EXPERIMENTAL

Acetylation of anthracene. (*a*) A mixture of 300 g. of benzene, 54 g. of anthracene and 72 g. of acetyl chloride was stirred at 0°, and 120 g. of powdered aluminum chloride was added in portions, the temperature being maintained at 5–10°. Stirring was continued for a further 2.50 hr. The red complex which had precipitated was collected on a sinter-funnel, washed with dry benzene, and hydrolyzed by adding to a stirred mixture of ice and 5 *N* hydrochloric acid. The benzene extract was washed with water, dried over sodium sulfate, filtered through a short column of alumina, and the filtrate evaporated. The residue was finally heated at 1 mm. and 100°, in order to remove acetophenone, and yielded 36 g. of 9-anthryl methyl ketone, m.p. 76°, on crystallization from benzene.

(*b*) As for (*a*). Stirring was continued for 1 hr., after addition of the aluminum chloride, at 5–10°, and then for 20 hr. at 20°. The product was isolated as in (*a*). The chromatographed mixture was crystallized from benzene, to give 4.2 g. of 2-anthryl methyl ketone, m.p. 185–186°; the mother liquors were evaporated and the residue crystallized from ethyl acetate, giving 22 g. of 1-anthryl methyl ketone, m.p. 105–106°.

Deformylation of 9-anthraldehyde. A solution of 1 g. of 9-anthraldehyde in 18 ml. of glacial acetic acid was treated with 2 ml. of concentrated sulfuric acid, and the mixture refluxed for 80 min., when an aliquot no longer gave a positive test with 2,4-dinitrophenylhydrazine solution, and then diluted with water. The precipitate (0.7 g.) on recrystallization from dilute acetic acid afforded 0.4 g. of anthracene, m.p. and mixed m.p. 210–212°, which on oxidation with chromic acid in glacial acetic acid gave anthraquinone, m.p. and mixed m.p. 282°–283°.

Sodium anthracene 9-sulfonate. Prepared and purified according to the method of Minaev and Fedorov.[7] Treatment of the salt with 3 *N* hydrochloric acid immediately produced, in the cold, some sulfur dioxide. Subsequent boiling produced no further amounts of the gas. The reported formation of anthracene was confirmed, but anthranol could not be detected.

Sodium 9,9'-dianthryl-10-sulfonate was prepared by the method of Minaev and Fedorov.[7] One gram of the salt was boiled for 3.5 hr. with 25 ml. of 4 *N* hydrochloric acid and 20 ml. of acetic acid. The reaction mixture on dilution with water gave 0.7 g. of dianthryl, m.p. 311–312°, after recrystallization from acetic acid.

1-Phenanthryl phenyl ketone. A mixture of 114 ml. of benzoyl chloride and 150 g. of aluminum chloride was heated until a clear solution resulted. The mixture was cooled, 850 ml. of carbon bisulfide was added, and the complex dissolved by stirring. One hundred seventy-five grams of phenanthrene was added to this solution during 20 min. Evolution of hydrogen chloride, at first rapid, ceased after a further 20 min., when the mixture was cooled to 0°. The precipitated complex was collected and decomposed by adding to a mixture of ice and 10 *N* hydrochloric acid. The residual carbon bisulfide was allowed to evaporate, and 38 g. of 1-phenanthryl phenyl ketone, m.p. 141–142°, was collected by filtration. A further crop of 2.4 g. of the ketone was obtained by extracting the above filtrate with chloroform, washing the extract with water, concentrating to 120 ml., adding 50 ml. of ether and setting aside at 0°. The pure ketone, obtained by recrystallization from acetone, had a melting point of 148–149.5° (literature m.p. 148–149°[40,41]).

Acetylation of phenanthrene. Using the method of Mosettig and de Kamp,[38] the reaction mixture being kept at 25°, (*a*) after 6 hr. a 16% yield of 2-phenanthryl methyl ketone, m.p. 142.5–143.5°, and a 62% yield of 3-phenanthryl methyl ketone, m.p. 72.5–73.5°, were obtained by careful fractional crystallization; (*b*) after 17 hr. the yields were 26% and 50%, respectively.

Attempted deacylations. (*a*) *1-Phenanthryl phenyl ketone.* A solution of 1 g. of the ketone in 50 ml. of glacial acetic acid, containing 5 ml. of concentrated sulfuric acid, was refluxed for 4.5 hr., and then poured into water. The product (0.98 g.) was the unchanged ketone, m.p. and mixed m.p. 144–145°.

(*b*) *9-Phenanthraldehyde.* One gram of the aldehyde was treated as in (*a*) for 3.5 hr. The product (0.9 g.) proved to be unchanged aldehyde, m.p. 94°, pure (m.p. and mixed m.p. 100°) after one recrystallization.

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[CONTRIBUTION FROM AVERY LABORATORY, UNIVERSITY OF NEBRASKA]

Naphthyridines. II. Synthesis of 1,7-Naphthyridines by Borsche Synthesis[1,2]

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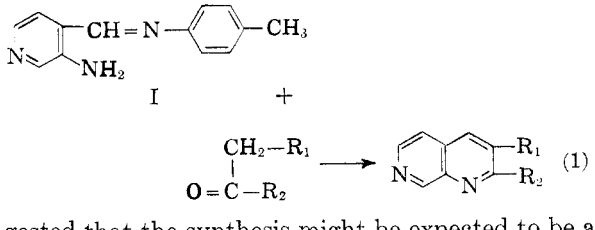
The preparation of six new 1,7-naphthyridines (II–VII) by condensation of the appropriate carbonyl compound with N-(3-amino-4-picolylidene)-*p*-toluidine is described.

In an earlier communication[2] the synthesis of two 1,7-naphthyridines using the Borsche[3] modification of the Friedlander synthesis was reported. The preparative sequence employed consisted of the synthesis of N-(3-amino-4-picolylidene)-*p*-toluidine (I) and the condensation of I with an appropriate carbonyl compound (Equation 1). It was suggested that the synthesis might be expected to be a general one for the preparation of 1,7-naphthyri-



(1)

(1) This work was supported in part by grant G-1090 of the National Science Foundation.

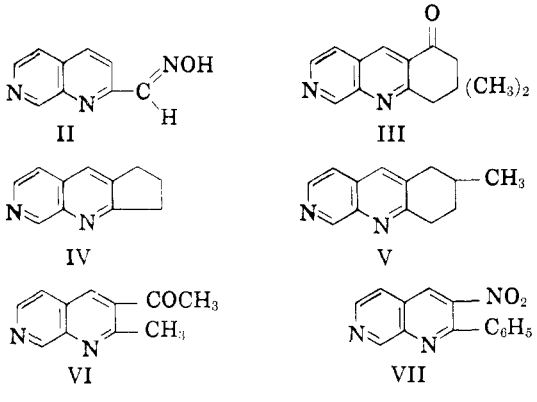
(2) Paper I, Baumgarten and Krieger, *J. Am. Chem. Soc.*, **77**, 2438 (1955).

(3) Borsche, Doeller, and Wagner-Roemich, *Ber.*, **76**, 1099 (1943); Borsche and Barthenhier, *Ann.*, **548**, 50 (1941); Borsche, Wagner-Roemich, and Barthenhier, *Ann.*, **550**, 165 (1942); Borsche and Ried, *Ann.*, **554**, 269 (1943).

dines. We have examined this synthesis further and report here its successful use in the preparation of six new 1,7-naphthyridines. Several modifications made in the synthesis of I are described in the Experimental section.

The condensation of I with isonitrosoacetone gave 1,7-naphthyridine-2-aldoxime (II) in 56% yield. From the condensation of dimethyldihydroresorcinol (methone) with I, 2,9-diaza-6,8-dihydro-7,7-dimethyl-5-oxoanthracene (III) was obtained in 20% yield. With cyclopentanone and *p*-methylcyclohexanone, I gave 7,9-diazabenz[f]indane (IV) and 2,9-diaza-5,6,7,8-tetrahydro-6-methylanthracene (V) in 56% and 58% yields, respectively. From acetylacetone and I, 2-methyl-3-acetyl-1,7-naphthyridine (VI) was obtained in 16% yield. The conditions used in each of these reactions were essentially the same as those described by Borsche[3] for the synthesis of quinoline derivatives.

Other experiments[4] in progress in this laboratory have shown that 2-aryl-3-nitroquinolines may be prepared in good yields by the reaction between ω-nitroacetophenones with *o*-aminobenzaldehyde or with *o*-aminobenzaltoluidine. The reaction between I and ω-nitroacetophenone gave 3-nitro-2-phenyl-1,7-naphthyridine (VII) but only in very low yield (10%).



The success of the Borsche procedure in the examples described here, which were selected to cover a reasonably large range of diverse structures, suggests that this synthesis should show the same generality of application as that shown by the well studied Borsche quinoline synthesis. The principal limitation of the method as applied to 1,7-naphthyridines appears to be the low yields encountered in the preparation of I.

EXPERIMENTAL[5]

N-(3-Amino-4-picolylidene)-p-toluidine (I) was prepared as described previously[2,6] from 2-amino-4-picoline with modifications in the individual steps as outlined in the following sections.

3- and 5-Nitro-2-chloro-4-picoline. A mixture of 113 g. (0.73 mole) of the crude mixed 3- and 5-nitro-2-hydroxy-4-picolines,[6] 125 ml. of phosphorus oxychloride and 20 g. of phosphorus pentachloride was heated to 110–120° in an oil bath for 4 hr. The mixture was cooled and poured slowly into ice water with stirring. When the hydrolysis of the excess phosphorus oxychloride was complete, the chloro compound was steam distilled from the acidic hydrolysis mixture. The distillate was extracted with ether. The ethereal solution was dried over magnesium sulfate, filtered, and evaporated on the steam bath. The residual mixture of 3- and 5-nitro-2-chloro-4-picoline, 111 g. (90%), was satisfactory for use in the following reaction. In other experiments the yields ranged from 80–95%, about 30% higher than reported earlier.

3-Nitro-4-picoline. A mixture of 64 g. (0.37 mole) of the crude mixed chloronitropicolines and 120 ml. of glacial acetic acid was stirred and heated to boiling under reflux using a wire gauze and a burner. Heating was continued while 100 g. (1.57 mole) of copper powder (Baker, purified) was added in portions over a period of 30 min. and until the mixture became too thick to stir (usually after an additional 15 min.). The setup was rearranged for steam distillation and the product was isolated as described previously[6] (4 l. of steam distillate being collected). The yield of 3-nitro-4-picoline hydrochloride was 25 g. (39%), m.p. 180–182°. In other experiments the yields ranged from 30–40%. These yields were as good as those obtained using benzoic acid and the operation was simpler.[7]

3-Nitro-4-pyridinecarboxaldehyde dihydrate. In a large number of experiments following our earlier procedure[2] the yields of recrystallized 3-nitro-4-pyridinecarboxaldehyde dihydrate, m.p. 91–93°, were in the range of 18–25%. An approximately equivalent amount of aldehyde remained in the mother liquors, as indicated by assay with 2,4-dinitrophenylhydrazine, but was not readily recovered on a small run.

N-(3-Amino-4-picolylidene)-p-toluidine. After trying many alternative procedures the following method has been adopted as giving the highest yields of very nearly pure product with a minimum of manipulation.[8] A solution of 0.75 g. (0.004 mole) of 3-nitro-4-pyridinecarboxaldehyde dihydrate and 0.43 g. (0.004 mole) of *p*-toluidine in 4 ml. of 95% ethanol was heated under reflux for 1 hr. Meanwhile solutions of 1.33 g. (0.0079 mole) of sodium sulfide pentahydrate and of 0.67 g. (0.0079 mole) of sodium bicarbonate in the minimum amounts of water were mixed and diluted with an equal volume of 95% ethanol. After 30 min. the solution was filtered. The aqueous-ethanolic solution of

(4) Baumgarten and Saylor, in press.

(5) Melting points are corrected. Microanalyses by Clark Microanalytical Laboratory, Urbana, Ill., and by Micro-Tech Laboratories, Skokie, Ill.

(6) Baumgarten, Su, and Krieger, *J. Am. Chem. Soc.*, **76**, 596 (1954).

(7) E. V. Brown (*J. Am. Chem. Soc.*, **76**, 3167 (1954)) has reported obtaining a 70% yield of 3-nitro-4-picoline by the action of copper and benzoic acid on pure 2-chloro-3-nitro-4-picoline. Unfortunately, Brown did not report any physical data to support the identity or purity of his product. Following his directions we obtained an apparent yield of 70% also; however, the product was found to be only 50% pure. As far as we are able to determine there is no advantage to be gained by separating the isomeric chloro compounds prior to the dechlorination and the separation (by steam distillation of the amino precursors of the chloro compounds) is tedious.

(8) We have been unable to duplicate our original yield of 77% of this material. In our original experiments[6] an ancient sample of sodium sulfide nonahydrate of dubious purity was used. Unfortunately, this material was discarded when fresh sodium sulfide pentahydrate became available to us. We have not been able to determine whether or not our original yield, which our records demonstrate to be real and not fancied, was made possible by the composition of the old sodium sulfide. This point is being studied further.

sodium hydrogen sulfide[9] was added to the hot solution above. On cooling and addition of water N-(3-amino-4-picolylidene)-*p*-toluidine was precipitated and was collected and air-dried, giving 0.42 g. (50%) of material melting at 153–154°.[10] Normally the product was pale yellow in color and did not require further purification.

1,7-Naphthyridine-2-aldoxime (II). A solution of 1.28 g. (0.0060 mole) of N-(3-amino-4-picolylidene)-*p*-toluidine and 0.55 g. (0.0063 mole) of isonitrosoacetone in 12 ml. of ethanol and 3.0 ml. of 50% potassium hydroxide was heated for 6 hr. under reflux. The reaction mixture was steam distilled to remove the ethanol and *p*-toluidine. The solution was filtered and made acidic with acetic acid to precipitate the oxime. The crude, dried oxime, 0.89 g., m.p. 235–245°, was recrystallized from ethanol (charcoal) giving 0.5 g. (56%) of 1,7-naphthyridine-2-aldoxime, m.p. 245–246°, as a pale yellow powder.

Anal. Calcd. for $C_9H_7N_3O$: C, 62.42; H, 4.07; N, 24.27. Found: C, 62.50; H, 3.98; N, 24.31.

2,9-Diaza-6,8-dihydro-7,7-dimethyl-5-oxoanthracene (III). A mixture of 0.21 g. (0.001 mole) of N-(3-amino-4-picolylidene)-*p*-toluidine, 0.14 g. (0.001 mole) of dimethyldihydroresorcinol and three drops of piperidine was heated on the steam bath for 8 hr. After cooling, the brown mass was pulverized and extracted with ether. Evaporation of the ether gave 0.16 g. (71%) of crude product, m.p. 140–152°. After 4 recrystallizations from Skellysolve C,[11] 45 mg. (20%) of 2,9-diaza-6,8-dihydro-7,7-dimethyl-5-oxoanthracene, m.p. 152–155°, was obtained as colorless flakes.

Anal. Calcd. for $C_{14}H_{14}N_2O$: C, 74.31; H, 6.24; N, 12.38. Found: C, 74.23; H, 6.00; N, 12.15.

7,9-Diazabenz[f]indane (IV). A solution of 0.465 g. (0.0022 mole) of N-(3-amino-4-picolylidene)-*p*-toluidine and 0.185 g. (0.0022 mole) of cyclopentanone in 5 ml. of ethanol and 1.5 ml. of 2*N* sodium hydroxide solution was heated for 6 hr. on the steam bath. The ethanol and *p*-toluidine were removed by steam distillation. After cooling the solution, the naphthyridine was filtered off and air-dried, giving 0.345 g. (92%) of crude product, m.p. 80–84°. After 1 recrystallization from Skellysolve C[11] the colorless needles of 7,9-diazabenz[f]indane, 0.210 g. (56%), melted at 86–87°.

Anal. Calcd. for $C_{11}H_{10}N_2$: C, 77.62; H, 5.92; N, 16.46. Found: C, 77.92; H, 5.80; N, 16.62.

2,9-Diaza-5,6,7,8-tetrahydro-6-methylanthracene. (V). A solution of 0.53 g. (0.0025 mole) of N-(3-amino-4-picolylidene)-*p*-toluidine and 0.27 g. (0.0025 mole) of 4-methylcyclohexanone in 6 ml. of ethanol and 2 ml. of 2*N* sodium hydroxide solution was heated on the steam bath for 6 hr. The ethanol and *p*-toluidine were removed by steam distillation, and the naphthyridine was extracted from the residue with ether. Evaporation of the ether gave 0.36 g. (76%) of crude product, m.p. 82–86°. After 2 recrystallizations from Skellysolve C,[11] 0.275 g. (58%) of 2,8-diaza-5,6,7,8-tetrahydro-6-methylanthracene, m.p. 86–88°, was obtained as colorless needles.

Anal. Calcd. for $C_{13}H_{14}N_2$: C, 78.75; H, 7.12; N, 14.13. Found: C, 78.73; H, 7.11; N, 13.85.

2-Methyl-3-acetyl-1,7-naphthyridine (VI). A mixture of 0.211 g. (0.001 mole) of N-(3-amino-4-picolylidene)-*p*-toluidine, 0.100 g. (0.001 mole) of acetylacetone and 3 drops of piperidine was heated on the steam bath for 8 hr. After cooling, the brown mass was pulverized and extracted with ether. Evaporation of the ether gave 0.11 g. (59%) of crude product, m.p. 102–106°. After two recrystallizations from water (8 ml./0.1 g.), 0.03 g. (16%) of 2-methyl-3-acetyl-1,7-naphthyridine (colorless needles), m.p. 112–113.5°, was obtained.

Anal. Calcd. for $C_{11}H_{10}N_2O$: C, 70.95; H, 5.41; N, 15.05. Found: C, 71.41; H, 5.55; N, 15.31.

3-Nitro-2-phenyl-1,7-naphthyridine (VII). A solution of 0.211 g. (0.001 mole) of N-(3-amino-4-picolylidene)-*p*-toluidine and 0.166 g. (0.001 mole) of ω-nitroacetophenone in 2 ml. of absolute ethanol was heated under reflux for 2 hr. The cooled solution was diluted with water and extracted with ether. The ethereal solution was dried over magnesium sulfate, filtered, and evaporated under reduced pressure. The resultant red oil was recrystallized from Skellysolve C[11] to yield 0.025 g. (10%) of 3-nitro-2-phenyl-1,7-naphthyridine (yellow prisms), m.p. 120–121°.

Anal. Calcd. for $C_{14}H_9N_3O_2$: C, 66.93; H, 3.61; N, 16.72. Found: C, 67.13; H, 3.60; N, 16.31.

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(9) Hodgson and Ward, *J. Chem. Soc.*, 242 (1948).

(10) In the earlier paper[2] both the crude and purified materials were reported to melt at 146–148°. This was a typographical error on our part for the analytical sample actually melted at 152–153°.

(11) A hydrocarbon solvent, b.p. 88–98°.

[CONTRIBUTION FROM THE CONVERSE MEMORIAL LABORATORY, HARVARD UNIVERSITY]

Substituted Biphenyls by Action of Benzoyl Chloride on Some β-Aroylpropionic Acids

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The reaction of three β-aroylpropionic acids with benzoyl chloride is shown to give substituted phthalides in the biphenyl series. The ultraviolet and infrared spectra of these products and some related biphenyls are discussed.

The reaction of β-benzoylpropionic acid with benzoyl chloride was reported by Kugel[1] to yield an unidentified alkali-stable compound which had the empirical formula $C_{20}H_{14}O_3$. The structure of this product has now been investigated and the reaction extended to other β-aroylpropionic acids.

In our hands, this reaction produced a low yield of a product that had a melting point slightly higher than that of Kugel's compound. Combustion and molecular weight data required a revision of the earlier formula to $C_{27}H_{18}O_4$. The implicit stoichiometry, which can be represented as 2 $C_6H_5COCH_2CH_2COOH + C_6H_5COCl \rightarrow C_{27}H_{18}O_4 + HCl + 3H_2O$, was supported by the extension of the reaction to β-*p*-methoxybenzoyl- and β-*p*-chlorobenzoylpropionic acids to give similar condensation

(1) Kugel, *Ann.*, 299, 61 (1898).