of 48% hydrobromic acid. After heating at reflux for 15 min., 6.25 ml. of 48% hydrobromic acid was added and heating continued one more hour. On cooling 0.620 g. (72%) of solid m.p. 148–150° (m) was filtered. After repeated crystallization from acetone-methanol, the melting point was 147–149°.

Anal. Calcd. for $C_{20}H_{18}Br_2$ (418.18): C, 57.44; H, 4.34. Found: C, 58.09, H, 4.59.

5,6-Dihydro-7,12-dimethylbenz(a)anthracene, X. A. *From the dibromo compound* XII. A solution of phenyllithium was prepared in an atmosphere of helium by adding slowly with stirring 1 ml. of bromobenzene to 0.157 g. (0.0227 g.-atom) of lithium suspended in 5 ml. of ether. The freshly prepared phenyllithium solution, followed by an ether wash, was transferred slowly in an atmosphere of helium to a stirred solution of 0.209 g. (0.0005 mole) of the dibromo compound, XII, in 20 ml. of benzene. The mixture was heated at reflux for 30 min., cooled, and decomposed with water and hydrochloric acid. The organic layer was washed with water, dried with sodium sulfate, and the solvent evaporated. The residual phenyl bromide was removed *in vacuo*. The residue was dissolved in cyclohexane and passed through Florisil. Cyclohexane was evaporated from the eluate and the residue crystallized from acetone-methanol to give 0.0671 g. (52%) of colorless[37] solid, m.p. 112–113°. This solid was identical with XII obtained below on the basis of mixed melting point and ultraviolet spectra determinations.

B. *From 7,12-Dimethylbenz(a)anthracene*, I. To a solution of 0.128 g. (0.0005 mole) of 7,12-dimethylbenz[a]anthracene. I, m.p. 122.5–123.1° in 50 ml. of 95% ethanol a small amount of catalyst (5% palladium on strontium carbonate) was added.[38] After several hours the catalyst was filtered and the solution was added to a hydrogenation flask containing 0.064 g. of prereduced catalyst (5% palladium on strontium carbonate); hydrogenation was slow and was continued overnight when 120% of the theoretical amount of hydrogen was absorbed. The catalyst was filtered and the solvent evaporated. The residue after crystallization from acetone-methanol gave 0.076 g. (59%) of colorless solid, m.p. 109–110.5° (m). After repeated crystallization from acetone-methanol and sublimation at 160° at 0.05 mm. the melting point was 112–113° (m.).

Anal. Calcd. for $C_{20}H_8$ (258.35); C, 92.98; H, 7.02. Found; C, 92.67; H, 7.04.

λ_{max} ($\log_{10}\epsilon$); 220 (4.486); 260 (4.918); 268 (4.981); 305 (3.955) λ_{min} ($\log_{10}\epsilon$) 234 (4.217); 264.5 (4.893); 284 (3.894).

In another experiment[39] the hydrogenation of 1.0 g. (0.0039 mole) of I using 50% palladium on strontium carbonate as the catalyst gave 0.731 g. (73%) of X, m.p. 112.3–112.8°. In this experiment the product was obtained subsequent to chromatography (see below) and crystallization from 95% ethanol.

Chromatographic separation of I *and* X. The separation of 1 mg. of I from 1 mg. X was accomplished on 1 g. of a 2:1 mixture of magnesia (Westvaco, Seasorb) and celite (Johns Manville) in an 8 mm. O.D. glass tube, under suction.

Fraction	Eluant		Eluate
1	10 ml. Cyclohexane		Nothing
2	2 ml. Cyclohexane		Nothing
3	10 ml. 1% Chloroform	99% Cyclohexane	X
4	10 ml. 1% Chloroform	99% Cyclohexane	Nothing
5	2 ml. 1% Chloroform	99% Cyclohexane	Nothing
6	10 ml. 20% Chloroform	80% Cyclohexane	I
7	10 ml. 20% Chloroform	80% Cyclohexane	I
8	2 ml. 20% Chloroform	80% Cyclohexane	Nothing

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(37) Repetition of this experiment likely would have given a higher yield.

(38) Prepared by the procedure of D. K. Banerjee, reference (35), footnote 33.

(39) Carried out by E. E. Smith.

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The Oxidation of Organic Substances by Potassium Peroxymonosulfate

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The reactions of a stable mixture of potassium peroxymonosulfate, potassium hydrogen sulfate, and potassium sulfate with a wide variety of organic substances have been investigated. The reactions with hydrocarbons, hydroxy compounds, carbonyl compounds, amines, nitrogen heterocycles, and with sulfur, phosphorus, and halogen compounds are described and discussed. The utility of peroxymonosulfates in halogenation reactions is also discussed. The behavior of peroxymonosulfates is compared with that of other inorganic peroxygen compounds and organic peroxyacids.

The existence of a peroxygen acid of sulfur was recognized nearly a century ago[1] but it was not until 1898 that Caro[2] demonstrated the existence of two such acids. It was known to Caro that salts of persulfuric acid (peroxydisulfuric acid, $H_2S_2O_8$) converted aniline to an insoluble dye (aniline black). When Caro treated aniline with a solution of ammonium persulfate in concentrated sulfuric acid, he obtained nitrosobenzene, but no aniline black. Three years later, Baeyer and Villiger[3] published conclusive evidence that Caro's acid was peroxymonosulfuric acid (H_2SO_5). It was not until 1910, however, that d'Ans and Friedrich[4] prepared pure, anhydrous peroxymonosulfuric acid.

The oxidation of aniline to nitrosobenzene by peroxymonosulfuric acid has already been cited;

(1) T. S. Price, *Per-Acids and Their Salts*, Longmans, Green and Co., London, 1912, p. 10.

(2) H. Caro, *Z. angew. Chem.*, 845 (1898).

(3) A. Baeyer and V. Villiger, *Ber.* **34**, 853 (1901).

(4) J. d'Ans and W. Friedrich, *Ber.* **43**, 1880 (1910).