Piperonylidene derivative, pale yellow leaflets, m.p. 158°, gave a violet-red coloration with sulfuric acid.

Anal. Calcd. for $C_{23}H_{17}ClO_4$: C, 70.3; H, 4.3. Found: C, 70.3; H, 4.3.

2-Furfurylidene derivative, shiny yellow leaflets, m.p. 148°, gave a bright red coloration with sulfuric acid.

Anal. Calcd. for $C_{20}H_{15}ClO_3$: C, 70.9; H, 4.4. Found: C, 70.7; H, 4.5.

2-Thenylidene derivative, pale yellow needles, m.p. 165°, gave a red coloration with sulfuric acid.

Anal. Calcd. for $C_{20}H_{15}ClO_2S$: C, 67.7; H, 4.2. Found: C, 67.7; H, 4.2.

3-Chloro-4-methoxybiphenyl-4'-carboxylic acid (III). A fine suspension of 4'-acetyl-3-chloro-4-methoxybiphenyl (1 mole) in an aqueous solution of sodium hypobromite (1.2 moles) was shaken with some dioxane for 4 hr., then heated for 1 hr. on the water bath. After addition of sodium hydrogen sulfite and filtration, the filtrate was acidified with hydrochloric acid, and the precipitate washed with water and recrystallized from dioxane. Yield: 80% of fine colorless prisms, m.p. 280–281°.

Anal. Calcd. for $C_{14}H_{11}ClO_3$: C, 64.0; H, 4.2. Found: C, 63.7; H, 4.3.

The corresponding *amide* crystallized from ethanol in fine colorless needles, m.p. 243°.

Anal. Calcd. for $C_{14}H_{12}ClNO_2$: C, 64.2; H, 4.6. Found: C, 64.1; H, 4.9.

4'-Propionyl-3-chloro-4-methoxybiphenyl (II; R = CH_3). Prepared in 86% yield as for the lower homolog, this ketone, b.p. 260–262°/15 mm., crystallized from ethanol in lustrous colorless leaflets, m.p. 111°.

Anal. Calcd. for $C_{16}H_{15}ClO_2$: C, 69.9; H, 5.5. Found: C, 70.0; H, 5.5.

4'-n-Butyryl-3-chloro-4-methoxybiphenyl (II; R = C_2H_5). This ketone (65% yield), b.p. 272–274°/18 mm., crystallized from ethanol in colorless leaflets, m.p. 86°.

Anal. Calcd. for $C_{17}H_{17}ClO_2$: C, 70.7; H, 5.9. Found: C, 70.5; H, 6.1.

4'-Phenacetyl-3-chloro-4-methoxybiphenyl (II; R = C_6H_5). This ketone (65% yield), b.p. 332–334°/17 mm., crystallized from a mixture of benzene and ethanol in colorless prisms, m.p. 144°.

Anal. Calcd. for $C_{21}H_{17}ClO_2$: C, 74.9; H, 5.1. Found: C, 74.8; H, 5.3.

The *semicarbazone* crystallized from acetic acid in fine colorless prisms, m.p. 245°.

4'-Benzoyl-3-chloro-4-methoxybiphenyl (IV). (a) *From benzoyl chloride* the yield was 68% of a ketone, m.p. 310–315°/20 mm., which crystallized from a mixture of ethanol and benzene in long colorless needles, m.p. 138°.

Anal. Calcd. for $C_{20}H_{15}ClO_2$: C, 74.4; H, 4.7. Found: C, 74.1; H, 4.5.

(b) *From 3-chloro-4-methoxybiphenyl-4'-carboxylic acid.* This acid was converted into its chloride by means of thionyl chloride in benzene solution on the water bath. The solvent was then distilled off and replaced by more benzene, aluminum chloride was added with cooling, and the mixture was left overnight. After the usual treatment, a ketone was obtained in 75% yield, identical with the one prepared from benzyl chloride.

Pfitzinger reactions with ketones II. The appropriate ketone was condensed with isatin in the usual way, the duration of reaction being 68 hr. for ketones II; R = H and R = CH_3, 100 hr. for ketone II; R = C_6H_5, and 120 hr. for ketone II; R = C_2H_5. Crystallization was from nitrobenzene producing fine yellowish prisms.

Demethylation of methoxy ketones II. A mixture of one part of the appropriate 4'-acyl-3-chloro-4-methoxybiphenyl and six parts of redistilled pyridine hydrochloride was gently refluxed for 15 to 30 min., and the cooled reaction product treated with dilute hydrochloric acid; the precipitate obtained was collected, washed, and purified *via* its sodium salt. Recrystallization was from benzene.

Reduction of methoxy ketones II. A solution of the methoxy ketone (1 mole) and 95% hydrazine hydrate (4 moles) in diethylene glycol was heated for a few minutes to allow formation of the hydrazone; potassium hydroxide (same weight as the hydrazine hydrate) was added after cooling, and the mixture refluxed for 1 hr. with removal of water. After cooling, water was added, the reduction product was taken up in benzene, the benzene solution was washed first with dilute hydrochloric acid, then with water, and dried over sodium sulfate. The solvent was removed, and the residue vacuum-distilled. Crystallization was from ethanol. Yield: 80 to 85%.

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[CONTRIBUTION FROM THE RESEARCH DIVISION, AMERICAN CYANAMID COMPANY, BOUND BROOK LABORATORIES]

Pyrido[2,3,4,5-*lmn*]phenanthridine

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Received November 13, 1956

The synthesis of pyrido[2,3,4,5-*lmn*]phenanthridine and its 5,10-dimethyl homolog is described.

The only pyrido[2,3,4,5-lmn]phenanthridines thus far described have been aryl derivatives. These have been obtained[1,2] in the preparation of the yellow vat dye flavanthrone, and in the synthesis of trypanocidal drugs.[3] An aluminum chloride-sodium chloride melt was used[1,2] to cyclize 2,2'-diphthalimidobiphenyl, although 10-benzamido-5-phenylphenanthridine cyclized readily upon treatment with phosphorus oxychloride in nitrobenzene.[3] The third synthesis employed[3] was the reduction and simultaneous cyclodehydration of 2,2'-diaroyl-6,6'-dinitrobiphenyls. By a modification of the first of these methods, we have now prepared the prototype of this ring system, and its dimethyl homolog.

A few simple modifications of Ullmann's synthesis[4] of 2,2'-dinitrobiphenyl permitted the convenient preparation of quantities of this material in

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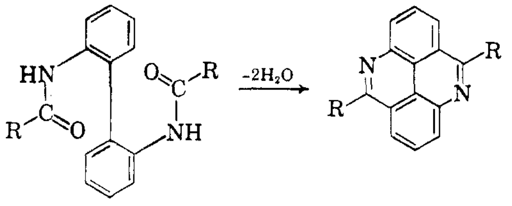
[1] F. Ebel, German Patent **614,196**; *Frdl.*, **22**, 1126 (1939); British Patent **431,790**; U. S. Patent **2,069,473**.

[2] V. Krepela and R. Štefec, *Collection Czechoslav. Chem. Commun.*, **9**, 29 (1937).

[3] A. E. S. Fairfull, D. A. Peak, W. F. Short, and T. I. Watkins, *J. Chem. Soc.*, 4700 (1952).

[4] F. Ullmann and J. Bielecki, *Ber.*, **34**, 2176 (1901).

about 71% yield. Stannous chloride has often[3,5,6] been used to reduce the nitro compound to 2,2′-diaminobiphenyl. Catalytic hydrogenation with palladium charcoal yielded the amine, but a product of better quality resulted from the neutral iron reduction of the dinitrobiphenyl. The diamine was converted to I and II by simply heating it to 150° in an open flask with, respectively, formic acid and acetic anhydride, and the yield and purity of the two products thus obtained were considerably improved over those previously described.



I (R=H)
II (R=CH$_3$)

III (R=H)
IV (R=CH$_3$)

Much time was spent finding conditions suitable for the cyclization of I and II to III and IV. The cyclization of the closely related 1-formamido-2-(2-formamidophenyl)naphthalene (under unspecified conditions) had been reported[7] unsuccessful. Treatment of I with (a) phosphorus oxychloride at 90°; (b) a mixture of phosphorus oxychloride, stannic chloride and nitrobenzene at reflux[8]; (c) polyphosphoric acid at 200° for 1 hr.; (d) an aluminum chloride-pyridine melt at 200° for 2 hr.; (e) an aluminum chloride-chlorobenzene slurry at reflux[9] for 2 hr., and (f) an aluminum chloride-sodium sulfite melt at 250° for 2 hr., each failed to produce detectible quantities of III. The best conditions found for the conversion of I and II to III and IV involve the use of a sodium chloride-aluminum chloride melt at 250° for 2 hr. Even with these conditions the yields are quite poor, and it is evident that the nature (aliphatic *vs.* aromatic, *etc.*) of the acyl group is a major factor in determining the yield of the pyrido[2,3,4,5-*lmn*]phenanthridine produced.

The ultraviolet absorption spectra of III and IV are essentially the same as that of pyrene with the exception that the "α" or "Group III" bands (350–370 mμ) are of much greater intensity than those of pyrene. This phenomenon is often encountered in comparing heterocyclic nuclei to their homocyclic analogs.[10] The curve of IV of course shows the expected slight bathochromic shift with respect to that of III.

Pyrido[2,3,4,5-*lmn*]phenanthridine proved surprisingly resistant to substitution by electrophilic reagents; it could not be nitrated or brominated in sulfuric acid solution although quinoline is readily nitrated[11] under these conditions. Attempts to oxidize III with hydrogen peroxide and a copper salt, conditions under which quinoline is converted to quinolinic acid,[12] were unsuccessful, and III was recovered unchanged.

EXPERIMENTAL[13]

2,2′-Dinitrobiphenyl. In a 3-necked flask equipped with a paddle stirrer, thermometer, and solid-addition funnel was placed 450 g. of 2-nitrochlorobenzene. This was melted and stirred at 240–245° while over a 2 hr. period 450 g. of copper powder (dust) was added in small portions. The mixture was then stirred for 2 hr. more at 250°, cooled somewhat, and poured into two liters of toluene. The solution was filtered, and the solids were washed well with toluene. The combined filtrate and washings were poured onto a 3″ × 18″ column of activated alumina. The first two liters of effluent contained only 6.1 g. of yellow oily impurities and were discarded. Several liters of toluene were then used to elute the product from the column. The eluate was stripped of solvent and the resulting solid was recrystallized once from benzene to give 220 g. (71% yield) of product, m.p. 119–122° (lit.[4] 124°).

2,2′-Diaminobiphenyl. A mixture of 60 g. of iron powder, 30 ml. of water and 2 ml. of acetic acid was stirred and boiled under reflux for 0.25 hr. Then 24.4 g. (0.10 mole) of powdered 2,2′-dinitrobiphenyl was added portionwise. During this addition a little ethanol was occasionally added (a total of 10 ml.). The resulting dark mixture was stirred and boiled under reflux for 5.5 hr., then cooled somewhat and 200 ml. of benzene was added, and the heating and stirring were continued for another hour. When the mixture had cooled, the benzene layer was decanted and the solids were washed well with additional benzene. The combined benzene extracts were dried with anhydrous potassium carbonate, treated with charcoal and filtered. The filtrate was stripped of solvent to give 18.0 g. (97.8% yield) of yellow crystalline product m.p. 75.4–77.6° (lit.[5,6] 79–80, 80–81°).

2,2′-Diformamidobiphenyl (I). A mixture of 92.0 g. of 2,2′-diaminobiphenyl and 80 ml. of 98% formic acid was heated in a flask equipped with a thermometer and a solvent "take-off" condenser. Water and formic acid distilled while the temperature of the residual liquid rose gradually to 150° where it was held for 0.5 hr. The melt was cooled, triturated with ethanol, then filtered and washed with ethanol and dried. The yield of crude product, m.p. 145.8–146.4° was 110.0 g. (91.7%). Two recrystallizations from methanol raised the melting point to 147.2–147.8° (lit.[5] 137°).

Anal. Calcd. for $C_{14}H_{12}N_2O_2$: C, 70.0; H, 5.00; N, 11.68. Found: C, 70.0; H, 4.93; N, 11.6.

2,2′-Diacetamidobiphenyl (II). A mixture of 18.4 g. of 2,2′-diaminobiphenyl, 10 ml. of acetic acid and 20 ml. of acetic anhydride was heated to 150° for 10 min., cooled and tri-

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(5) St. v. Niementowski, *Ber.*, **34**, 3325 (1901).

(6) S. Sako, *Mem. Coll. Eng. Kyushu Imp. Univ.*, **6**, 263 (1932); *Chem. Zentr.*, *I*, 3791 (1937).

(7) W. M. Whaley, M. Meadow, and C. N. Robinson, *J. Org. Chem.*, 19, 973 (1954).

(8) D. W. Ockenden and K. Schofield, *J. Chem. Soc.*, 717 (1953).

(9) J. T. Braunholtz and F. G. Mann, *J. Chem. Soc.*, 3046 (1952).

(10) G. M. Badger, R. S. Pearce, and R. Pettit, *J. Chem. Soc.*, 3199 (1951).

(11) L. F. Fieser and E. B. Hershberg, *J. Am. Chem. Soc.*, 62, 1640 (1940).

(12) A. T. Hawkinson and A. A. Elston, U. S. Patent 2,371,691.

(13) All melting points were taken in Pyrex capillaries, using a Hershberg melting-point apparatus (Ace Scientific Company) and Anschütz thermometers. The ultraviolet spectra of III and IV were measured in ethanol solution with a Cary Automatic Recording Spectrophotometer, Model 10. The curve of pyrene shown was plotted from Jones' data.[14] Inflection points are indicated by asterisks.

(14) R. N. Jones, *J. Am. Chem. Soc.*, **67**, 2127 (1945).

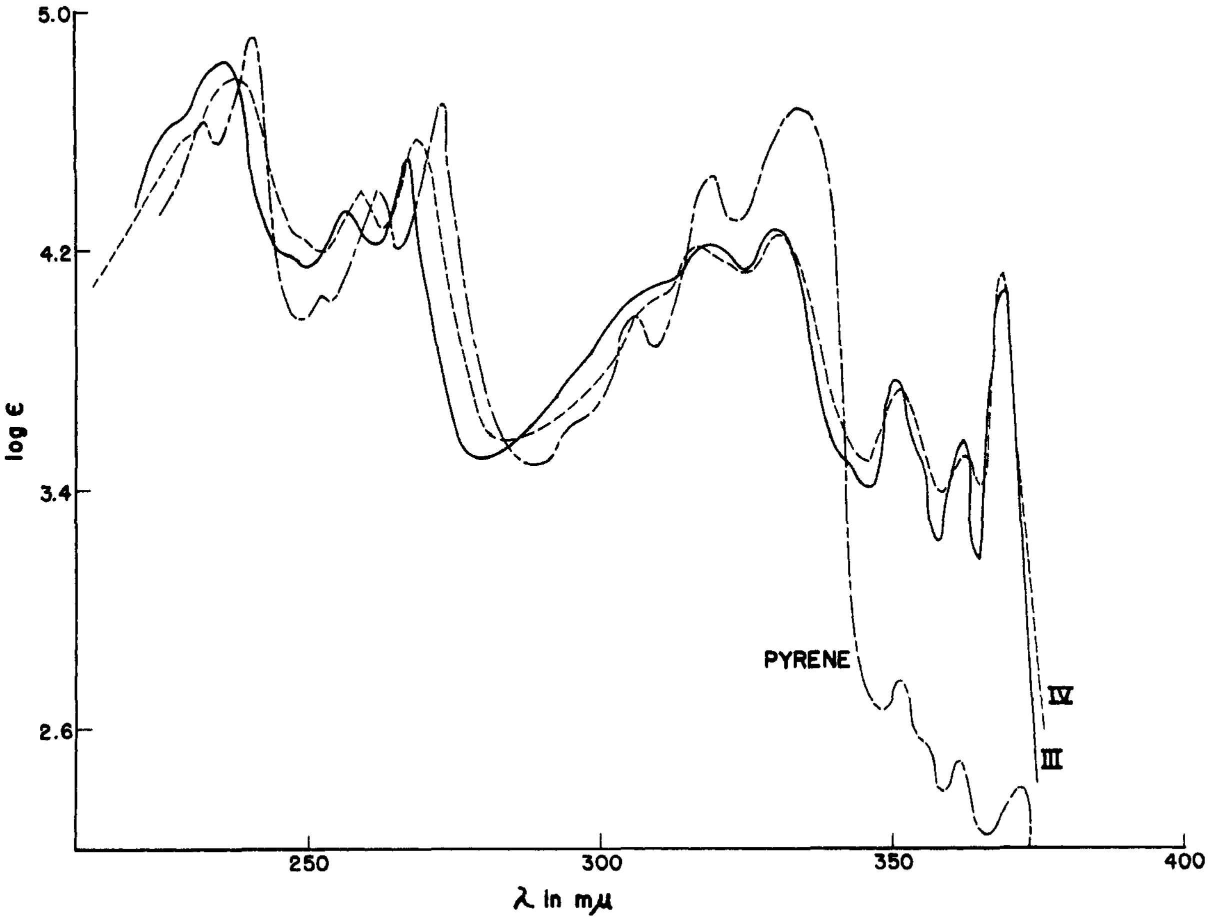

FIG. 1.—ULTRAVIOLET ABSORPTION SPECTRA IN ETHANOL SOLUTION OF: III (——), IV (- - -), AND PYRENE (—-—).

turated with a little methanol. The solid was filtered, washed with methanol and ether and dried, giving 21.5 g. of crude product. Two recrystallizations from benzene gave a product melting at 164.2–165.3° (lit.[15] 161°).

Pyrido[2,3,4,5-lmn]phenanthridine (*III*). A mixture of 35 g. of anhydrous aluminum chloride and 15 g. of sodium chloride was melted and stirred in an oil bath at 250°. In one lot was added 10.0 g. of 2,2′-diformamidobiphenyl and the mixture was stirred for 2 hr. at 250°, then drowned onto ice and hydrochloric acid. The resulting solution was boiled and filtered from a little insoluble matter.

At this point the solution could be worked up in two ways depending upon whether the hydrochloride (A) or picrate (B) was desired.

(*A*) *Hydrochloride.* The original aqueous hydrolysis mixture was concentrated to incipient crystallization and allowed to cool. The product obtained was recrystallized from a very small volume of water, giving, in about 12% yield, orange needles, m.p. 301–2°.

Anal. Calcd. for $C_{14}H_8N_2 \cdot HCl$; N, 11.62; Cl, 14.75. Found: N, 11.7; Cl, 15.0.

(*B*) *Picrate.* The aqueous hydrolysis mixture was concentrated to a volume of about 300 ml. and was treated with an excess of a methanolic solution of picric acid. The resulting precipitate was filtered, washed with methanol and dried, giving 5.48 g. (30.4% yield) of crude picrate, m.p. 226–8°. It could be recrystallized from methanol in orange-red leaves, m.p. 226.8–228.3°.

Anal. Calcd. for $C_{20}H_{11}N_5O_7$; C, 55.5; H, 2.54; N, 16.2; O, 25.8. Found: C, 54.6, 55.1; H, 3.50, 3.02; N, 16.3, 16.4; O, 25.8.

(*C*) *Base.* The base was obtained by recrystallizing the hydrochloride from pyridine, or by basifying aqueous solutions of the salt and recrystallizing the precipitated base from pyridine. It formed very pale yellow needles, m.p. 220.0–220.7°; $\lambda_{max.}$ 227*, 235, 256, 266.5, 311*, 318, 329, 351.5, 364.5, and 371.8 mμ (log ϵ 4.61, 4.83, 4.33, 4.50, 4.10, 4.22, 4.27, 3.77, 3.57, and 4.08).

Anal. Calcd. for $C_{14}H_8N_2$: C, 82.4, H, 3.92; N, 13.72. Found, C, 81.9; H, 3.98; N, 14.1.

5,10-Dimethylpyrido[2,3,4,5-lmn]phenanthridine (*IV*). The same cyclization conditions and isolation technique used to obtain III were applied to II. The crude base was twice recrystallized from pyridine to give a 13% yield of IV, m.p. 260.0–261.4°; $\lambda_{max.}$ 230*, 237, 248*, 258.5, 268, 310*, 316, 320*, 330.5, 352, 364.5, and 371.5 mμ (log ϵ 4.59, 4.78, 4.25, 4.40, 4.58, 4.05, 4.20, 4.19, 4.27, 3.84, 3.52, and 4.13).

Anal. Calcd. for $C_{16}H_{12}N_2$: C, 82.7; H, 5.17; N, 12.07. Found: C, 82.7; H, 5.15; N, 12.1.

The *picrate* appeared less stable than that of III; it charred without melting if put into the melting point bath below 260°, but melted instantaneously at 261.0–261.5°.

Acknowledgment. The author is indebted to Mr. H. X. Kaempfen for valuable technical assistance; to Mr. F. C. Dexter for measuring the ultraviolet spectra, and to Mr. O. E. Sundberg and his associates for the microanalyses.

BOUND BROOK, N. J.

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(15) Tauber, *Ber.*, **24**, 199 (1891).