potassium permanganate, which produced *p*-bromobenzoic acid, m. p. 245–246.5°.

Twenty-five grams of *p*-bromophenylpropionic acid was refluxed gently for five hours with four equivalents of thionyl chloride, and the excess of thionyl chloride was removed by distillation. The residual acid chloride was taken up in 75 cc. of benzene and the solution was added slowly, with stirring, to an excess of diphenylzinc. The latter was prepared by the addition of 27 g. (0.2 mole) of anhydrous zinc chloride in 25 cc. of absolute ether, to 0.45 mole of phenylmagnesium bromide.[14] After the reaction had been completed the mixture was hydrolyzed with dilute acid; the benzene–ether layer was separated, washed with dilute alkali, and finally with water. After removal of the solvent the crude product was recrystallized from ethyl alcohol, and finally from methyl alcohol. The purified ketone formed white needles, m. p. 68–69°. This material was identical with a small sample of the ketone which had been obtained by treating the sodium derivative of ethyl benzoylacetate with *p*-bromobenzyl bromide and saponifying the resulting ethyl benzoyl-*p*-bromobenzylacetate.

Anal. Calcd. for $C_{15}H_{13}OBr$: C, 62.30; H, 4.50. Found: C, 61.89; H, 4.78.

(14) Job and Reich, *Bull. soc. chim.*, [4] **33**, 1428 (1923).

The semicarbazone of the synthetic ketone melted at 160–161.5°, and the 2,4-dinitrophenylhydrazone at 67–67.5°. The synthetic ketone and its semicarbazone showed no depression of the melting point when mixed with the specimens obtained from *p*-bromobenzylphenylacetylene.

Summary

1,3-Diphenylpropyne (benzylphenylacetylene) and two isomeric bromo derivatives have been prepared, and their chemical reactions investigated.

It has been shown that active prototropy of the propyne–allene type does not occur in these compounds, and that the 1,3-diarylpropynes exhibit low proton mobility.

Comparison with benzyl cyanide and 3-phenyl-1-propyne indicates that the phenylethynyl group has less activating effect than —C≡N or —C≡CH, which is in agreement with the anticipated order.

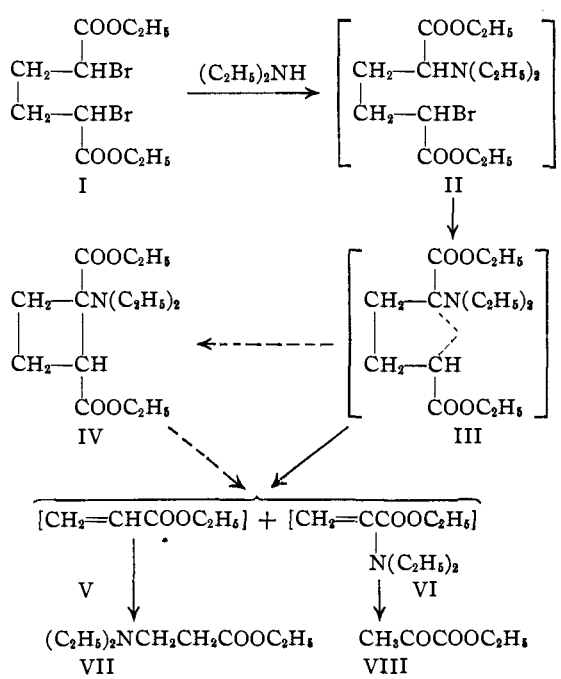
ITHACA, N. Y. RECEIVED APRIL 25, 1938

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF ILLINOIS]

The Mechanism of the Cleavage of Ethyl α,α′-Dibromoadipate by Diethylamine

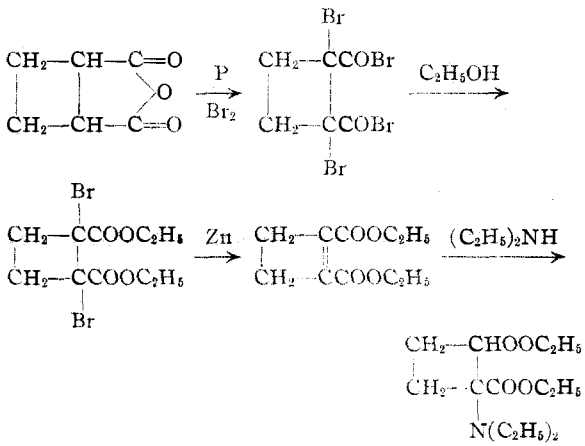
BY REYNOLD C. FUSON AND WM. E. LUNDQUIST

The cleavage of ethyl α,α′-dibromoadipate (I) by secondary amines, discovered by von Braun, Leistner and Münch,[1] may be interpreted in the light of Criegee's recently proposed theory of chain cleavages.[2] This postulate suggests that the cleavage may be explained by the formation of a 1,4-biradical. According to Criegee such radicals may stabilize themselves in two ways: (1) by closure to a four-membered ring or (2) by chain fission between atoms 2 and 3 to give two molecules of olefinic character. Applied to the cleavage of ethyl α,α′-dibromoadipate (I) by diethylamine this theory suggests that the biradical (III) may be produced from the intermediate bromoamino ester (II) by the loss of hydrogen bromide. The biradical might be expected to decompose to give ethyl acrylate (V) and ethyl α-diethylaminoacrylate (VI). The products actually isolated were ethyl β-diethylaminopropionate (VII) and ethyl pyruvate (VIII)—compounds which may be regarded as transformation products of V and VI, respectively. The formation of these compounds constitutes an example of the second mode of stabilization of the biradical.



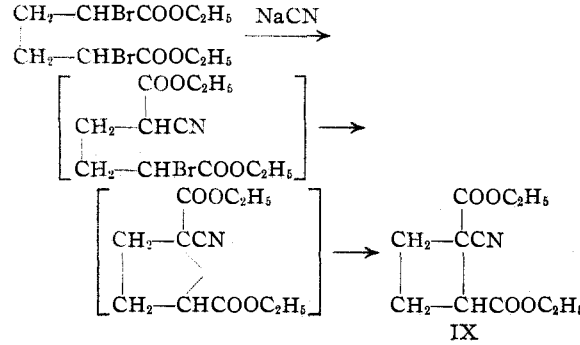
(1) Von Braun, Leistner and Münch, *Ber.*, **59**, 1950 (1926).
(2) Criegee, *ibid.*, **68B**, 665 (1935).

If the biradical stabilized itself by the first mode, *i. e.*, by closure to a four-membered ring, the product would be ethyl 1-diethylamino-1,2-cyclobutanedicarboxylate (IV). Although none of this compound was isolated, it was important to determine whether it might be a possible intermediate in the cleavage as was suggested by Fuson[3] in 1928. We have made this compound (IV), and have tested its thermal stability. The synthesis was carried out by the following sequence of transformations

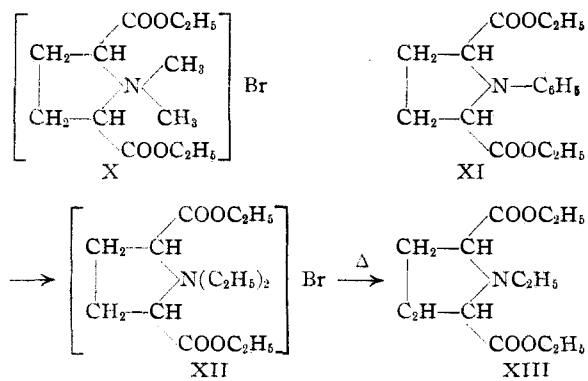


The amino ester was analyzed, and its molecular refraction and parachor were determined as a check on its identity. Its picrate was also prepared and characterized. The amino ester was found to be stable toward aqueous acid and alkali and could be distilled under diminished pressure without decomposition. It is therefore extremely unlikely that it is an intermediate in the cleavage of ethyl α,α'-dibromoadipate by diethylamine. This conclusion lends support to Criegee's theory.

It is interesting to note that on the strength of his original theory—a theory which is no longer tenable—Fuson predicted that ethyl α,α'-dibromoadipate should react with sodium cyanide to give a cyclobutane derivative, and experiments showed that good yields of a stable cyclized product (IX) could be obtained.[4] This formation of a four-membered ring appears to be an example of the stabilization of a 1,4-biradical by ring closure. Thus the reactions of ethyl α,α'-dibromoadipate with sodium cyanide and diethylamine may be interpreted as examples of two ways in which 1,4-biradicals can stabilize themselves.

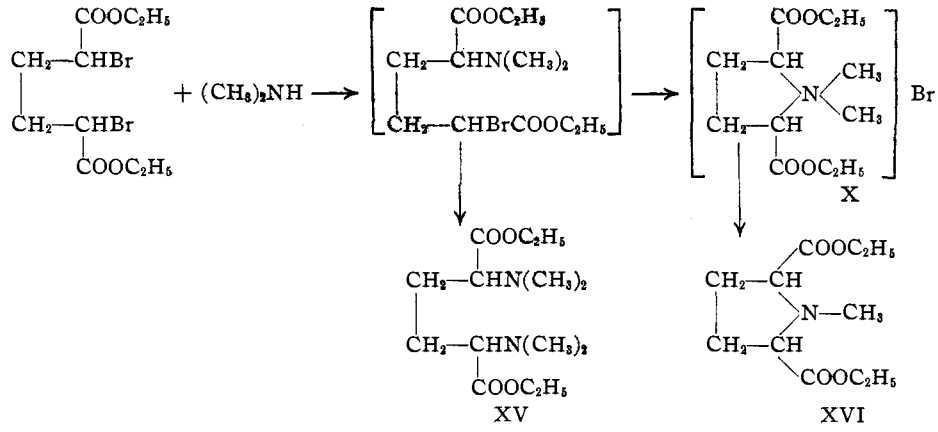


It might be expected that ethyl α-bromo-α'-diethylaminoadipate (II), postulated as the first product of the reaction, would tend to form the corresponding pyrrolidinium bromide. Ethyl α,α'-dibromoadipate reacts with dimethylamine in alcohol to give a pyrrolidinium bromide (X),[5] and with aniline,[6] ethylaniline,[7] and diethylaniline[8] at 100° or above to give ethyl 1-phenyl-2,5-pyrrolidinedicarboxylate (XI). The work of Menschutkin[9] on the velocity of the reaction of triethylamine with ethyl iodide in various solvents suggests that ethyl α,α'-dibromoadipate might be converted to a pyrrolidine derivative (XII) if the treatment with diethylamine were carried out in a suitable solvent.



The reaction was therefore repeated using acetone, ethyl alcohol and benzene as diluents in

(3) Fuson, THIS JOURNAL, **50**, 1444 (1928).
(4) Fuson and Kao, *ibid.*, **51**, 1536 (1929).
(5) Fuson and Connor, *ibid.*, **52**, 2985 (1930).
(6) Von Braun and Seemann, *Ber.*, **56B**, 1840 (1923).
(7) Le Sueur, *J. Chem. Soc.*, **95**, 273 (1909).
(8) Le Sueur and Haas, *ibid.*, **97**, 173 (1910).
(9) Menschutkin, *Z. physik. Chem.*, **6**, 41 (1890).



comparable runs. The ethyl alcohol and acetone would be expected to hasten the formation of the intermediate, II, and the further reaction of II with more diethylamine to give the diamino product (XIV) or with itself by ring closure to give the quaternary pyrrolidinium salt (XII). The reaction in benzene would be expected to proceed in much the same manner as if there were no solvent;[10] that is, cleavage should result. It was found that the solvents had the expected effect. In ethyl alcohol the pyrrolidine derivative (XII) was formed with no evidence of any cleavage. In acetone the pyrrolidine derivative was also obtained but there was evidence of a small amount of cleavage. In benzene only a small amount of pyrrolidine was formed and both of the cleavage products (VII and VIII) were found. The salt, XII, was not isolated as such but rather as its thermal decomposition product, XIII.

The effect of solvents on the course of the reaction between diethylamine and ethyl α,α′-dibromoadipate made it seem necessary to reinvestigate the reaction of the ester with dimethylamine. It had been carried out in benzene solution by von Braun and Münch[11] who obtained a 20% yield of ethyl α,α′-tetramethyldiaminoadipate (XV). Fuson and Connor[5] using alcohol obtained small amounts of the diamino ester (XV) and the pyrrolidinium bromide (X). To favor cleavage the reaction was carried out rapidly and without a solvent. Dimethylamine and ethyl α,α′-dibromoadipate were heated in a sealed tube on a steam-bath for one-half hour and the crude reaction product was distilled. In this way there was obtained a 35% yield of ethyl 1-methyl-2,5-pyrrolidinedicarboxylate (XVI) with no evidence of any cleavage products.

(10) Moelwyn-Hughes and Hinshelwood, *J. Chem. Soc.*, 230 (1932).
(11) Von Braun and Münch, *Ber.*, **59B**, 1941 (1926).

Experimental

Ethyl 1-Diethylamino-1,2-cyclobutanedicarboxylate.—The anhydride of 1,2-cyclobutanedicarboxylic acid[12] was treated with bromine and red phosphorus[13] and then with ethyl alcohol to produce ethyl 1,2-dibromo-1,2-cyclobutanedicarboxylate. Dehalogenation with zinc in ether[14] gave ethyl Δ′-1,2-cyclobutenedicarboxylate.[15] The properties found for this substance are: b. p. 92–94° (2 mm.); $n^{20}D$ 1.4610; d^{20}_4 1.081; γ^{20} 33.8 dynes/cm.;[16] M_D 50.3; *P*, 442.1. Calcd. for $C_{10}H_{14}O_4$: M_D 49.51;[17] *P*, 442.2.[18]

Diethylamine was added to this unsaturated material by the method of Körner and Menozzi.[19] Two grams of ethyl Δ′-1,2-cyclobutenedicarboxylate, 2 g. of diethylamine, and 5 cc. of absolute alcohol were heated at 100° in a sealed tube for five hours. The alcohol and excess diethylamine were removed by distillation, and the amine was then dissolved in ether leaving the amide behind. The amine was extracted from the ether with cold dilute sulfuric acid, and the aqueous solution was washed well with ether. Sodium hydroxide liberated an oil which was removed by ether extraction. The ethereal solution was washed well with water to remove much of the coloring matter, and was then dried with magnesium sulfate. Removal of the ether left a red oil which distilled under diminished pressure to give a clear colorless oil; b. p. 100–101° (2 mm.); $n^{20}D$ 1.4540; d^{20}_4 1.016; γ^{20} 29.7 dynes/cm.[16]

Anal. Calcd. for $C_{14}H_{25}O_4N$: C, 61.97; H, 9.28; M_D 72.56;[17] *P*, 638.8.[18] Found: C, 62.25, 62.25; H, 9.43, 9.27; M_D 72.3; *P*, 623.4.

The picrate of the amine was prepared by adding 1 g. of ethyl 1-diethylamino-1,2-cyclobutanedicarboxylate to a saturated solution of 1 g. of picric acid in ethyl alcohol. The yellow crystals which soon appeared were recrystal-

(12) Ellingboe and Fuson, THIS JOURNAL, **56**, 1774 (1934).
(13) Perkin, *J. Chem. Soc.*, **65**, 950 (1894).
(14) Michael and Schulthess, *J. prakt. Chem.*, [2] **43**, 587 (1891).
(15) Kon and Nandi, *J. Chem. Soc.*, 1628 (1933).
(16) Surface tension measurements were made by the capillary rise method.
(17) Calculated from values found in Gilman "Organic Chemistry," Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1938, p. 1739.
(18) Calculated from Sugden's values found in Gilman, ref. 17, p. 1733.
(19) Körner and Menozzi, *Atti accad. Lincei*, Rome, V, **5**, I, 456 (1896).

lized several times from ethyl alcohol; m. p. 125–130.5°. The crystals are sensitive to direct sunlight.

Anal. Calcd. for $C_{20}H_{28}O_{11}N_4$: C, 48.00; H, 5.64; N, 11.20. Found: C, 47.96; H, 5.67; N, 11.22.

Ethyl 1-Ethyl-2,5-pyrrolidinedicarboxylate.—This substance was prepared by the method of von Braun and Seemann.[6] Thirty-six grams (0.1 mole) of ethyl *meso*-α,α'-dibromoadipate and 50 g. of dry benzene containing 13.5 g. (0.3 mole) of ethylamine were placed in a sealed tube. The tube soon became warm, and ethylamine hydrobromide began to separate. After standing at room temperature for twenty-four hours the bomb was warmed in a steam-bath for four hours. It was then cooled and the solution was filtered to remove ethylamine hydrobromide. The filtrate was diluted with ether and was extracted with an excess of cold dilute sulfuric acid to remove the basic fraction. The aqueous solution was washed with ether and was then made alkaline with sodium bicarbonate. The oil which separated was removed by ether extraction, the ethereal solution was washed with water and dried, and the ether was removed by distillation. Vacuum distillation of the residual oil gave 7 g. (30% of the theoretical amount) of a colorless oil, b. p. 108–114° (2 mm.). Redistillation gave a fraction boiling at 108–109° (2 mm.); $n^{20}D$ 1.4508; d^{20}_4 1.052; γ^{20} 32.5 dynes/cm.[16]

Anal. Calcd. for $C_{12}H_{21}O_4N$: C, 59.24; H, 8.70; M_D 62.84;[17] P, 557.7.[18] Found: C, 59.33, 59.34; H, 8.56, 8.63; M_D 62.2; P, 552.2.

The chloroplatinate of the pyrrolidine was prepared by treating 0.8 g. of ethyl 1-ethyl-2,5-pyrrolidinedicarboxylate with 0.7 g. of platinic chloride and 1 cc. of concd. hydrochloric acid in 20 cc. of ethyl acetate. The product was recrystallized from a mixture of equal volumes of ethyl alcohol and ethyl acetate to obtain pale orange crystals; m. p. 133.5–135.5°.

Anal. Calcd. for $(C_{12}H_{21}O_4N)_2 \cdot H_2PtCl_6$: Pt, 21.77. Found: Pt, 21.70, 21.70.

Reaction of Diethylamine with Ethyl α,α'-Dibromoadipate. Reaction in Alcohol.—Thirty-six grams of ethyl α,α'-dibromoadipate and 60 cc. of diethylamine were added to 150 cc. of 95% ethyl alcohol and the mixture was allowed to stand at room temperature. At the end of one day all of the dibromo ester had not dissolved so the mixture was warmed until solution was complete. The solution was then let stand at room temperature for an additional forty hours. The solvent and excess diethylamine were removed from the solution by distillation through a 12-in. (30-cm.) Widmer column, and the residue was then heated under diminished pressure to liberate as much material as possible from the diethylamine hydrobromide. The crude distillate obtained in this way was redistilled to obtain 6.5 g. (27% of the theoretical amount) of ethyl 1-ethyl-2,5-pyrrolidinedicarboxylate, boiling at 113–114° (3 mm.).

Reaction in Acetone.—Thirty-six grams of ethyl α,α'-dibromoadipate and 60 cc. of diethylamine were dissolved in a mixture of 145 cc. of acetone and 5 cc. of water, and the solution was allowed to stand at room temperature for two days. The solvent was then removed by distillation and the residue was distilled under reduced pressure. The crude distillate obtained was redistilled to get about 0.5 cc. of a product boiling at 90–95° (18 mm.) and 3 cc. of ethyl 1-ethyl-2,5-pyrrolidinedicarboxylate, boiling at 143–145° (18 mm.).

Reaction in Benzene.—Thirty-six grams of ethyl α,α'-dibromoadipate and 60 cc. of diethylamine were dissolved in 150 cc. of benzene and the solution was allowed to stand at room temperature for sixty hours. It was then filtered to obtain 30 g. of crude diethylamine hydrobromide (the theory calls for 30.8 g. of diethylamine hydrobromide). The diethylamine and benzene were removed from the filtrate by fractional distillation through a 12-in. (30 cm.) Widmer column. The residue was then distilled under diminished pressure to obtain 7 g. of a product boiling at 83–88° at 16 mm. pressure. This was allowed to stand with a slight excess of cold dilute hydrochloric acid for an hour, and it was then extracted with ether. Evaporation of the ether from this extract left a small quantity of an oil which was shown to be ethyl pyruvate by conversion to its phenylhydrazone.

The acid solution was made alkaline with sodium hydroxide and the liberated amine was removed by extraction with ether. The ether solution was dried and the ether was removed by distillation. The residual oil was distilled under diminished pressure to give 3.5 g. (20% of the theoretical) of ethyl β-diethylaminopropionate boiling at 85–86° (15 mm.); $n^{20}D$ 1.4268.

The crude diethylamine hydrobromide was heated under reduced pressure to yield a small amount of an oil which on redistillation gave about 0.5 cc. of ethyl 1-ethyl-2,5-pyrrolidinedicarboxylate boiling at 110° (2–3 mm.).

Reaction of Dimethylamine with Ethyl α,α'-Dibromoadipate.—Eighteen grams of ethyl α,α'-dibromoadipate was placed in a glass tube and the tube was cooled in a dry ice–acetone bath. Dimethylamine, prepared by dropping a commercial aqueous solution on solid potassium hydroxide and dried by passing the gas over solid potassium hydroxide, was condensed and added to the tube until the weight of the tube had increased by 13.5 g. The tube was then sealed and allowed to warm up to room temperature. A spontaneous reaction occurred and after fifteen minutes the tube had become hot. It was heated for an additional half hour in a steam-bath, cooled and opened. The excess dimethylamine quickly vaporized and the remainder of the product was then distilled under diminished pressure. Redistillation of the crude product obtained gave 4 g. (35% of the theoretical) of ethyl 1-methyl-2,5-pyrrolidinedicarboxylate boiling at 138–141° (20 mm.). This when redistilled had the following properties: b. p. 114–115° (4 mm.), $n^{20}D$ 1.4515, d^{20}_4 1.072.

Summary

Ethyl 1-diethylamino-1,2-cyclobutanedicarboxylate has been prepared and found to be stable at ordinary temperatures. It is therefore concluded that this ester cannot be an intermediate in the cleavage of ethyl α,α'-dibromoadipate by diethylamine.

The reaction of diethylamine α,α'-dibromoadipate has been carried out using ethyl alcohol, acetone and benzene as solvents in comparable

runs. It has been found that the solvent affects the course of the reaction; ethyl 1-ethyl-2,5-pyrrolidinedicarboxylate is produced in these solvents. It is therefore concluded that 1,1-diethyl-2,5-dicarbethoxypyrrolidinium bromide cannot be an intermediate in the cleavage.

The 1,4-biradical theory of Criegee offers a satisfactory explanation of the facts.

The reaction of dimethylamine and ethyl α,α'-dibromoadipate carried out without a solvent gives a 35% yield of ethyl 1-methyl-2,5-pyrrolidinedicarboxylate with no evidence of any cleavage.

URBANA, ILLINOIS RECEIVED MAY 2, 1938

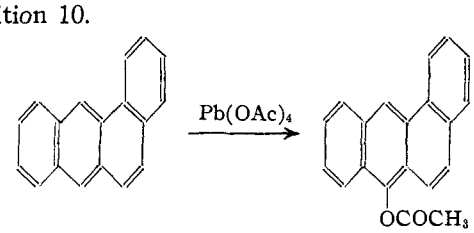
[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

Substitution Reactions and Meso Derivatives of 1,2-Benzanthracene

BY LOUIS F. FIESER AND E. B. HERSHBERG[1]

Among various miscellaneous observations reported in this paper is a study of the action of lead tetraacetate on 1,2-benzanthracene and two related carcinogenic hydrocarbons. The idea of investigating the action of this oxidizing agent on polynuclear aromatic hydrocarbons was suggested by an observation of K. H. Meyer[2] which heretofore has attracted little attention. Schulze[3] at an early date had investigated the action of lead dioxide on anthracene in acetic acid solution, but it remained for Meyer to interpret the reaction correctly and to show that with two moles of oxidizing agent the chief product is hydroxyanthrone acetate. Using one mole of lead dioxide, Meyer obtained anthranyl acetate in 40–50% yield and noted that this was the first instance of the direct oxidation of a hydrocarbon to a phenol derivative. It occurred to us that this method of hydroxylation might have preparative value, that it might afford a useful method of probing for centers of reactivity in polynuclear compounds, and that the reaction would form an interesting model for a possible hydroxylation of carcinogenic hydrocarbons introduced into the animal organism.

In trial experiments lead tetraacetate was found to act as well as lead dioxide and it is a generally superior reagent. The reaction of one mole of lead tetraacetate with 1,2-benzanthracene in glacial acetic acid is complete after short heating on the steam-bath, and the purified reaction product, isolated in 52% yield, was found to be identical with synthetic 1,2-benzanthranyl-10-acetate[4] (II). The chief point of attack in the oxidation therefore is at the less hindered meso position 10.



I II

Little previous work has been done on the orientation of 1,2-benzanthracene in monosubstitutions. Cook and Hewett[5] found that the chief product of the Friedel and Crafts reaction with acetyl chloride at a low temperature is a meso ketone, but a distinction between the 9- and 10-positions was not made. With oxalyl chloride, Dansi[6] obtained besides a diketone a small amount of an acidic substance regarded as 1,2-benzanthracene-10-carboxylic acid. Barnett and Matthews[7] prepared a mononitro compound which they regarded as a 9- or 10-derivative, but they did not investigate the structure. We prepared a sample of the nitro compound by their method and reduced it to the amine. The same amine was obtained in good yield from 1,2-benz-10-anthranol[4] by the Bucherer reaction, from which it is evident that the nitration product prepared by Barnett and Matthews is 10-nitro-1,2-benzanthracene. The nitration of the hydrocarbon thus follows the same course as the oxidation with lead tetraacetate. Since 10-substituted derivatives of 1,2-benzanthracene are of particular interest in connection with the problem of carcinogenesis, it is significant that such compounds are available by the route of direct substitution reac-

(1) Research Fellow on funds from the National Cancer Institute and the Ely Lilly Company.

(2) K. H. Meyer, *Ann.*, **379**, 73 (1911).

(3) Schulze, *Ber.*, **18**, 3036 (1885).

(4) Fieser and Hershberg, THIS JOURNAL, **59**, 1028 (1937).

(5) Cook and Hewett, *J. Chem. Soc.*, 1408 (1933).

(6) Dansi, *Gazz. chim ital.*, **67**, 85 (1937).

(7) Barnett and Matthews, *Chem. News*, **130**, 339 (1925).