water. Upon agitation the iodine color began to fade. After several minutes an additional 35 mg. of silver oxide was introduced and upon shaking a further decrease in the iodine color was noted. Addition of 20 mg. more of silver oxide caused no visible effect. The silver salts were filtered off and washed with methanol. The combined filtrate and washes were treated with 40–45 drops of aqueous 0.1 *N* sodium thiosulfate solution, then poured into 130 ml. of ice-water from which a white precipitate of the product separated. After refrigerating it was filtered off and purified by dissolving with stirring in 50 ml. of aqueous 1% sodium hydroxide solution. A little Norit A was added and the mixture was filtered. After addition of some ice to the filtrate, the bromoiodopyrrole was precipitated by acidifying gradually with glacial acetic acid until no more precipitate formed. The mixture was refrigerated overnight, then filtered to give 452 mg. or 72% of crude product melting at 114–120° with some softening beginning at about 110°. Recrystallization from warm ethanol–water afforded 309 mg. of product melting at 120–121°, and recrystallization of the crude recovered from the mother liquor gave an additional 21 mg. of product melting at 119.5–120.5°. Total yield of thus purified product, 330 mg. or 53%. One subsequent recrystallization from warm ethanol–water afforded the analytically pure bromoiodopyrrole melting at 121–122°.

Anal. Calcd. for $C_5H_3O_2NBrI$: C, 26.84; H, 2.53. Found: C, 26.90; H, 2.25.

Mixed melting points with the 2-bromo-3-methyl-4-carbethoxy-5-iodopyrrole from XIII showed no depression. Mixed melting point with III (5.8 mg. of II + 1.1 mg. of III), 117–121°.

2,5-Dicarboxy-3-methyl-4-carbethoxypyrrole (XIV).[8b,d]—This was prepared by the alkaline hydrolysis[8b] of 2,4-dicarbethoxy-3-methyl-5-carboxypyrrole. It was found advantageous to extend the reflux period to 3 hours. The product was twice recrystallized from acetone–water before utilization in the next reaction.

2,5-Diiodo-3-methyl-4-carbethoxypyrrole (XV).—Seven and three-tenths grams of sodium bicarbonate and 8.0 g. of 2,5-dicarboxy-3-methyl-4-carbethoxypyrrole were dissolved by stirring with 325 ml. of water. A solution of 17.9 g. of iodine and 23 g. of potassium iodide in 145 ml. of water was then added dropwise with stirring during 65 minutes. At first a white precipitate of the diiodopyrrole formed rapidly, then a dark-colored foam accumulated gradually atop the reaction mixture, preventing efficient mixing of the reactants. Considerable additional water was introduced and the mixture was stirred manually at intervals while the reaction proceeded nearly to completion during several hours. The product was finally filtered off, washed and dried *in vacuo*. Yield 12.5 g. or 93% of crude product melting at 147–151° with decomposition. The substance was recrystallized for analysis from warm ethanol–water; m.p. 151–152.5° with decomposition.

Anal. Calcd. for $C_8H_9O_2NI_2$: C, 23.72; H, 2.24. Found: C, 23.86; H, 2.55.

3-Methyl-4-carbethoxypyrrole (VI).[6,7]—The catalyst for the reduction was prepared by hydrogenation of a mixture of 17.0 g. of 10% palladium chloride solution, 40 ml. of water and 10.2 g. of Norit A for one hour, at 35 lb. gage pressure. The catalyst was filtered off, washed well with water, then methanol, and transferred to a hydrogenation bottle. Eight grams of magnesium oxide, 40.5 g. (100 mmol.) of crude 2,5-diiodo-3-methyl-4-carbethoxypyrrole and 135 ml. of methanol were then added, and the mixture was hydrogenated for 48 hours during which time gage pressure dropped from 39.7 to 24.3 lb. of hydrogen, corresponding to an uptake of approximately 0.2 mole of hydrogen. After addition of a little sodium bisulfite to prevent reoxidation of the iodide ion, the catalyst was removed by suction, then gravity filtration. Gradual addition of the pale yellow filtrate to 775 ml. of ice-water caused the product to separate as a solid. After refrigerating overnight, the crude 3-methyl-4-carbethoxypyrrole was filtered off; weight 12.7 g., m.p. 74–75°. A second crop melting at 73–74° was obtained by freezing, then thawing the filtrate; total yield 13.1 g. or 86% of product.

BALTIMORE, MARYLAND

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT, UNIVERSITY OF MICHIGAN]

Pyrido-2,3-furoxane[1]

BY J. H. BOYER,[2] D. I. MCCANE, W. J. MCCARVILLE AND A. T. TWEEDIE

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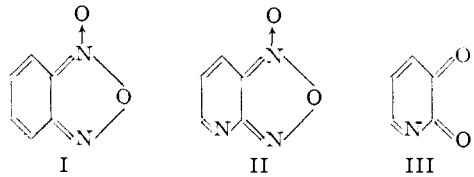
Pyrido-2,3-furoxane (II) has been prepared by the pyrolysis of 8-nitropyridotetrazole (IV). A quinonoid structure with an unsymmetrical arrangement of the N_2O_2 group for II and related furoxanes is in agreement with both analysis of infrared spectra and revised parachor values.

Inasmuch as certain derivatives of benzfuroxane (I), *e.g.*, 5-(or 6)-methylbenzfuroxane,[3] 5-(or 6)-chlorobenzfuroxane[3] and naphtho-1,2-furoxane[3] fail to exist in isomeric forms as required by the generally accepted quinonoid structures, it is recognized that these representations do not adequately describe furoxanes of this type. Not only does pyrido-2,3-furoxane (II) offer a new example in which there appears to be the possibility for two modifications but it also illustrates the hitherto unreported fusion of a heterocyclic aromatic ring to the furoxane moiety. In addition the synthesis of this compound has afforded preliminary investigations on the pyrolysis of pyridotetrazoles, and has offered the possibility of studying an azaquinone structure. Apparently the only previously reported example of this type of compound is 3-aza-*o*-benzoquinone[4] (III) prepared by the oxidation of 2,3-dihydroxypyridine. Certain potential hydroxyazaquinones exist in the keto modification, *e.g.*, alloxan, tetraketopiperazine and phthalonimide.



I II III

Syntheses of pyridotetrazoles have consisted in reactions which would appear to yield the isomeric α-pyridyl azides, *e.g.*, the displacement of halogen by the azido group[5] or the action of nitrous acid upon the hydrazino group.[6] If possible, utiliza-

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(3) A. G. Green and F. M. Rowe, *J. Chem. Soc.*, **103**, 897 (1913).

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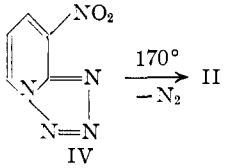
tion of the corresponding diazotized aminopyridine would be more direct. The action of hydrazoic acid upon diazotized α-aminopyridine, however, led only to α-pyridone. From a mixture of concentrated ammonium hydroxide and a perbromide of α-pyridyldiazonium bromide both α-bromopyridine and α-pyridone but no pyridotetrazole were found.

A reinvestigation of the application of the halogen–azide interchange to 2-halopyridine and its 3- and 5-nitro derivatives was then undertaken. Preparation of 3-nitro-2-pyridone by low temperature nitration of α-pyridone[7] proved more convenient than diazotization of 3-nitro-2-aminopyridine followed by hydrolysis.[8] The latter method applied to 5-nitro-2-aminopyridine was employed for the synthesis of 5-nitropyridone. Phosphorus pentachloride in phosphorus oxychloride brought about the transformation of the nitropyridines into corresponding chlorides. A previous report claimed that 2-chloropyridine reacted with hydrazoic acid (but not with sodium azide) in a sealed tube at 100°.[5] Pyridotetrazole and its 6- and 8-nitro derivatives have now been prepared from the corresponding halides and hydrazoic acid in refluxing aqueous ethanol.

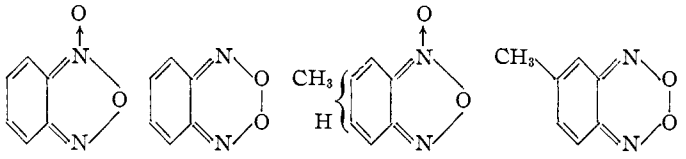
Each of the three tetrazoles underwent the loss of nitrogen when brought to temperatures between 160 and 180°. The products from pyridotetrazole and 6-nitropyridotetrazole were amorphous, high-melting, red solids which have not been identified. When heated by itself or in an inert solvent, *e.g.*, diphenyl ether, 8-nitropyridotetrazole (IV) afforded a quantitative yield of pyrido-2,3-furoxane (II); however, a red, amorphous solid by-product also was formed if the pyrolysis was carried out at higher temperatures. Typical furoxane properties of the monomeric product included reduction by sodium sulfide to 2,3-diaminopyridine, oxidation of hydroxylamine in alkaline solution, reaction with bromine, and liberation of iodine from hydrogen iodide. In agreement with the unsymmetrical benzfuroxanes cited above, only one isomer of pyrido-2,3-furoxane was obtained.



Chemical and physical properties are in agreement with a quinonoid structure for benzfuroxane and related furoxanes; however, differentiation between the symmetrical and unsymmetrical arrangement of the N_2O_2 group is not yet possible. A strong similarity with the furoxanes obtained from the dioximes of linear dicarbonyl compounds has been noted.[9] The unsymmetrical arrangement of the N_2O_2 group in this case was demonstrated by the existence of structural isomers for those derived from unsymmetrical dicarbonyl compounds.[10] Hammick[9] has considered that parachor values supported the quinonoid structure for benzfuroxane and 5-(or 6)-methylbenzfuroxane. A preference for the unsymmetrical representation is indicated by revised calculations (Table I) according to Samuel's unit parachor values,[11] and is supported by analysis of the infrared spectra of benzfuroxane, 5,6-tetramethylenebenzfuroxane and pyrido-2,3-furoxane (Table II). Strong absorption at 1630–1600 cm.$^{-1}$ is attributed to the >C=N– group,[12] while absorption at 1545–1540 cm.$^{-1}$ is close to 1555 cm.$^{-1}$, a characteristic band reported for dimeric nitroso compounds and nitro groups.[12,13]

TABLE I

PARACHOR VALUES



P (calcd.)[a]	272.6	262.0	311.6	301.0
P (obsd.)[b]	274.3		311.4	

[a] Calculated according to unit parachor values reported by Samuel.[11] [b] Reference 9.

TABLE II

INFRARED ABSORPTION DATA[a] IN THE REGION 1400–1700 CM.$^{-1}$

No.	Compound	Strong absorption, cm.$^{-1}$
1	Benzfuroxane (I)	1630, 1600, 1545, 1500
2	5,6-Tetramethylenebenzfuroxane	1630, 1605, 1545, 1490
3	Pyrido-2,3-furoxane (II)	1630, 1545
4	Pyridotetrazole	1660, 1520
5	6-Nitropyridotetrazole	1645, 1565, 1540, 1500, 1470
6	8-Nitropyridotetrazole (IV)	1640, 1540, 1470

[a] Samples 1–4 were analyzed by a Baird Associates double-beam infrared spectrophotometer with a sodium chloride prism from 5% solutions in carbon tetrachloride or chloroform. We are indebted to Samuel P. Sadtler and Son, Inc., Philadelphia, Pa., for the analyses of samples 5 and 6 which were determined from the Nujol mull of each.

Experimental[14]

α-Pyridone was prepared and nitrated according to the procedures of Bishop, Cavell and Chapman[7] and of Maier-Bode and Binz.[15] The major product was 3-nitro-2-hydroxypyridine, with smaller amounts of 3,5-dinitro-2-hydroxypyridine.

α-Aminopyridine was nitrated according to the method of Kornfeld and Caldwell.[16] The major product was 5-nitro-2-aminopyridine, with traces of 3-nitro-2-aminopyridine.

(7) R. R. Bishop, E. A. S. Cavell and N. B. Chapman, *J. Chem. Soc.*, 437 (1952).

(8) A. E. Tschitschibabin and I. G. Blynkin, *Chem. Zentr.*, **94**, III, 1020 (1923); **86**, 1066 (1915).

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(13) J. Goubeau and I. Fromme, *Z. anorg. Chem.*, **258**, 18 (1949).

(14) Melting points are not corrected: microanalyses by the Micro-Tech Laboratories, Skokie, Illinois.

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(16) W. T. Caldwell and E. C. Kornfeld, THIS JOURNAL, **64**, 1695 42).

The compounds were transformed into the corresponding 5-nitro-2-chloropyridine[16] and 3-nitro-2-chloropyridine[8] according to Tschitschibabin's method.

Reactions with α-Aminopyridine (I).—Into a 3-necked round bottomed flask equipped with a stirrer, dropping funnel and thermometer were added with stirring 80 ml. of 48% hydrobromic acid (0.8 mole) and 15 g. (0.16 mole) of α-aminopyridine. Bromine, 24 ml. (0.48 mole), was added dropwise with stirring and external cooling to 0–10°. The solution became turbid and the solid orange amine perbromide separated. A solution of 27.5 g. (0.40 mole) of sodium nitrite in 40 ml. of water was added to the cold solution. There was a vigorous evolution of gas and heat. A heavy oily layer which separated was washed with ice-water and treated with an excess of 10% ammonium hydroxide. The solution was extracted with ether, dried and the ether removed by evaporation. Upon standing, α-pyridone separated from the dark oily residue and was isolated by filtration, 1.0 g., m.p. 95–98°. The oil, upon distillation, b.p. 84° (18 mm.), was identified as α-bromopyridine, 8.5 g. (37%), $n^{20}D$ 1.5710 (lit.[17] $n^{20}D$ 1.5713).

II.—A solution of 10 g. (0.1 mole) of α-aminopyridine (IIIa) in 200 ml. of 25% sulfuric acid was cooled to 0°. To the cold solution a concentrated solution of 20 g. (0.3 mole) of sodium nitrite in 80 ml. water was added slowly. After a few minutes a solution of 10 g. (0.15 mole) of sodium azide in 75 ml. of water was added in small portions. During this operation there was a vigorous evolution of nitrogen gas. The solution was then made basic to litmus by adding solid sodium bicarbonate, and the insoluble inorganic salts were separated by filtration. The aqueous filtrate was then evaporated to dryness in an air stream and the residue was extracted with ethanol. Evaporation of the alcohol solution to dryness was followed by extraction of the residue with benzene. Precipitation of the product by adding low-boiling petroleum ether permitted the isolation of 4.8 g. (49%) of α-pyridone, m.p. 104–106°.

Preparation of the Tetrazoles.—A 10% aqueous alcohol solution of an α-halopyridine (0.01 mole) was mixed with an aqueous alcohol solution of sodium azide (0.02 mole) in a round-bottomed flask equipped with a reflux condenser. After careful addition of 5 ml. of 10% hydrochloric acid, the solution was refluxed for 30–45 hours. Concentration of the volume of solution by distillation, followed by cooling, brought about separation of solid tetrazoles which were recrystallized from alcohol acidified with a few drops of mineral acid: pyridotetrazole, colorless, m.p. 156–158°,[5] 69% yield from α-bromopyridine; 6-nitropyridotetrazole, light yellow, m.p. 138–140° dec.,[18] 74% yield, from 2-chloro-5-nitropyridine; 8-nitropyridotetrazole, light tan, m.p. 167–168° dec., 81% yield, from 2-chloro-3-nitropyridine.

Anal. Calcd. for $C_5H_3N_5O_2$: C, 36.37; H, 1.83; N, 42.42. Found: C, 36.45; H, 1.98; N, 42.37.

Pyridotetrazole was recovered unchanged from sulfuric acid heated to 120° and there was no visible decomposition of 6-nitropyridotetrazole by sulfuric acid at 100°; however, 8-nitropyridotetrazole decomposed under these conditions. Warm alcoholic potassium hydroxide decomposed 6-nitropyridotetrazole. Pyridotetrazole is soluble in most organic solvents with the exception of carbon disulfide. The nitropyridotetrazoles are, however, practically insoluble in benzene, carbon disulfide, dioxane, carbon tetrachloride, chloroform and petroleum ether; they rapidly develop colored solutions in pyridine, N,N-dimethylformamide and alcoholic alkali; they are very soluble in acetone and in acetonitrile.

Pyrolysis of Pyridotetrazole and 6-Nitropyridotetrazole.—Decomposition in decalin, diphenyl ether or without solvent yielded primarily reddish-brown solids which did not melt below 220°. These compounds have not been characterized, and are apparently polymeric.

Pyrolysis of 8-Nitropyridotetrazole.—In a 12-ml. centrifuge tube was placed 0.5 g. of 8-nitropyridotetrazole. The tetrazole was decomposed in a constant temperature bath of refluxing *m*-dichlorobenzene (170°) and was heated at this temperature for 10 minutes after the initial vigorous reaction had subsided. After cooling to room temperature, the thick red liquid product was extracted twice with 5-ml. portions of anhydrous ether, leaving a reddish-brown residue (less than 10 mg.) which did not melt below 220°.

The ether extracts were evaporated to dryness, yielding 0.40 g. (97%) of pyrido-2,3-furoxane as yellow crystals, m.p. 52–53° to amber melt.

Anal. Calcd. for $C_5H_3N_3O_2$: C, 43.80; H, 2.21; N, 30.65; mol. wt., 137.09. Found: C, 43.86; H, 2.52; N, 31.32; mol. wt. (Rast), 133, 136.

Reduction of Pyrido-2,3-furoxane.—A solution of 0.5 g. (0.004 mole) of pyrido-2,3-furoxane in 25 ml. of methanol was treated with 8.0 g. of sodium sulfide nonahydrate and 1.0 g. of sodium bicarbonate in 20 ml. of water. There was an immediate formation of a deep red color. The reaction mixture was allowed to reflux for 12 hours. An equal volume of water was then added and the mixture was filtered to remove traces of sulfur and undissolved inorganic salts. The dark red solution was evaporated to dryness and the residue upon recrystallization from ethanol afforded 0.08 g. (17% yield) of 2,3-diaminopyridine, m.p. 112°,[19] plus an unidentified oily product which may be pyrido-2,3-furazane.

Benzfuroxane[20] was prepared from *o*-nitrophenylazide.

2-Azido-3-nitrotetralin.—A solution of 15.5 g. (0.066 mole) of 2-acetylamino-3-nitrotetralin[21] in alcoholic hydrochloric acid was refluxed, for 15 minutes on the steam-cone. After cooling the solution to 0–5° in an ice–salt-bath it was treated with 4.55 g. (0.066 mole) of sodium nitrite in 10 ml. of water and allowed to stand with intermittent stirring for half an hour. To the cold filtered solution of the diazonium salt was added 4.42 g. (0.066 mole) of sodium azide in 10 ml. of water. Almost immediately 2-azido-3-nitrotetralin separated as a yellow solid, which upon recrystallization from ethanol separated as orange needles, m.p. 84–86°, wt. 13.1 g. (91.4% yield). After two more recrystallizations the melting point was constant at 85–86°.

Anal. Calcd. for $C_{10}H_{10}N_4O_2$: C, 55.04; H, 4.62. Found: C, 56.42; H, 4.59.

5,6-Tetramethylenebenzfuroxane.—A solution of 1.0 g. (0.005 mole) of 2-azido-3-nitrotetralin in 100 ml. of xylene (b.p. 137–140°) was heated between 110 and 120° for one hour or until nitrogen evolution (which was first detected at 107°) ceased. Evaporation of the solvent left a solid residue, of 5,6-tetramethylenebenzfuroxane, which after two recrystallizations from ethanol separated as orange plates, m.p. 106–107°, wt. 0.8 g. (92% yield).

Anal. Calcd. for $C_{10}H_{10}N_2O_2$: C, 63.15; H, 5.30; N, 14.73. Found: C, 63.52; H, 5.53; N, 14.73.

ANN ARBOR, MICHIGAN

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