TABLE III

DERIVATIVES OF 2-BENZOYLBENZOIC ACID

Substituents	Form	M. p., °C.	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
4,5-Dimethyl	Micro plates	197.5	75.57	75.43	5.55	5.42
4',4,5-Trimethyl	Micro plates	194.5	76.09	76.16	6.01	6.35
2',4',4,5-Tetramethyl	Micro prisms	204.5	76.56	76.32	6.43	6.63
2',5',4,5-Tetramethyl	Needles	230	76.56	76.44	6.43	6.41
4'-Methoxy-4,5-dimethyl	Needles	195.5	71.81	71.87	5.68	5.57

TABLE IV

ANTHRAQUINONES

Substituents	Form	M. p., °C.	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
2,3-Dimethyl[a]	Yellow needles	209				
2,3,6-Trimethyl[a]	Yellow needles	233				
2,3,6,8-Tetramethyl	Yellow needles	196	81.78	82.05	6.11	6.36
2,3,5,8-Tetramethyl	Yellow needles	178	81.78	82.20	6.11	6.34
2,3-Dimethyl-6-methoxy	Yellow needles	212	76.67	76.79	5.30	5.62

[a] Found identical with a sample prepared by Fieser and Seligman, THIS JOURNAL, **56**, 2690 (1934).

Like other di-α-substituted anthraquinones, 2,3,5,8-dimethylanthraquinone does not form a vat with alkaline hydrosulfite solution.

4'-Methoxy-4,5-dimethyl-2-benzylbenzoic acid was obtained by heating a mixture of 1.2 g. of 4'-methoxy-4,5-dimethyl-2-benzoylbenzoic acid, 10 g. of zinc dust, 50 cc. of water, and 15 cc. of 25% sodium hydroxide solution (added in portions) for two to three days on the steam-bath; yield, 1 g. The acid forms clusters of small, colorless needles from benzene–ligroin, m. p. 142°.

Anal. Calcd. for $C_{17}H_{18}O_3$: C, 75.52; H, 6.71. Found: C, 75.30; H, 6.53.

2,3-Dimethyl-6-methoxyanthrone-10 was obtained in quantitative yield by dissolving the above acid in concentrated sulfuric acid (10 cc. per 0.5 g.) at room temperature, and after two hours pouring the solution onto ice. The anthrone crystallized from alcohol as thin, yellow plates m. p. 151.5°.

Anal. Calcd. for $C_{17}H_{16}O_2$: C, 80.92; H, 6.40. Found: C, 81.30; H, 6.51.

On heating a solution of the anthrone (0.2 g.) and sodium dichromate (0.17 g.) in glacial acetic acid (5 cc.) on the steam-bath for ten minutes and diluting with water, 0.15 g. of the corresponding quinone (Table IV) was obtained.

Summary

Anthraquinones can be synthesized by adding dienes to aroylacrylic acids, dehydrogenating the adducts in the form of the esters, and cyclizing the *o*-aroylbenzoic esters.

CONVERSE MEMORIAL LABORATORY
CAMBRIDGE, MASS.
RECEIVED JULY 9, 1935

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

1',9-Methylene-1,2,5,6-dibenzanthracene

BY LOUIS F. FIESER AND EMANUEL B. HERSHBERG

In view of the high potency of methylcholanthrene in initiating malignant growth,[1] a knowledge of related compounds is desirable. Using the modified Elbs reaction developed for the synthesis of methylcholanthrene,[2] we have prepared a hydrocarbon having the cholanthrene ring system and one additional aromatic ring.

The starting material was 1-nitroacenaphthene, prepared according to Morgan and Harrison[3] by the nitration of acenaphthene with diacetyl orthonitric acid (22% yield). This was converted into the 1-iodo compound[3] and attempts were made to condense this through the Grignard compound with α-naphthoyl chloride. Like Cook, Haslewood and Robinson,[4] who used 1-iodoacenaphthene in their cholanthrene synthesis, we experienced difficulty in obtaining a satisfactory yield of a condensation product by the usual Grignard technique. We do not agree with these authors that the difficulty is connected with the reluctance of the halide to react with magnesium, for we readily obtained an ethereal solution which was found by titration to contain 90% of the theo-

---

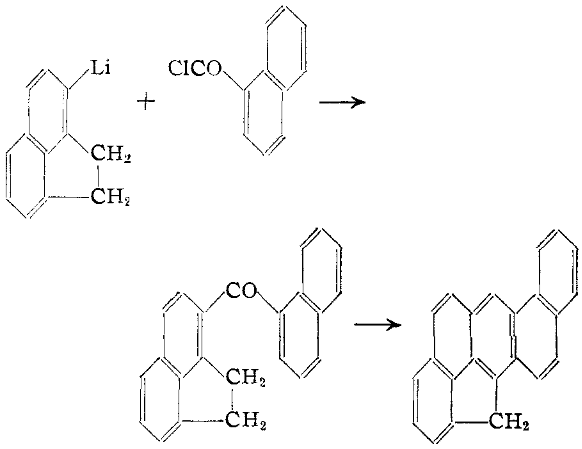
(1) Cook and Haslewood, *J. Chem. Soc.*, 428 (1934); Barry, Cook, Haslewood, Hewett, Hieger and Kennaway, *Proc. Roy. Soc.* (London), **B117**, 318 (1935).

(2) Fieser and Seligman, THIS JOURNAL, **57**, 228, 942 (1935).

(3) Morgan and Harrison, *J. Soc. Chem. Ind.*, **49**, 413T (1930).

(4) Cook, Haslewood and Robinson, *J. Chem. Soc.*, 667 (1935).

retical amount of basic magnesium compounds, and it seems more likely that the magnesium is present in an inactive combination. The lithium compound was found to be more satisfactory, and on reaction with α-naphthoyl chloride the ketone I was obtained in 21% yield.



I II

The pyrolysis of I proceeded smoothly, giving the pale yellow hydrocarbon II.

As another possible route to II, it was thought that the Friedel and Crafts reaction between α-naphthoyl chloride and acenaphthene might give, in addition to the expected 3-[α-naphthoyl]-acenaphthene, a certain amount of the isomeric ketone I. This was found to be the case, but the amount was so small that this simple synthesis does not appear to be practical.

1′,9-Methylene-1,2,5,6-dibenzanthracene, IV, has several interesting features of structure. It may be regarded as derived from cholanthrene by the fusing of a benzene ring to one corner of the molecule, and one of the added carbon atoms occupies the same position as that of the methyl group of methylcholanthrene. The substance is a derivative of the carcinogenically active 1,2,5,6-dibenzanthracene,[5] and it bears at least a superficial resemblance to the potent 1,2-benzpyrene.[6] It appears, however, that the substance is more closely related to the carcinogenic 1,2,5,6-dibenzanthracene than to the more potent hydrocarbons. The absorption spectrum is practically identical with that of 1,2,5,6-dibenzanthracene except for a slight shift of the bands in the direction of longer wave length (Dr. Egon Lorenz), and mice injected with the crystalline material have developed no tumors after 116 days (Dr. M. J. Shear). The hydrocarbon is definitely less active than cholanthrene and methylcholanthrene, but it is too early to make a comparison with 1,2,5,6-dibenzanthracene.

Experimental Part[7]

1-[α-Naphthoyl]-acenaphthene (I).—Since the preparation of 1-iodoacenaphthene is mentioned but not described by Morgan and Harrison,[3] the following procedure was used. A solution of 11.6 g. of sodium nitrite in 150 cc. of water was added slowly to a stirred suspension from 27.5 g. of finely powdered 1-aminoacenaphthene, 130 cc. of concentrated hydrochloric acid and 400 cc. of water at 0°, when the material soon dissolved. The filtered, brown-yellow solution was added with stirring to a solution at 0° of 80 g. of potassium iodide in 2 liters of water. The orange precipitate decomposed on warming the mixture slowly to the boiling point, giving a black tar which solidified on cooling This was extracted with ether and the solution was washed thoroughly with bisulfite solution and with alkali until there was no further separation of tar. After drying and removing the ether the 1-iodoacenaphthene was distilled (b. p. 189–193° (8.5 mm.)) and crystallized from ether; yield, 21 g. (46%); m. p. 86–87°.

A solution of 15 g. of 1-iodoacenaphthene in 450 cc. of dry ether was added slowly with stirring to 1.48 g. of lithium in the form of short rods cut from 1-mm. wire. The reaction started at once, giving a red-brown solution. After refluxing for one-half hour, the solution was added slowly to an ice-cold solution of 20.4 g. of α-naphthoyl chloride in 100 cc. of dry ether. After standing for eighteen hours the solution was decanted, treated with dilute hydrochloric acid, and the solvent and the excess iodine were removed by steam distillation. The tarry residue was twice suspended in soda solution and treated with steam, and then dried in ether and distilled (b. p. 302–306° (10 mm.)). After crystallization from hexane the ketone was obtained as needles melting at 105–107°; yield, 3.5 g. (21%). On recrystallization from hexane or from ether–petroleum ether, the compound formed fine colorless needles, m. p. 107–108°, but on further crystallization the substance invariably formed thin plates, m. p. 102–104°.

Anal. Calcd. for $C_{23}H_{16}O$: C, 89.75; H, 5.10. Found: C, 89.55; H, 5.26.

1′,9-Methylene-1,2,5,6-dibenzanthracene (II).—The ketone (2 g.) was heated at 400–415° for fifteen minutes and the residue was then distilled in vacuum, giving a red-orange oil (1.1 g.) which solidified in the receiver. After crystallization from benzene the hydrocarbon was obtained as light brown prisms, m. p. 245–250°; yield, 0.6 g. (32%). Some extraneous coloring matter was removed by passage of a benzene solution of the crude hydrocarbon through a tower of activated alumina, and a further purification was accomplished by shaking the solution in benzene with small portions of concentrated sulfuric acid. The material was then crystallized as the di-picrate to a constant melting point, and after decomposition with ammonia the hydrocarbon crystallized from benzene–ligroin as pale greenish-yellow, diamond-shaped prisms, m. p. 266–267°, corr.

---

(5) Kennaway and Hieger, *Brit. Med. J.*, I, 1044 (1930).

(6) Cook, Hewett and Hieger, *J. Chem. Soc.*, 395 (1933).

(7) Microanalyses by Mrs. G. M. Wellwood.

The substance fluoresces bright blue under ultraviolet light.

Anal. Calcd. for $C_{23}H_{14}$: C, 95.14; H, 4.86. Found: C, 95.11; H, 4.86.

The *di-picrate* forms fine, orange needles from benzene, m. p. 201–201.5° corr.

Anal. Calcd. for $C_{35}H_{20}O_{14}N_6$: C, 56.13; H, 2.69. Found: C, 56.55; H, 2.71.

3-[α-Naphthoyl]-acenaphthene.—The condensation of α-naphthoyl chloride (33.4 g.) with acenaphthene (30 g.) was carried out in 250 cc. of tetrachloroethane at 20–25°, using 26 g. of aluminum chloride. After working up the product in the usual way and distilling the neutral fraction in vacuum, 48 g. (89%) of a light yellow solid was obtained, b. p. 299–302° (7.5 mm.). Recrystallization from benzene–ether gave 41 g. (76%) of the pure 3-isomer as yellow prisms, m. p. 159–160° corr.

Anal. Calcd. for $C_{23}H_{16}O$: C, 89.75; H, 5.10. Found: C, 89.49; H, 5.37.

The oily residue was collected from the mother liquors and subjected to pyrolysis. This afforded 0.2 g. of purified hydrocarbon identical with the material (II) prepared by the other method.

Summary

A hydrocarbon having the cholanthrene ring system and one additional benzene ring has been synthesized.

CONVERSE MEMORIAL LABORATORY
CAMBRIDGE, MASS.

RECEIVED JULY 12, 1935

[CONTRIBUTION FROM THE LABORATORIES OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH]

The Thermodynamic Ionization Constants of Carbonic Acid at 38° from Electromotive Force Measurements

BY D. A. MACINNES AND DONALD BELCHER

In a recent paper from this Laboratory[1] the authors described measurements, at 25°, on concentration cells without liquid junctions, leading to the determination of the two ionization constants of carbonic acid. The measurements have been repeated at body temperature, 38°, with the results and conclusions to be outlined in this paper.

(a) The First Ionization Constant.—As in our previous work, the potentials, E'_A, were obtained of cells of the type

$$\text{Ag; AgCl, KHCO}_3\text{, KCl, CO}_2\text{ (dissolved), } \textit{glass}\text{, 0.1 } N\text{ HCl, AgCl; Ag} \qquad \text{(A)}$$

in which the concentrations of potassium chloride and potassium bicarbonate were kept equal. The results were interpreted with the aid of the equation

$$pK_1' = pK_1 - \log f_H f_{Cl}/f_H f_{HCO_3} = - \frac{E_A - E_0 + E_g}{(RT/F)} + \log SP_{CO_2} \qquad (1)$$

Here pK_1 is the negative logarithm of the thermodynamic ionization constant, f_H, f_{Cl} and f_{HCO_3} are the activity coefficients of the indicated ion constituents, E_A is the potential of Cell A, after correction for the asymmetry potential of the glass electrode, E_0 is the limiting potential of the cell

$$\text{Ag; AgCl, HCl; H}_2 \qquad \text{(B)}$$

E_g is the potential of the cell

$$\text{Ag; AgCl, HCl (0.1 } N\text{); H}_2 \qquad \text{(C)}$$

S is the Henry law constant, and P_{CO_2} is the partial pressure of carbon dioxide. Since the activity coefficients approach unity as the concentration is decreased, pK_1 may be obtained by a suitable extrapolation from a series of values of pK_1'.

Except for the change of temperature the experimental arrangements, the preparation of solutions, etc., were exactly as described in our previous paper. The new experimental data are given in Table I, which is self-explanatory. To compute pK_1' values the potentials of Cells B and C are necessary. The first of these, $E_0 = -0.2135$, was obtained from the work of Harned and Ehlers,[2] who give a formula connecting E_0 of this cell with the temperature, based on their extensive experimental work. The second, $E_g = -0.3495$, was interpolated from the same measurements, and agrees closely with direct measurements made in this Laboratory. The Henry law constant, $S = 0.02443$ mole/liter/atm., was obtained from the data of Van Slyke, Sendroy, Hastings and Neill,[3] and has been corrected for the deviation of the equation of state of carbon dioxide from that of a perfect gas. The partial pressure, P_{CO_2}, was obtained from the barometric pressure, the analysis of the tank gas and the vapor pressure of water. The small correction arising from the formation of bicarbonate ion

---

[1] MacInnes and Belcher, THIS JOURNAL, **55**, 2630 (1933).

[2] Harned and Ehlers, *ibid.*, **55**, 2179 (1933).

[3] Van Slyke, Sendroy, Hastings and Neill, *J. Biol. Chem.*, **78**, 765 (1928).