

73. *Arylpyridines. Part I. Phenylpyridines and Nitrophenylpyridines.*

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A new method is developed for the preparation of arylpyridines, which consists in the addition of an aqueous solution of a diazonium salt to an excess of pyridine at temperatures varying from about 20° to 70° : $\text{RN}_2\text{Cl} + \text{C}_5\text{H}_5\text{N} \longrightarrow \text{R}\cdot\text{C}_5\text{H}_4\text{N} + \text{N}_2 + \text{HCl}$. The yields vary from about 20 to 80% depending on the temperature and the amine used. The reaction gives rise to a mixture of α -, β - and γ -arylpyridines. This communication deals with the preparation of the three phenylpyridines from diazotised aniline and pyridine, and with the nine nitrophenylpyridines obtained from diazotised *o*-, *m*-, and *p*-nitroaniline and pyridine. The three phenylpyridines are separated by fractional crystallisation of the picrates from acetone. The constitutions of the products formed in these reactions are established, where necessary, by relation to known compounds, *e.g.*, α -2-nitrophenylpyridine is reduced to α -2-aminophenylpyridine, which gives α -phenylpyridine on elimination of the amino-group. In similar manner, β -2-nitrophenylpyridine and γ -3-nitrophenylpyridine are converted into β -phenylpyridine and γ -phenylpyridine respectively. Suggestions are put forward with regard to the reaction mechanism, which appears to follow closely

that of the biaryl synthesis of Gomberg for which a process involving free radicals has been proposed.

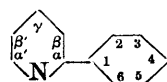
MÖHLAU and BERGER (*Ber.*, 1893, **26**, 1994), by the action of a suspension of dry solid benzenediazonium chloride on pyridine, obtained a mixture of isomeric phenylpyridines from which they isolated α -phenylpyridine (18% yield) and a mixture of α - and γ -phenylpyridine (3% yield). Using the same procedure, from the dry diazonium chloride prepared from *p*-aminodimethylaniline, Koenigs and Ruppelt (*Annalen*, 1934, **509**, 142) obtained less than 1% of γ -4-dimethylaminophenylpyridine* (cf. also Gattermann and Rolfes, *Annalen*, 1921, **425**, 151). Kühling (*Ber.*, 1895, **28**, 523; 1896, **29**, 165) claimed to have obtained α -4-nitrophenylpyridine in "good yield" by the action of dry sodium *p*-nitrobenzeneisodiazotate on pyridine in presence of glacial acetic acid or acetyl chloride, but a repetition of this work by Forsyth and Pyman (*J.*, 1926, 2912) showed that the product was a mixture consisting of α -, β - and γ -4-nitrophenylpyridine in 15, 5 and 2% yield respectively. The action of solid dry di-*p*-nitrobenzenediazosulphide on pyridine is recorded by Bamberger and Kraus (*Ber.*, 1896, **29**, 274), who obtained a mixture of 4-nitrophenylpyridines, but no yield was recorded. Moreover the explosive nature of the diazosulphide renders this method unattractive. Tschitschibabin (*Ber.*, 1904, **37**, 1373) obtained a mixture of phenylpyridines in "very small" yield by the action of acetic acid on a mixture of aniline, powdered sodium nitrite and pyridine, and the same procedure was later used by Tschitschibabin and Schemyakina (*Chem. Zentr.*, 1923, III, 1024), who, from *p*-nitroaniline and pyridine, obtained a mixture of α - and γ -4-nitrophenylpyridine, but no yield was recorded. Gomberg and Bachmann (*J. Amer. Chem. Soc.*, 1924, **46**, 2339) obtained a "phenylpyridine," m. p. 54—55°, by the addition of aqueous alkali to a mixture of aqueous benzenediazonium chloride and pyridine, but again no yield was recorded. The identity of this compound is uncertain, since of the three isomeric phenylpyridines γ -phenylpyridine alone is a solid at the ordinary temperature and melts, according to Forsyth and Pyman (*loc. cit.*), at 74°.

It would thus appear that existing methods for the preparation of arylpyridines by the action of a diazo-compound on pyridine are far from satisfactory. Yields are low, the nature of the products is often uncertain, and most of the methods involve the isolation of a dry, often explosive, diazo-compound for a reaction in a non-aqueous medium.

Other methods for the preparation of phenylpyridines not involving the use of diazo-compounds have also been described (Skraup and Cobenzl, *Monatsh.*, 1883, **4**, 472; Hantzsch, *Ber.*, 1884, **17**, 1518; Ciamician and Silber, *Ber.*, 1887, **20**, 192; Scholtz, *Ber.*, 1895, **28**, 1728; Leben, *Ber.*, 1896, **29**, 1678; Pictet, *Ber.*, 1905, **38**, 1946; Tschitschibabin, *J. Russ. Phys. Chem. Soc.*, 1915, **47**, 711; Overhoff and Tilman, *Rec. Trav. chim.*, 1929, **48**, 993; Wieland *et al.*, *Annalen*, 1934, **514**, 145), but again the yields are often very poor, the reactions involve many stages, and in some cases the claims have been questioned by later workers (cf. Walters and McElvain, *J. Amer. Chem. Soc.*, 1933, **55**, 4625). Improved methods for the preparation of α -phenylpyridine have recently been introduced by Ziegler and Zeiser (*Ber.*, 1930, **63**, 1851), Walters and McElvain (*loc. cit.*), and Bergstrom and McAllister (*J. Amer. Chem. Soc.*, 1930, **52**, 2845), using either phenyl-lithium or phenyl-magnesium bromide, but these reactions cannot be regarded as general, since they would be inapplicable to the preparation of many substituted phenylpyridines.

With regard to the nitrophenylpyridines in which the nitro-group is attached to the benzene nucleus Kühling (*loc. cit.*) claimed to have obtained α -4-nitrophenylpyridine, m. p. 117° (originally regarded as the γ -isomeride), which he reduced to α -4-aminophenylpyridine, m. p. 102°. From the same reaction, however, Forsyth and Pyman (*loc. cit.*) obtained α -4-nitrophenylpyridine, m. p. 130.5—131.5°, β -4-nitrophenylpyridine, m. p. 148—149°, and γ -4-nitrophenylpyridine, m. p. 123—124°, which on reduction yielded the corresponding amines melting at 97—98°, 102—104°, and 232—234° respectively. The melting

* The following method of numbering will be used in this series of papers:



point recorded for α -4-nitrophenylpyridine by Tschitschibabin and Schemyakina (*loc. cit.*) is also 131°. From these melting points it is obvious that Kühling's product, m. p. 117°, is a mixture, and the α -4-nitrophenylpyridine, m. p. 118°, of Bamberger and Kraus (*loc. cit.*) must also be placed in the same category. By the nitration of the phenylpyridines Forsyth and Pyman (*loc. cit.*) obtained α -2-, α -3-, α -4-, β -4-, γ -2-, γ -3- and γ -4-nitrophenylpyridine.

A new and simple general method is now described for the preparation of aryl- and substituted aryl-pyridines. The procedure consists in the slow addition of an aqueous solution of a diazonium salt to an excess of pyridine at temperatures varying from about 20° to 70° depending on the amine used. A brisk evolution of nitrogen takes place as soon as the solutions are brought together and a mixture of arylpyridines is obtained in yields varying from about 20 to 80% depending on the amine used. If, on the other hand, pyridine is added to the aqueous diazonium salt, a point is reached at which a sudden vigorous reaction sets in, which in many cases cannot be controlled and much tar is formed. The product normally consists of a mixture of the α -, β - and γ -isomerides, which can be separated by appropriate treatment. The product may be isolated by pouring the reaction mixture into water and filtering off the arylpyridine if solid or, if liquid, by addition of alkali, steam-distillation to remove the excess of pyridine, and extraction with benzene or ether. The yields and purity of the products depend to a certain extent on the quality of the pyridine used, pure pyridine giving the best results. If a crude solvent pyridine is used, which contains picolines and lutidines, less satisfactory results are obtained. The present communication is confined to the preparation of phenyl- and nitrophenyl-pyridines.

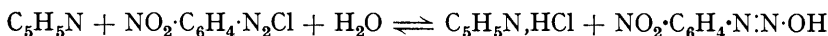
Addition of an aqueous solution of benzenediazonium chloride to an excess of pyridine at 30° gave a mixture of phenylpyridines in 40% yield. Separation into the constituent isomerides by fractional crystallisation of the picrates showed that all three isomerides were present, the α -isomeride preponderating. By addition of an aqueous solution of *p*-nitrobenzenediazonium chloride to an excess of pyridine at 40° a mixture of crude 4-nitrophenylpyridines was obtained in about 75% yield with almost complete absence of tar. Separation of the product into its constituent isomerides, following the method described by Forsyth and Pyman (*loc. cit.*), gave pure α -, β -, and γ -4-nitrophenylpyridine in yields of 24, 9, and 4.5% respectively. A small quantity of a di-4-nitrophenylpyridine, probably $\alpha\alpha'$ -di-4-nitrophenylpyridine, was also isolated. Similar reactions were carried out with diazotised *m*-nitroaniline and *o*-nitroaniline. In the former case a mixture of 3-nitrophenylpyridines was obtained and in the latter a mixture of 2-nitrophenylpyridines, both in about 35% yield. In both cases the product was shown to contain all three isomerides, which were separated and isolated. Thus, from the interaction of diazotised *o*-, *m*-, and *p*-nitroaniline with pyridine all the nine isomeric nitrophenylpyridines, in which the nitro-group is attached to the benzene nucleus, have been obtained.

The constitutions of the nitrophenylpyridines thus prepared depend ultimately on the use of α -, β -, and γ -phenylpyridine as reference compounds. The constitutions of the three phenylpyridines have been placed beyond doubt, since on oxidation α -phenylpyridine yields picolinic acid, β -phenylpyridine nicotinic acid, and γ -phenylpyridine isonicotinic acid. The three phenylpyridines form characteristic picrates, which can be identified readily both by melting point and by crystalline form.

The three 4-nitrophenylpyridines obtained from *p*-nitroaniline were identified by correspondence with the melting points established by Forsyth and Pyman. In the case of the three 3-nitrophenylpyridines the α -isomeride was identified by correspondence with the melting point recorded by Forsyth and Pyman; the constitution of the γ -isomeride was proved by reduction to γ -3-aminophenylpyridine, followed by diazotisation, reduction to the hydrazine, and treatment with copper acetate, γ -phenylpyridine being then isolated. By elimination the third 3-nitrophenylpyridine must be β -3-nitrophenylpyridine. In the case of the three 2-nitrophenylpyridines the constitution of the β -2-nitrophenylpyridine was proved by conversion by means of the hydrazine into β -phenylpyridine, and that of the α -isomeride by reduction, diazotisation, and treatment with methyl alcohol to give α -phenylpyridine, although in this case α -2-methoxyphenylpyridine was expected, of which an authentic specimen was available. By elimination the third isomeride, which was

obtained only in small quantity in the form of a picrate, must be γ -2-nitrophenylpyridine. In general, it is the α -isomeride which predominates in these reactions, but in the reaction with *o*-nitroaniline the proportion of the β -isomeride formed is unusually high, with a consequent diminution in the quantity of the γ -isomeride.

With regard to the mechanism of this reaction for the preparation of arylpyridines the following observations are pertinent: Addition of pyridine to aqueous *p*-nitrobenzenediazonium chloride results in no perceptible reaction until the base has been added somewhat in excess of that equivalent to the amount of acid (both free and combined) present, after which further addition of pyridine results in a vigorous reaction. Again, if pyridine is added to aqueous *p*-nitrobenzenediazonium chloride equivalent to the amount of free acid present together with sufficient to form an intermediate compound of the type $\text{NO}_2\cdot\text{C}_6\text{H}_4\cdot\text{N}:\text{N}\cdot\text{N}\cdot\text{C}_5\text{H}_5\text{H}_3\text{Cl}$, and the resulting mixture is stirred with an excess of benzene, *p*-nitrodiphenyl but no *p*-nitrophenylpyridine is formed. Since aqueous diazonium salts do not react with benzene, a reactive intermediate of the type indicated above may be involved. Alternatively, the active agent may be the diazohydroxide produced thus:



and in this case the conditions closely resemble those present in the biaryl synthesis of Gomberg (*J. Amer. Chem. Soc.*, 1924, **46**, 2339; 1926, **48**, 1372). Further, aqueous diazonium salts do not react with solutions of quaternary pyridinium salts to yield arylpyridines. With aqueous pyridine methiodide, diazotised *p*-nitroaniline gives only *p*-iodonitrobenzene; with aqueous pyridine methyl methosulphate no action takes place at room temperature but on warming *p*-nitrophenol is formed.

It appears most likely that the active agent is a diazohydroxide (or diazoic acid) and that the underlying mechanism is similar to that which obtains in the biaryl synthesis of Gomberg (cf. Hey and Waters, *Chem. Reviews*, 1937, **21**, 169; Grieve and Hey, *J.*, 1938, 108). The arylpyridine synthesis, however, possesses an additional advantage in that the whole reaction proceeds in a homogeneous medium, whereas in the biaryl synthesis a two-phase system is involved. This probably accounts for the fact that, in general, the yields in the arylpyridine reaction are very much higher than those in the biaryl reaction. Further as in the Gomberg biaryl synthesis, the available evidence also favours a free-radical mechanism for the arylpyridine synthesis, since, in general, all three isomeric arylpyridines are formed. This indicates that the normal polar directive influences of the pyridine nucleus are not operating, either in any process of direct substitution or in any process involving a migration reaction from the nitrogen atom.

EXPERIMENTAL.

Action of Diazotised Aniline on Pyridine.—An aqueous solution of benzenediazonium chloride, prepared in the normal manner from aniline (30 g.), was dropped during 2 hours into pyridine (300 c.c.) with stirring at 30°. Nitrogen was freely and continuously evolved and the solution darkened. The reaction was completed by warming on the steam-bath for 1 hour. Concentrated aqueous sodium hydroxide was added to the mixture when cold and the pyridine layer was separated, poured into water, and extracted with ether. The extract, dried over potassium hydroxide, was distilled, finally under reduced pressure. A mixture of phenylpyridines (20 g.) was collected at 170—190°/10—20 mm. When cold, some γ -phenylpyridine separated in colourless flakes, but was not removed by filtration. The whole, dissolved in a small quantity of alcohol, was added to a hot solution of picric acid (23 g.) in alcohol (300 c.c.), and the mixture heated to boiling and filtered hot. A yellow residue (12 g., A) was obtained and the filtrate, on cooling, deposited a further precipitate of picrate (28 g., B). Fractions (A) and (B) were separately submitted to systematic fractional crystallisation from acetone. The former yielded mainly γ -phenylpyridine picrate; the latter consisted largely of the α -isomeride together with some of the β -isomeride. The final products from the fractional crystallisations were: (a) α -phenylpyridine picrate, large, yellow, rhombic prisms (12 g.), m. p. 175—176° (Found: C, 53.2; H, 3.6. Calc. for $\text{C}_{11}\text{H}_9\text{N}, \text{C}_6\text{H}_3\text{O}_7\text{N}_3$: C, 53.1; H, 3.1%); (b) β -phenylpyridine picrate, long, silky, yellow needles (5 g.), m. p. 159—160° (Found: C, 53.4; H, 2.8%); and (c) γ -phenylpyridine picrate, hard orange needles (5 g.), m. p. 195—196° (Found: C, 53.4; H, 3.2%). The

m. p.'s previously recorded for the three picrates are 176—177° (Forsyth and Pyman, *loc. cit.*), 162—164° (Forsyth and Pyman, *loc. cit.*), and 195—196° (Hantzsch, *loc. cit.*) respectively. In a second experiment the solid γ -phenylpyridine, which separated from the distillate on cooling, was filtered off. After crystallisation from light petroleum (b. p. 60—80°) it melted at 69—70°, and yielded a picrate, m. p. 195—196°. The three phenylpyridines were isolated from the picrates by warming with 5% aqueous sodium hydroxide, followed by extraction with ether. The extracts were dried over potassium hydroxide and after removal of the ether the free bases were obtained as yellow oils, the γ -isomeride only solidifying when cold.

Action of Diazotised p-Nitroaniline on Pyridine.—An aqueous solution of *p*-nitrobenzenediazonium chloride (from *p*-nitroaniline, 70 g.) was added dropwise during 2 hours to pyridine (500 c.c.) stirred at 40°; the heat of reaction maintained the temperature. Nitrogen was freely evolved. The reaction was completed by warming on the steam-bath for 1 hour. The mixture, containing some nitrophenylpyridine in suspension, was then poured into a large volume of water, and the brown precipitate obtained was filtered off, washed, and dried in a steam-oven. The product (75 g.) was dissolved in boiling benzene (300 c.c.) and filtered from some insoluble matter. When cold, a yellow solid (0.5 g.) separated, which after sublimation in a vacuum and crystallisation from nitrobenzene yielded a compound, regarded as $\alpha\alpha'$ -*di-4-nitrophenylpyridine*, in fibrous needles, m. p. 293° (Found: C, 63.1; H, 3.6. $C_{17}H_{11}O_4N_3$ requires C, 63.5; H, 3.4%). Removal of benzene from the filtrate left a yellow solid residue of nitrophenylpyridines (55 g., m. p. 105—115°). Alternatively the crude product may be purified by direct distillation under reduced pressure, the distillate being collected at 170—220°/<1 mm, as a yellow solid (45 g. from 70 g. of *p*-nitroaniline) rather purer than that obtained in the former method. Separation into the constituent isomerides was effected by the method of Forsyth and Pyman (*loc. cit.*), 100 g. of the purified mixed nitrophenylpyridines giving α -, m. p. 130—131° (Found: C, 66.2; H, 4.0. Calc.: C, 66.0; H, 4.0%), β -, m. p. 146—147° (Found: N, 13.9. Calc.: N, 14.0%), and γ -4-nitrophenylpyridine, m. p. 122—123° (Found: N, 14.0%), in yields of 54 g., 20 g., and 10 g. respectively. The three bases were converted into picrates by treatment with alcoholic picric acid, followed by crystallisation from acetone, from which they separated in fibrous needles. α -4-Nitrophenylpyridine picrate melted at 168° (Tschitschibabin and Schemyakina, *loc. cit.*, record m. p. 167—167.5°) (Found: C, 47.8; H, 2.6. Calc.: C, 47.6; H, 2.6%), β -4-nitrophenylpyridine picrate at 220° (Found: N, 16.0. $C_{11}H_8O_2N_2 \cdot C_6H_3O_7N_3$ requires N, 16.3%), and γ -4-nitrophenylpyridine picrate at 228—229° (Found: N, 16.6%).

Action of Diazotised m-Nitroaniline on Pyridine.—An aqueous solution of *m*-nitrobenzenediazonium chloride (from *m*-nitroaniline, 70 g.) was added to pyridine (500 c.c.) as described above for the corresponding reaction with *p*-nitroaniline. The reaction mixture was made strongly alkaline with ammonia, and the excess of pyridine removed with steam. The viscous dark oil, which separated when cold, was extracted with benzene, and the extract filtered from insoluble matter, dried, and distilled. After removal of the benzene the *m*-nitrophenylpyridines (35 g.) were collected at 160—190°/<1 mm. as a yellow oil, which solidified when cold. It was dissolved in hot 5*N*-hydrochloric acid (66 c.c.), from which solution the hydrochlorides of α - and β -3-nitrophenylpyridine separated on cooling. Addition of ammonia liberated the free bases (13 g.). Evaporation of the hydrochloric acid mother-liquor deposited further quantities of the hydrochlorides, which on basification yielded more base (12 g.). Addition of alkali to the final mother-liquor gave crude γ -3-nitrophenylpyridine (5 g.), which was purified as the nitrate by crystallisation from 2*N*-nitric acid. Basification of the nitrate, followed by treatment with alcoholic picric acid, gave γ -3-nitrophenylpyridine picrate, which separated from acetone in fibrous yellow needles, m. p. 250° (Found: C, 47.8; H, 3.0. $C_{11}H_8O_2N_2 \cdot C_6H_3O_7N_3$ requires C, 47.6; H, 2.6%). The pure free base, regenerated from the picrate by treatment with 5% aqueous sodium hydroxide, separated as an oil which solidified. Crystallisation from acetone—light petroleum (b. p. 60—80°) gave γ -3-nitrophenylpyridine in colourless needles, m. p. 109—110° (Found: N, 14.2. Calc.: N, 14.0%) (Forsyth and Pyman, *loc. cit.*, record m. p. 109—110°). The mixture containing α - and β -3-nitrophenylpyridine was subjected to fractional crystallisation from alcohol, which yielded α -3-nitrophenylpyridine in colourless needles, m. p. 74° (Forsyth and Pyman give m. p. 73—74°) (Found: C, 66.0; H, 3.8. Calc.: C, 66.0; H, 4.0%), and, on concentration of the mother-liquors, β -3-nitrophenylpyridine, which was purified by crystallisation first of the hydrochloride from 5*N*-hydrochloric acid and finally of the free base from acetone—light petroleum (b. p. 60—80°), from which it separated in colourless needles, m. p. 101—102° (Found: N, 13.8. $C_{11}H_8O_2N_2$ requires N, 14.0%). The bases were separately treated with hot alcoholic picric acid; the resulting picrates separated from acetone in yellow needles. The picrate of α -3-nitrophenylpyridine melted at 157° (Found: C, 47.7; H, 2.6.

$C_{11}H_8O_2N_2, C_6H_3O_7N_3$ requires C, 47.6; H, 2.6%, and that of the β -isomeride at 200—201° (Found: C, 47.5; H, 2.8%).

Conversion of γ -3-Nitrophenylpyridine into γ -Phenylpyridine.—A solution of stannous chloride (6 g.) in concentrated hydrochloric acid (12 c.c.) was added to a solution of γ -3-nitrophenylpyridine (1 g.) in concentrated hydrochloric acid (2 c.c.) and warmed on the steam-bath for 1 hour. γ -3-Aminophenylpyridine, liberated by the addition of aqueous sodium hydroxide, was extracted with ether, recovered (0.6 g.), dissolved in a mixture of concentrated hydrochloric acid (4 c.c.) and water (6 c.c.), and diazotised at 5—10° with sodium nitrite (0.3 g.) in water. A cold solution of stannous chloride (3 g.) in hydrochloric acid (6 c.c.) was then added and after 1 hour the γ -3-hydrazinophenylpyridine was liberated with aqueous sodium hydroxide and extracted with benzene. The product obtained on removal of solvent was dissolved in glacial acetic acid (4 c.c.), and powdered copper acetate (1.5 g.) added. After removal of copper as sulphide, the filtrate was made alkaline and extracted with ether. Removal of the ether from the dried extract left γ -phenylpyridine, which was identified as the picrate, m. p. and mixed m. p. 195—196°

*Action of Diazotised *o*-Nitroaniline on Pyridine.*—An aqueous solution of *o*-nitrobenzene-diazonium chloride (from *o*-nitroaniline, 70 g.) was added to pyridine (500 c.c.), and the product worked up as described above for the corresponding reaction with *m*-nitroaniline. Removal of the benzene left a residue which on distillation under reduced pressure yielded a mixture of *o*-nitrophenylpyridines as an orange liquid (33 g.), b. p. 220—235°/40—50 mm. This was dissolved in hot alcohol and added to a hot solution of picric acid (36 g.) in alcohol (330 c.c.). The mixture of picrates (58 g.), which separated on cooling, was fractionally crystallised from acetone. β -2-Nitrophenylpyridine picrate (23 g.) separated first in sparingly soluble, fibrous, yellow needles, m. p. 182—183° after recrystallisation from acetone (Found: C, 47.6; H, 3.0. $C_{11}H_8O_2N_2, C_6H_3O_7N_3$ requires C, 47.6; H, 2.6%). Concentration of the original acetone mother-liquors gave α -2-nitrophenylpyridine picrate (20 g.) in yellow prisms, m. p. 151—152° after recrystallisation from acetone (Found: C, 47.8; H, 2.8%). Further concentration of the acetone mother-liquors yielded γ -2-nitrophenylpyridine picrate (<1.5 g.) in orange-yellow needles, m. p. 206—207° (Found: N, 16.1. $C_{11}H_8O_2N_2, C_6H_3O_7N_3$ requires N, 16.3%). The free base prepared from α -2-nitrophenylpyridine picrate by treatment with warm 5% aqueous sodium hydroxide separated as an oil, which solidified; m. p. 58—59° after crystallisation from ether (Forsyth and Pyman, *loc. cit.*, record m. p. 60—61°). β -2-Nitrophenylpyridine was similarly obtained as a pale yellow oil which did not solidify.

Conversion of α -2-Nitrophenylpyridine into α -Phenylpyridine.— α -2-Nitrophenylpyridine (0.5 g.) was reduced with stannous chloride as described above for γ -3-nitrophenylpyridine. The α -2-aminophenylpyridine (0.3 g.), obtained as a pale yellow oil, was dissolved in concentrated hydrochloric acid (2 c.c.), diazotised at 5—10° with a solution of sodium nitrite (0.15 g.) in water, methyl alcohol (50 c.c.) added, and the mixture boiled under reflux for 2 hours. The solution was evaporated to small bulk, poured into dilute aqueous sodium hydroxide, and extracted with ether. Removal of the ether left a yellow oil, which on treatment with hot alcoholic picric acid gave α -phenylpyridine picrate which separated from acetone in yellow prisms, m. p. and mixed m. p. 175—176°.

Conversion of β -2-Nitrophenylpyridine into β -Phenylpyridine.— β -2-Nitrophenylpyridine (2.2 g.) was reduced by means of stannous chloride in hydrochloric acid, and the resulting β -2-aminophenylpyridine (1.5 g.) diazotised, reduced to the hydrazine, and treated with copper acetate exactly as described above for the conversion of γ -3-nitrophenylpyridine into γ -phenylpyridine. The resulting β -phenylpyridine was obtained as a yellow oil giving a picrate, which separated from acetone in yellow needles, m. p. and mixed m. p. 159—160°.

Experiments on Reaction Mechanism.—Suspensions of *p*-nitroaniline (10 g.) in a mixture of hydrochloric acid (*d* 1.16, 25 c.c.) and water (15 c.c.) were diazotised with sodium nitrite (5 g.) and treated as follows: (a) A quantity of pyridine (8.4 g.) equivalent to the amount of excess acid present was added to one batch. No action was observed. After addition of a further quantity of pyridine (6.6 g.) again no action was observed, but addition of yet a further quantity (7.0 g.) resulted in an extremely vigorous reaction with production of much tar. Addition of water precipitated more tarry material, from which a mixture of crude 4-nitrophenylpyridines (3 g.) was extracted with hot 5*N*-hydrochloric acid. (b) Pyridine (15 c.c.) was added to a second batch, and the resulting solution added to benzene (200 c.c.) and stirred overnight. After filtration the benzene layer was separated and after evaporation of the benzene the residue was distilled. A fraction (2.6 g.) was collected at 330°, which on crystallisation from alcohol gave 4-nitrodiphenyl, m. p. and mixed m. p. with an authentic specimen 112—113°. No nitro-

phenylpyridine could be extracted either from the distillate or from the residue with hot hydrochloric acid. (c) A third batch of the diazonium solution was added dropwise to a solution of pyridine methiodide (50 g.) in water (100 c.c.). Nitrogen was evolved, and a brown solid deposited. After warming on the steam-bath to complete the reaction, the precipitated solid (14 g.) was collected; on sublimation it yielded *p*-iodonitrobenzene, m. p. 170°. (d) A fourth batch was added dropwise to a solution of pyridine methyl methosulphate (80 g.) in water (100 c.c.). No action took place in the cold. On warming, nitrogen was evolved and from the clear solution, decanted from some tarry matter, ether extracted *p*-nitrophenol, m. p. and mixed m. p. with an authentic specimen 112—113°

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