[CONTRIBUTION FROM THE RESEARCH LABORATORY, DOMINION RUBBER COMPANY LIMITED]

Electrolytic Oxidation of Quinoline and 3-Picoline

BY MARSHALL KULKA

Nicotinic acid is made available by the oxidation of nicotine,[1] anabasine[2] and 3-picoline.[3] It is also produced from quinolinic acid which is the oxidation product of quinoline[4] substituted or unsubstituted in the benzene ring.

Yokoyama[5] describes the electrolytic oxidation of 3-picoline and nicotine by means of a lead dioxide anode in dilute sulfuric acid but there does not seem to be any record in the literature of the electrolytic oxidation of quinoline. This paper now reports an investigation into an electrolytic process for the conversion of quinoline to quinolinic acid. The effects of anolyte, current density, temperature, anodic materials, oxygen carriers and voltage on the oxidation of quinoline were studied.

The most suitable anolyte was aqueous sulfuric acid and the concentration of the acid had a marked effect on the oxidation. Best results were obtained by employing 75 to 85% (by weight) sulfuric acid. In 50% sulfuric acid a dark oxidation product was formed from which very little quinolinic acid could be isolated and in more dilute acid solutions no oxidation took place. The current density at the anode was studied over a range of 0.04 to 0.1 ampere per sq. cm. and it did not appear to have any appreciable effect on the oxidation. The reaction proceeded with best yields and highest current efficiency at a temperature of 70 to 90° at a platinum anode and 65 to 70° at a lead dioxide anode.

The choice of anodic materials was limited to platinum and lead because other metals and graphite disintegrated quickly in the strongly acid anolyte. Platinum and lead were not entirely resistant and considerable amounts also dissolved during the electrolysis (approximately one-half mg. of platinum per hour of oxidation). Platinum proved to be a better anode material than lead, 10 to 15% higher yields of quinolinic acid being obtained with the former. The most suitable form of platinum was a fine gauze or better still gauze coated electrolytically with a thin layer of platinum black. In order to find the most active oxygen carrier, the effects of manganese dioxide, potassium fluozirconate, ceric sulfate, ammonium molybdate, acetic acid, chromium trioxide, selenium dioxide and vanadium pentoxide on the oxidation were noted. It was found that the addition of small amounts of chromium trioxide, selenium dioxide and vanadium pentoxide to the anolyte resulted in increased yields of 5, 8 and 18% of quinolinic acid, respectively, the other compounds having no effect on the reaction. Voltage was an important factor in this oxidation. Best yields of quinolinic acid could be obtained when a voltage of three to four was maintained between the electrodes. Operation at higher voltages reduced the yield considerably. Finally when the optimum conditions were employed in the electrolytic oxidation, a 77% yield of quinolinic acid determined as the copper salt was obtained.

In the electrolytic oxidation of 3-picoline the optimum conditions were found somewhat different from those required for quinoline. They are described in the experimental.

Experimental

Electrolytic Oxidation of Quinoline.—A porous cup 2 inches in diameter was wrapped with a 52-mesh 3 by 6 inches fine platinum gauze (coated electrolytically with a thin layer of platinum black), tied with fine strands of platinum wire and placed inside an 800-cc. beaker. A 3 by 5 inches, 52-mesh piece of platinum gauze was introduced into the interior of the porous cup. The anolyte consisting of quinoline (150 g.), 75% (by weight) sulfuric acid (225 cc.) and vanadium pentoxide (0.1 g.) was introduced into the beaker, and the catholyte, 20% sulfuric acid, into the porous cup so that the levels of the liquids inside and outside the porous cup were the same. The platinum gauze on the exterior of the porous cup was made the anode and that on the interior the cathode by connecting to a d. c. car generator the speed of which was regulated so that it delivered a voltage of 3.2 to 3.5 across the electrodes. The anolyte was stirred mechanically and the temperature maintained at 80 to 90° by external heat application. The vigorous evolution of hydrogen at the cathode vaporized a considerable amount of the catholyte. It was replace by dropwise addition of 5% sulfuric acid. During the electrolysis the current flowing through the circuit varied from 4 to 4.5 amperes and after one-hundred and sixty-eight hours the oxidation was complete as shown by a change in appearance of the reaction mixture from dark non-transparent to a clear amber solution. The reaction mixture was then diluted with water and the electrodes and porous cup washed well in order to remove adsorbed quinolinic acid. The combined reaction mixture and washings were treated with 30% sodium hydroxide solution until just acid to congo red and the precipitated brown resinous material filtered off. The filtrate was heated to 90° and a hot aqueous solution of copper sulfate pentahydrate (385 g.) added. After heating on the steam-bath for about an hour, the reaction mixture was cooled, the light bluish-green copper salt (238 g., 77%) filtered off, washed and dried at 100°. The copper salt was converted to quinolinic acid in the usual manner by suspending in hot water and treating with hydrogen sulfide. The quinolinic acid so obtained was decarboxylated in boiling cyclohexanol to nicotinic acid in 90% yield.

Electrolytic Oxidation of 3-Picoline.—A thin perforated sheet of lead 3 by 1.5 inches was wrapped around a small porous cup and then placed in a small beaker containing the anolyte consisting of 3-picoline (9.3 g.) and 30% sulfuric acid (50 cc.). The cathode, a perforated lead sheet 2 by 1 inches and the catholyte, 30% sulfuric acid, were introduced into the interior of the porous cup. A current

---

(1) McElvain, "Organic Syntheses," Coll. Vol. I, p. 385; Woodward, Badgett and Willaman, *Ind. Eng. Chem.*, **36**, 540 (1944).

(2) Sadykov, *J. Gen. Chem. U. S. S. R.*, **15**, 252 (1945) [*C. A.*, **40**, 2159 (1946)].

(3) Woodward, Badgett and Kaufmann, *Ind. Eng. Chem.*, **36**, 544 (1944).

(4) Stix and Bulgatsch, *Ber.*, **65B**, 11 (1932); Van de Kamp and Sletzinger, U. S. Patent 2,392,437 (1946) [*C. A.*, **40**, 2473 (1946)].

(5) Yokoyama, *Bull. Chem. Soc. Japan*, **7**, 69, 103 (1932) [*C. A.*, **26**, 3256, 4050 (1932)].

of 3.6 to 3.9 amperes flowed through the circuit at a voltage of 3.8 to 4.0. The temperature of the anolyte was maintained at 40 to 45°. At the end of eight hours the oxidation was complete. The reaction mixture was worked up as in the case of the quinoline oxidation and copper nicotinate (9.6 g. or 60%) was obtained.

Summary

1. Quinoline has been oxidized electrolytically at a platinum anode in 75% sulfuric acid to quinolinic acid with a yield of 77%.

2. Nicotinic acid has been obtained by decarboxylation of quinolinic acid in cyclohexanol and also by the electrolytic oxidation of 3-picoline at a lead anode.

GUELPH, ONTARIO RECEIVED JUNE 17, 1946

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE JOHNS HOPKINS UNIVERSITY]

A Synthetic Ferroporphyrin Complex that is Passive to Oxygen[1]

BY ALSOPH H. CORWIN AND J. GORDON ERDMAN[2]

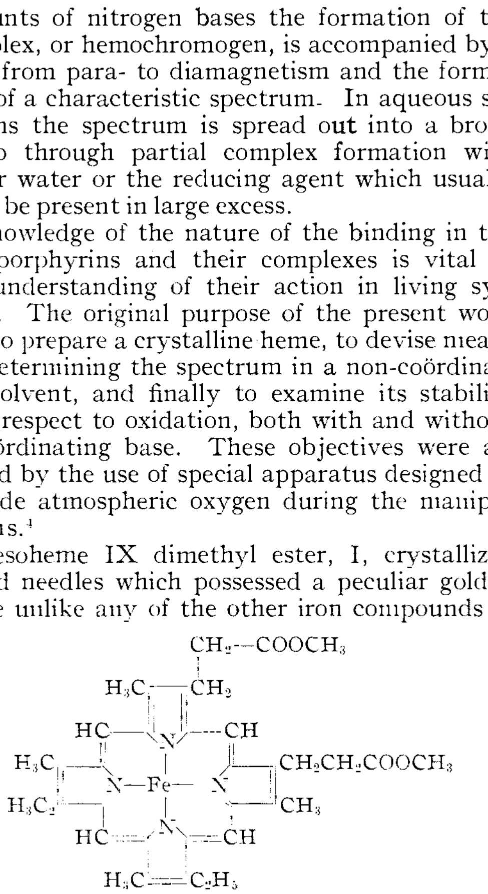
Hemoglobin possesses remarkable chemical properties other than its ability to combine reversibly with molecular oxygen. One of these is its passivity to oxygen, a property which has not been reported heretofore in ferroporphyrin complexes of known structure. Hemoglobin is a ferrous complex, potentially susceptible to oxidation, yet capable of combining with and transporting oxygen without being oxidized to the ferric state. An elucidation of the conditions under which passivity to oxygen may be expected should provide one of the specifications for the synthesis of compounds paralleling the chemical behavior of hemoglobin. The first step in a program with this objective would be the preparation of solutions of hemes, free from reducing agents, suitable for oxidation studies. This paper reports experimental conditions under which this objective may be attained. In the course of this work, conditions were discovered under which a ferroporphyrin complex coupled with pyridine is passive to atmospheric oxygen. The necessary reactions have been followed and the preparations analyzed spectroscopically.

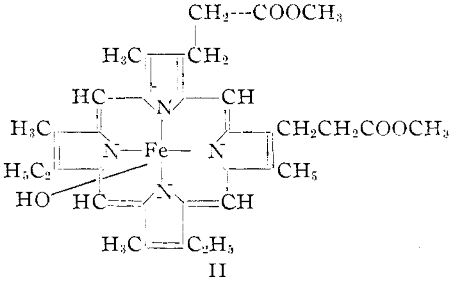
Preparation of pure ferroporphyrins, or hemes, has proved difficult, due to their extreme sensitivity to oxidation. So far an absorption spectrum for one of these substances in a non-coördinating solvent has not been reported. Fischer, Treibs and Zeile[3] prepared crystalline hemes for the first time. They report powder spectra of three bands somewhat resembling the ferric porphyrin chlorides or hemins. Powder spectra are complicated by strong molecular interactions and by selective scattering of the particles.

Spectra obtained by the addition of reducing agents such as hydrazine hydrate or sodium hydrosulfite to solutions of the ferric porphyrins in alkaline aqueous media or in nitrogen bases such as pyridine are complicated by the tendency of the iron to form complexes through its two remaining coördinate valencies. In the presence of large amounts of nitrogen bases the formation of the complex, or hemochromogen, is accompanied by a shift from para- to diamagnetism and the formation of a characteristic spectrum. In aqueous solutions the spectrum is spread out into a broad hump through partial complex formation with either water or the reducing agent which usually must be present in large excess.

Knowledge of the nature of the binding in the ferroporphyrins and their complexes is vital to our understanding of their action in living systems. The original purpose of the present work was to prepare a crystalline heme, to devise means for determining the spectrum in a non-coördinating solvent, and finally to examine its stability with respect to oxidation, both with and without a coördinating base. These objectives were attained by the use of special apparatus designed to exclude atmospheric oxygen during the manipulations.[4]

Mesoheme IX dimethyl ester, I, crystallized in red needles which possessed a peculiar golden lustre unlike any of the other iron compounds of


I


II

---

[1] Studies in the Pyrrole Series XVIII; Paper XVII, Erdman and Corwin, THIS JOURNAL, **68**, 1885 (1946).

[2] Present address, Mellon Institute, University of Pittsburgh, Pittsburgh, Pennsylvania.

[3] Fischer, Treibs and Zeile, *Z. physiol. Chem.*, **195**, 1 (1931).

[4] *Cf.* Hieber, Sonnekalb and Becker, *Ber.*, **63**, 978 (1930).