TABLE III

CHROMATOGRAPHIC RETENTION VOLUMES OF PYRIDINE BASES

| Compound | Retention Volume[a] |
|---|---|
| α-Picoline | 0.26 |
| 2-Methyl-6-ethylpyridine | 0.35 |
| 2,5-Dimethylpyridine | 0.44 |
| 2-Methyl-6-vinylpyridine | 0.63 |
| 2-Methyl-5-ethylpyridine | 0.69 |
| 2-Methyl-4-ethylpyridine | 0.80 |
| 2-Methyl-5-vinylpyridine | 1.00 |
| 2-Methyl-4-vinylpyridine | 1.37 |

[a] Temp. = 130°; support = polyethylene glycol 400 (C. Erba, Milan), 28% on Celite.

pyridine, the other products being α-picoline, pyridine, etc.

2-Methyl-6-vinylpyridine was identified by molecular weight (mass spectrometry) (calcd., 119; found, 119), picrate (methanol, m.p., 160° (lit.[2] m.p., 160.5°) b.p., 72°/21 mm. (lit.[2] b.p., 73°/21 mm.).

2-Methyl-6-ethylpyridine was produced by hydrogenation in ethanol; the catalyst was palladium on carbon.

The infrared spectrum in the sodium chloride region coincides with the one already given in the literature.[14]

*2-Methyl-4-vinylpyridine.* From the chromatogram of the dehydrogenated fraction II, the peak with a 1.37 retention volume was identified as 2-methyl-4-vinylpyridine (conversion on 2-methyl-4-ethylpyridine, 40%). The product, separated with great purity from the chromatographic column, formed a picrate (methanol) which melted at 166.5–167.5°, $n_D^{20}$ 1.5410, and b.p. 76–77°/20 mm. Its molecular weight (mass spectrometry) is 119 (calcd. for $C_8H_9N$, 119).

*Anal.* Calcd. for $C_8H_9N$: N, 11.76. Found: N, 11.6.

The product, hydrogenated in ethanol, catalyst palladium on carbon, absorbed hydrogen, g. 1.65/100 g. (calcd. for $C_8H_9N$, 1.68), giving 2-methyl-4-ethylpyridine.

The permanganate oxidation gave 2,4-pyridinedicarboxylic acid, identified by paper chromatography.[15]

*Infrared.* Infrared spectra were determined with Perkin-Elmer model 21, from 2.5–15 μ with sodium chloride prism, and from 12–24.5 μ with potassium bromide prism; 0.05-mm. cells were used in both cases.

Spectra were measured immediately after the chromatographic separation. The 3450-cm.$^{-1}$ band is due to atmospheric moisture, which condensed on the walls of the Dry Ice–cooled trap, in which the chromatographic fractions were collected.

*Ultraviolet.* Spectra were determined from 350–220 mμ with a Spectracord Model 4000A, with 1-cm. silica cells.

The pyridine bases were examined in methanolic solutions, and in aqueous solutions of hydrochloric acid and sodium hydroxide at different *p*H values, in concentration of 0.12 mmole/l. (2-methyl-6-vinylpyridine) and 0.1 mmole/l. (2-methyl-4-vinylpyridine).

*Acknowledgment.* The authors are indebted to Dr. L. Biasin of this laboratory for the chromatographic analyses and separations.

BOLLATE 2, ITALY

(14) *Sadtler Standard Spectra*, Midget Ed., 1959.

(15) F. Kufner and N. Faderl, *Monatsh.*, **86**, 955 (1955).

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[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT, TEMPLE UNIVERSITY]

# Further Preparation of Substituted 2,6-Bis(2′-pyridyl)pyridines[1]

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The preparation of some substituted terpyridines by the condensation of 2-acetylpyridine with aromatic aldehydes and ammonia is described. This procedure failed to provide the desired terpyridines when aliphatic aldehydes or acylpyridines other than acetyl were employed. A new route to unsubstituted 2,6-bis(2′-pyridyl)pyridine is described.

The effect of nuclear substituents upon the molecular extinction coefficient and oxidation potential of 1,10-phenanthroline- and 2,2′-bipyridine-iron(II) complexes has received considerable attention.[2] Analogous effects should be observable in the case of 2,6-bis(2′-pyridyl)pyridine-iron(II) complexes but preparative difficulties encountered in the terpyridine series have curtailed inquiry into this point.

2,6-Bis(2′-pyridyl)pyridine has been prepared by dehydrogenation of pyridine[3] and by coupling of bromopyridines.[4] Both these methods are of limited applicability because of the rigorous conditions of reaction and the complexity of products. Frank and Riener[5] demonstrated that benzaldehyde and 2-acetylpyridine undergo cyclization with ammonia to provide 2,6-bis(2′-pyridyl)-4-phenylpyridine. This procedure (Method A, Experimental) was employed in previous work[6] to prepare a number of symmetrically substituted terpyridines. However, only benzaldehyde and 2-acetylpyridine bearing simple alkyl substituents were used. In order to study the scope of this reaction further, a number of variously substituted 2-acylpyridines was required. Their preparation was accomplished by converting the appropriate

(1) This work was supported by a grant (G 2162) from the National Science Foundation.

(2) W. W. Brandt, F. P. Dwyer, and E. C. Gyarfas, *Chem. Revs.*, **54**, 959 (1954).

(3) G. T. Morgan and F. H. Burstall, *J. Chem. Soc.*, 20 (1932).

(4) F. H. Burstall, *J. Chem. Soc.*, 1664 (1938).

(5) R. L. Frank and E. F. Riener, *J. Am. Chem. Soc.*, **72**, 4182 (1950).

(6) F. H. Case and T. J. Kasper, *J. Am. Chem. Soc.*, **78**, 5842 (1956).

2-aminopyridines to the 2-cyano analogs which were then treated with an alkylmagnesium halide.

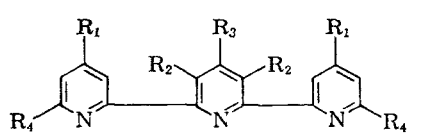
The requisite 2-aminopyridines resulted from the action of sodium amide on the corresponding pyridines. 2,4-Dimethylpyridine and 4-*n*-amylpyridine reacted normally but two moles of sodium amide were required with 4-benzylpyridine. In the latter case the first mole of sodium amide was consumed by the formation of a sodium derivative at the active methylene linkage. Subsequent attack in the normal manner provided the 2-amino derivative. This reaction sequence is supported by the facts that a large quantity of ammonia was evolved during the initial reaction and that one mole of sodium amide produced a high-melting solid which reacted vigorously with water to regenerate the unchanged base.

The 2-aminopyridines, upon diazotization, gave the bromo derivatives which reacted with cuprous cyanide to form the 2-cyano analogs. The reactions of the 2-cyanopyridines with appropriate Grignard reagents proceeded normally and provided the desired 2-acylpyridines. It was noted that the product obtained from the reaction of 2-cyanopyridine and benzylmagnesium chloride according to the directions of Nakashima[7] differed from that reported by Bachman and Schisla[8] as benzyl pyridyl ketone obtained from the bimolecular reduction of pyridine and methyl phenylacetate. In view of the drastic conditions of the reduction, it seems likely that a structural isomer of the acylpyridine resulted in that case.

A different series of reactions was employed for the preparation of 2-acetyl-4-methoxypyridine. The reactive halogen of methyl 4-chloropicolinate was readily displaced by sodium methoxide and the resulting methoxy analog condensed with ethyl acetate to afford ethyl 4-methoxypicolinoylacetate. This ketonic ester was cleaved by acid to provide the desired product.

The condensation of the 2-acylpyridines, benzaldehyde, and ammonia proceeded normally with simple alkyl substituents on the pyridine nucleus ($R_1 = R_4 = CH_3$—, $R_2 = H$, $R_3 = C_6H_5$—) and ($R_1 = n\text{-}C_5H_{11}$—, $R_2 = R_4 = H$, $R_3 = C_6H_5$—).

$$2\,R_1R_4C_5H_2NCOCH_2R_2 + R_3CHO + NH_3 \rightarrow$$



When more complex substituents were present ($R_1 = C_6H_5CH_2$— or $CH_3O$—, $R_2 = R_4 = H$, $R_3 = C_6H_5$—) or when higher acylpyridines were employed ($R_1 = R_4 = H$, $R_2 = CH_3$— or $C_6H_5$—, $R_3 = C_6H_5$—), a solid product could not be isolated from the complex reaction mixtures. 4-Methoxybenzaldehyde reacted normally ($R_1 = R_2 = R_4 = H$, $R_3 = CH_3OC_6H_4$—) but pyridine-2- and 4-carboxaldehyde ($R_1 = R_2 = R_4 = H$, $R_3 = C_5H_4N$—) gave high melting crystalline solids which were not identified. Aliphatic aldehydes selected for their resistance to aldol type condensations ($R_1 = R_2 = R_4 = H$, $R_3 = Cl_3C$—, $(CH_3)_2$-CH—, or $CH_3O$—), produced complex oils from which a solid product could not be isolated.

Weiss[9] has described the preparation of several substituted pyridines from carbonyl compounds and ammonia by refluxing a solution of the reactants in acetamide. Although 2-acetylpyridine and benzaldehyde ($R_1 = R_2 = R_4 = H$, $R_3 = C_6H_5$—) formed a terpyridine under these conditions (Method B, Experimental), this modification offered no particular advantage when applied to the other cases described above. In several instances, however, the primary condensation product of the aldehyde and the ketone was isolated. Thus, from the reaction of benzaldehyde and 2-propionylpyridine, a fair yield of benzylidinebis-(2-propionylpyridine) was obtained.

The method which utilizes 1,5-diketones as starting materials is perhaps the most general manner of synthesizing specific substituted pyridines. Its most widely used application is that due to Hantzsch[10] in which a $\beta$-ketonic ester and an aldehyde are condensed followed by cyclization with ammonia. This procedure was adapted to the preparation of 2,6-bis(2′-pyridyl)pyridine with excellent results. The condensation product resulting from the reaction of formaldehyde and ethyl picolinoylacetate reacted with ammonia to furnish a cyclic dihydro base. Nitrous acid smoothly oxidized this intermediate to 2,6-bis(2′-pyridyl)-3,5-dicarbethoxypyridine. Saponification and subsequent decarboxylation of this ester provided an excellent yield of almost pure 2,6-bis(2′-pyridyl)-pyridine.

The over-all yield of 2,6-bis(2′-pyridyl)pyridine (30% based on ethyl picolinoylacetate) compares very favorably with that obtained from the dehydrogenation of pyridine (7%)[1] and by coupling of bromopyridines (7%).[2] In addition, the product is free from bipyridines, isomeric terpyridines, and higher polypyridines which complicate its purification when these other procedures are used. The method also provides a degree of flexibility which may allow the preparation of a variety of substituted products.

The hitherto undescribed picolinoylacetonitrile was prepared with a view to its use in the above

(7) T. Nakashima, *Yakugaku Zasshi*, **77**, 1298 (1957); *Chem. Abstr.*, **52**, 6345g (1958).

(8) G. B. Bachman and R. M. Schisla, *J. Org. Chem.*, **22**, 1302 (1957).

(9) M. Weiss, *J. Am. Chem. Soc.*, **74**, 200 (1952).

(10) Reviewed in detail by C. Hollins, *Synthesis of Nitrogen Ring Compounds*, D. Van Nostrand Co., London, 1924, pp. 227–231.

type of reaction, but when this was attempted no definite reaction products could be isolated.

## EXPERIMENTAL

*2-Amino-4-n-amylpyridine.* A suspension of 46.8 g. (1.2 moles) of sodium amide in 149 g. (1.0 mole) of 4-amylpyridine and 266 g. (2.2 moles) of *N,N*-dimethylaniline was heated at 140–150° with agitation for 6 hr. The resulting purple solution was cooled and poured on 300 g. of chopped ice. The oily layer was separated and the solvent removed. Distillation of the residual oil *in vacuo* provided 96 g. (60%) of a fraction boiling at 161° (20 mm.) which solidified on cooling. An analytical sample was recrystallized from petroleum ether (b.p. 90–100°) yielding sparkling plates, m.p. 58.0–58.5°.

*Anal.* Calcd. for $C_{10}H_{16}N_2$: C, 73.12; H, 9.82. Found: C, 73.53; H, 9.87.

*2-Bromo-4-n-amylpyridine.* The procedure was essentially that described[11] for the preparation of 2-bromopyridine. The fraction boiling at 135–145° was collected and redistilled through a 6-in. Vigreux column to provide 104 g. (76%) of pale yellow oil, b.p. 122–123° (4 mm.).

*Anal.* Calcd. for $C_{10}H_{14}BrN$: C, 52.65; H, 6.18. Found: C, 53.31; H, 6.17.

*2-Cyano-4-n-amylpyridine.* A suspension of 11.7 g. (0.13 mole) of cuprous cyanide in 27.3 g. (0.12 mole) of 2-bromo-4-*n*-amylpyridine and 10.3 g. (0.13 mole) of pyridine was heated at 135–140° for 1.5 hr. with agitation. The resulting brown oil was cooled to 60° and 60 ml. of concd. aqueous ammonia was added. After further cooling, the mixture was extracted with ether and the extract was dried over sodium sulfate. Following removal of the solvent, the residual oil was distilled *in vacuo* to provide 17.5 g. (85%) of pale yellow oil, b.p. 133° (4 mm.).

*Anal.* Calcd. for $C_{11}H_{14}N_2$: C, 75.83; H, 8.09. Found: C, 75.45; H, 8.02.

*2-Acetyl-4-n-amylpyridine.* A procedure similar to that described previously[6] for the preparation of 2-acetyl-4-methylpyridine was employed. A solution of 17.4 g. (0.1 mole) of 2-cyano-4-*n*-amylpyridine in 100 ml. of dry benzene was added dropwise, with stirring, to excess methylmagnesium iodide (from 35.5 g. of methyl iodide and 6.1 g. of magnesium) in 100 ml. of ether. The temperature was kept below 5° during the addition. Excess ammonium chloride solution was added, the oily layer was separated, and the aqueous portion was extracted twice with benzene. The combined ether and benzene solutions were dried over sodium sulfate and the solvent was recovered. Upon distillation, the residual oil furnished 9.0 g. (47%) of colorless oil, b.p. 112–114° (3 mm.); semicarbazone, needles from ethanol water, m.p. 152–153°.

*Anal.* Calcd. for $C_{11}H_{20}N_4O$: C, 62.87; H, 8.12. Found: C, 62.64; H, 8.02.

*2-Acetyl-4,6-dimethylpyridine.* A similar sequence of reactions was used to prepare 2-acetyl-4,6-dimethylpyridine from the corresponding dimethylpyridine. From 9.9 g. of 2-cyano-4,6-dimethylpyridine (m.p. 52–53°, lit.[12] 53°) was obtained 4.8 g. (43%) of the 2-acetyl derivative. The product was a pale yellow oil, b.p. 78–79° (1 mm.); semicarbazone, m.p. 200–200.5°.

*Anal.* Calcd. for $C_{10}H_{14}N_4O$: C, 58.23; H, 6.84. Found: C, 58.03; H, 6.82.

*2-Amino-4-benzylpyridine.* When 4-benzylpyridine was subjected to the action of sodium amide as outlined in the preparation of 2-amino-4-*n*-amylpyridine, a violent exothermic reaction ensued. A large quantity of ammonia was evolved and a dark oil separated at the bottom of the reaction vessel. This oil solidified on cooling and reacted vigorously with water to regenerate the starting material.

In another experiment, over twice the theoretical amount of sodium amide was employed. A suspension of 117 g. (3.0 moles) of sodium amide in 200 g. (1.2 moles) of 4-benzylpyridine and 411 g. (3.4 moles) of *N,N*-dimethylaniline was heated at 140° for 16 hr. with stirring. A dark oil separated as before and solidified on cooling. The supernatant liquid was decanted and the black solid was cautiously hydrolyzed with warm water. A bright yellow oil resulted which was separated from the aqueous portion and distilled. Following the recovery of 120 g. (60%) of starting material, 47 g. (58%) of a fraction boiling at 155–158° (3 mm.) was collected. The oil solidified on cooling. An analytical sample was recrystallized from petroleum ether yielding silvery plates, m.p. 103.5–104.0°.

*Anal.* Calcd. for $C_{12}H_{12}N_2$: C, 78.22; H, 6.53. Found: C, 78.08; H, 6.42.

*2-Acetyl-4-benzylpyridine.* When 18.4 g. of 2-amino-4-benzylpyridine was subjected to the procedure referred to under 2-bromo-4-*n*-amylpyridine, 15.0 g. of pale yellow oil, b.p. 151–153° (2 mm.), was obtained. Repeated fractionation of this oil failed to provide an analytically pure sample of 2-bromo-4-benzylpyridine. The combined product from two such experiments was treated with cuprous cyanide in the same manner as described for the preparation of the 4-*n*-amyl analog. The resulting yellow liquid (12.5 g.), b.p. 165–167° (3 mm.) was free of halogen.

This oil, presumably crude 2-cyano-4-benzylpyridine, was converted to the 2-acetyl derivative by the usual procedure. The fraction boiling at 149–151° (3 mm.) amounted to 5.1 g. (24% based on 2-amino-4-benzylpyridine). A semicarbazone was prepared, m.p. 198–199°.

*Anal.* Calcd. for $C_{15}H_{16}N_4O$: C, 67.14; H, 6.01. Found: C, 66.71; H, 6.00.

*Methyl 4-methoxypicolinate.* To a solution of sodium methoxide prepared from 3.2 g. of sodium dissolved in 200 ml. of methanol was added 24 g. of methyl 4-chloropicolinate.[13] The solution was refluxed for 6 hr., cooled, and filtered free of sodium chloride. The methanol was carefully evaporated and the residue extracted with several small portions of benzene. The extract was distilled and the fraction boiling at 120–123° (2 mm.) was collected. The distillate solidified on cooling and was recrystallized from benzene–petroleum ether to yield 15.5 g. (66%) of colorless needles melting at 49–50°.

*Anal.* Calcd. for $C_8H_9NO_3$: C, 57.48; H, 5.43. Found: C, 57.61; H, 5.46.

*2-Acetyl-4-methoxypyridine.* A solution of 15 g. (0.09 mole) of methyl 4-methoxypicolinate in 15 g. (0.18 mole) of methyl acetate was added dropwise to a suspension of 8.1 g. (0.15 mole) of sodium methoxide in 100 ml. of gently refluxing benzene. A yellow paste resulted which was kept at incipient reflux temperature for 6 hr. The cooled mixture was filtered and the solid sodium salt was suspended in 100 ml. of water. A 17-ml. portion of concentrated hydrochloric acid was added, and the solution was refluxed for 2 hr. Upon addition of excess sodium bicarbonate, a tan solid precipitated which was separated by filtration. The solid and the filtrate were both extracted with three 50-ml. portions of diethyl ether. The combined extracts were dried over sodium sulfate and the ether was removed. Upon recrystallization, the residual oil afforded 5.2 g. (38%) of colorless plates, m.p. 58.5–59.0°.

*Anal.* Calcd. for $C_8H_9NO_2$: C, 63.53; H, 6.00. Found: C, 63.25; H, 6.21.

The semicarbazone melted at 215–216°.

*2-Phenacetylpyridine.* A solution of 18.7 g. (0.18 mole) of 2-cyanopyridine in 100 ml. of diethyl ether was added to a stirred solution of 0.18 mole of benzylmagnesium chloride (from 22.8 g. of benzyl chloride and 4.4 g. of magnesium)

(11) C. F. Allen and J. Thirtle, *Org. Syntheses*, Coll. Vol. III, 136 (1955).

(12) T. M. Robinson and G. J. Janz, U. S. Patent 2,494,204; *Chem. Abstr.*, 44, 7353f (1950).

(13) H. Mosher and M. Look, *J. Org. Chem.*, 20, 283 (1955).

in 200 ml. of ether at a rate sufficient to maintain gentle refluxing. After standing overnight, 200 ml. of 20% aqueous ammonium chloride and 50 ml. of concentrated hydrochloric acid were added. The mixture was filtered and the yellow precipitate stirred into a solution of sodium bicarbonate in excess. The resulting oil was separated from the aqueous portion and distilled. A fraction boiling at 142–145° (2 mm.) [lit[7]. 138–142° (2 mm.)] was collected. Yield: 15.8 g. (45%); semicarbazone, m.p. 151–152°.

*Anal.* Calcd. for $C_{14}H_{14}N_4O$: C, 66.10; H, 5.55. Found: C, 66.40; H, 5.65.

*Terpyridines: Method A.* An appropriately substituted 2-acylpyridine, an aldehyde, ammonium acetate, and 28% aqueous ammonia (1, 0.5, 0.1, and 4*M* proportions, respectively) were sealed in a Pyrex tube and heated at 250–300° for 4–5 hr. The oil which resulted was dissolved in a minimum quantity of petroleum ether (with addition of benzene if very difficultly soluble) and the solution was poured onto an 8-in. column of 1-in. diameter containing Alcoa F-12 activated alumina. The column was eluted with the original solvent followed by benzene, chloroform, and ethanol in that order. The eluent was collected in 100-ml. fractions which were then evaporated to dryness. Most of the solid product was usually isolated from the early benzene fractions.

*2,6-Bis(4',6'-dimethyl-2'-pyridyl)-4-phenylpyridine.* From 4.5 g. of 6-acetyl-2,4-dimethylpyridine and 1.6 g. of benzaldehyde, using method A, was obtained a crude yellow solid which was recrystallized from petroleum ether to give 0.63 g. (12%) of colorless prisms, m.p. 179–180°.

*Anal.* Calcd. for $C_{25}H_{23}N_3$: C, 82.16; H, 6.34. Found: C, 82.07; H, 6.18.

*2,6-Bis(4'-n-amyl-2'-pyridyl)-4-phenylpyridine.* Similarly, 5.0 g. of 2-acetyl-4-*n*-amylpyridine and 1.4 g. of benzaldehyde, using method A, gave 0.61 g. (11%) of pale yellow needles, m.p. 106.5–107.5°.

*Anal.* Calcd. for $C_{31}H_{35}N_3$: C, 82.83; H, 7.84. Found: C, 82.72; H, 7.74.

*2,6-Bis(2'-pyridyl)-4-p-methoxyphenylpyridine.*[14] The crude yellow solid obtained from 4.8 g. of 2-acetylpyridine and 2.7 g. of *p*-methoxybenzaldehyde, using method A, was recrystal lized from ethanol to give 1.2 g. (18%) of pale yellow needles, m.p. 151–152°.

*Anal.* Calcd. for $C_{21}H_{17}N_3O$: C, 77.85; H, 5.05. Found: C, 77.47; H, 4.98.

*Terpyridines: Method B.* A solution of an acylpyridine, an aldehyde, and ammonium acetate in acetamide (1, 0.5, 7.5, and 15M proportions, respectively) was refluxed gently for 1.5 hr. The hot solution was poured into excess aqueous alkali and boiled for an additional hour. The resulting mixture was extracted with an equal volume of chloroform. The solvent was recovered and the residue recrystallized from benzene–petroleum ether.

*2,6-Bis(2'-pyridyl)-4-phenylpyridine.* From 7.2 g. of 2-acetylpyridine and 3.2 g. of benzaldehyde, using method B, was obtained 0.93 g. (10%) of a colorless solid, m.p. 206–207°; lit.,[5] 208°.

*Benzylidinebis(2-propionylpyridine).* The reaction of 4.1 g. of 2-propionylpyridine and 2.1 g. of benzaldehyde produced 1.4 g. of a pale yellow solid, m.p. 194.0–194.5°.

*Anal.* Calcd. for $C_{23}H_{22}N_2O_2$: C, 77.05; H, 6.18. Found: C, 77.20; H, 6.11.

*Ethyl picolinoylacetate.* This was prepared by the method of Gilman and Broadbent.[15]

*Picolinoylacetonitrile.* To a suspension of 0.15 mole of sodium ethoxide in 50 ml. of gently refluxing toluene was added 22.7 g. (0.15 mole) of ethyl picolinate, followed by dropwise addition of 8.2 g. (0.20 mole) of acetonitrile. A clear solution resulted which was refluxed for 4 hr. and then was kept overnight at room temperature. The reaction mixture was poured on 100 g. of chopped ice, neutralized with 10% hydrochloric acid and made alkaline with solid sodium bicarbonate. A yellow precipitate formed which was removed by filtration. Upon recrystallization from benzene–petroleum ether, 3.9 g. (18%) of colorless prisms, m.p. 93–94°, was obtained.

*Anal.* Calcd. for $C_8H_6N_2O$: C, 65.74; H, 4.14. Found: C, 66.04; H, 4.55.

*2,6-Bis(2'-pyridyl)-3,5-dicarbethoxy-1,4-dihydropyridine.* A mixture of 19.3 g. (0.1 mole) of ethyl picolinoylacetate and 4.0 g. of 37% formalin (0.05 mole of formaldehyde) was treated with 1 drop of diethylamine. The mixture was kept overnight at 5° and then for 48 hr. at room temperature. It was extracted with 50 ml. of diethyl ether and the extract was concentrated by distillation. The residual oil was diluted with ethanol to a total volume of 25 ml. The alcoholic solution was cooled in an ice bath and saturated with gaesous ammonia. The solution was stored for 24 hr. at 5° and then for 48 hr. at room temperature. The ethanol was removed by slow evaporation on a steam bath and 25 ml. of diethyl ether was added to the residual oil. Upon prolonged cooling, the ethereal solution deposited 11.5 g. (61%) of large, yellow rhombs. An analytical sample was recrystallized from diethyl ether, m.p. 140–141°.

*Anal.* Calcd. for $C_{21}H_{21}N_3O_4$: C, 66.49; H, 5.54. Found: C, 66.42; H, 5.68.

*2,6-Bis(2'-pyridyl)-3,5-dicarbethoxypyridine.* A solution of ten times the theoretically required amount of nitrous acid was prepared by slowly adding 147 ml. of ice cold 10% sulfuric acid to an ice-cold solution of 21 g. of sodium nitrite in 100 ml. of water. This solution was covered with 300 ml. of diethyl ether and then 11.3 g. (0.3 mole) of the dihydro ester was partly dissolved, partly suspended in the upper layer. After standing overnight at room temperature, the ether layer contained a large quantity of a colorless, crystalline solid. The mixture was shaken with excess solid sodium bicarbonate until all of the solid had dissolved. The ether layer was separated and the solvent removed by distillation. The oily residue solidified on cooling and was recrystallized from petroleum ether. Yield: 9.0 g. (80%) of colorless needles, m.p. 105.5–106.0°.

*Anal.* Calcd. for $C_{21}H_{19}N_3O_4$: C, 66.83; H, 5.07. Found: C, 66.66; H, 5.26.

*2,6-Bis(2'-pyridyl)-pyridine-3,5-dicarboxylic acid.* A solution of 2.2 g. (0.04 mole) of potassium hydroxide in 30 ml. of absolute ethanol was added in three portions to a refluxing solution of 6.0 g. (0.16 mole) of the ester in 30 ml. of ethanol. The solution was concentrated to 30 ml. by distillation and diluted with water until slightly turbid. The solution was again concentrated to 30 ml. and then acidified to Congo Red with dilute hydrochloric acid. Upon cooling the dicarboxylic acid precipitated. It was recrystallized from dilute ethanol to give 4.9 g. (96%) of colorless needles, m.p. 239° dec.

*Anal.* Calcd. for $C_{17}H_{11}N_3O_4$: C, 63.55; H, 3.45. Found: C, 63.14; H, 3.73.

*2,6-Bis(2'-pyridyl)-pyridine.* To a vigorously stirred suspension of 1.0 g. of copper powder in 30 g. of quinoline, heated to 230°, was added 4.9 g. (0.15 mole) of the dicarboxylic acid in ten portions over a period of 10 min. After heating for an additional 10 min., the mixture was cooled and filtered free of copper. The filtrate was distilled *in vacuo* and the fraction boiling at 177–180° was collected. The distillate solidified on cooling (3.3 g., m.p. 86–88°) and was recrystallized from petroleum ether to provide 2.7 g. (77%) of colorless needles, m.p. 87.0–87.5° [not depressed by admixture with authentic 2,6-bis(2'-pyridyl)pyridine obtained from G. F. Smith Chemical Co.]; picrate, m.p. 209–210°; lit.,[3] 210°.

PHILADELPHIA, PA.

(14) This compound has been found by Dr. Harvey Diehl to have molecular extinction coefficient 30,000, as the Fe(II) complex.

(15) H. Gilman and H. Broadbent, *J. Am. Chem. Soc.*, **70**, 2755 (1948).