Catalytic Liquid-Phase Oxidation of Aldehydine to Nicotinic Acid

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HE demands during the recent World War II for vitamins stimulated research on converting a number of potential raw materials into these products. Nicotinic acid was one vitamin to receive attention. The common methods of preparation included oxidation of natural products, such as nicotine (3) and trigonelline (5, 22), and of certain coal tar bases, such as β -picoline (1, 8) and quinoline (7, 20, 23), and the conversion of pyridine into cyanopyridine followed by hydrolysis (14, 17). Usually liquid phase reactions were carried out, but vapor phase oxidations have also been reported (2, 24), generally with lower yields. Oxidizing agents, such as nitric acid (4), chlorine (15, 21), permanganates and chromates (12), have been used but the recent work has been largely with sulfuric acid and a catalyst. Woodward and coworkers (23), Mueller (10, 11), and others (9) in a number of patents report the use of selenium as an oxidation catalyst. Mueller (11) uses nitric acid with sulfuric acid to lower the reaction temperature and Teeters (16) uses halogen compounds as catalysts for the sulfuric acid oxidation.

In certain German reports (18, 19) it was shown that aldehydine was oxidized with nitric acid, hydrolyzable nitrates, and chromates to nicotinic acid or at least to the dicarboxylic acid of pyridine. High pressure equipment, expensive oxidizing agents, and corrosion problems offered complications in these cases.

In this work the oxidation of aldehydine was carried out with sulfuric acid and a selenium catalyst following somewhat the procedure used by Woodward and coworkers (23).



Copper, mercury, nickel, cobalt, and manganese were among the catalysts tried but only with selenium dioxide were good yields obtained. This is in agreement with the superior catalytic behavior of selenium as a catalyst for reactions involved in the Kjeldahl analysis (13). The increased oxidation rate, in the presence of selenium, is probably due to a rapid and reversible reaction of the type Se $+ O_2 \leftrightarrows SeO_2$. Very little oxidation took place below the boiling point of the sulfuric acid but, at that temperature, a mixture of sulfur dioxide, carbon dioxide, water, selenium, and sulfuric acid distilled over.

A comparison of the yields obtained in this investigation with those reported by Woodward and coworkers shows that the yields were equivalent or somewhat above those obtained from β -picoline or quinoline. However, more of the oxidizing agent was required to oxidize the side chains. At the temperature of the reaction, the isochincomeronic acid was decarboxylated to nicotinic acid which remained in the residue as the acid sulfate. Instead of recovering the nicotinic acid as the copper salt, followed by a caustic treatment to liberate the nicotinic acid, it was recovered directly by solvent extraction. To accomplish this the oxidation residue was diluted with water and neutralized to a pH of approximately 3.5 with sodium hydroxide, in a manner designed to obtain a solution saturated with sodium sulfate. A pH of 3.5 was found optimum for nicotinic acid recovery. This solution was continuously extracted at 95° to 98° C. with butyl alcohol until substantially all of the nicotinic acid was in the butyl alcohol. Removal of the butyl alcohol by simple distillation yielded a crude product, which was purified by carbon treatment and recrystallization from water.

EXPERIMENTAL

The aldehydine used in this work was prepared by the reaction of paraldehyde, ammonia, and ammonium acetate under pressure, following the method of Frank and others (θ). It had a boiling point of 177° C. at 760 mm., specific gravity of 0.919 at 24° C., and a refractive index of 1.4970 $\frac{20}{D}$.

OXIDATION. A typical experiment illustrates the method used.

A 5-liter, 3-neck round-bottomed flask was fitted with a thermometer graduated from 0° to 360° C., an air bleed leading below the surface of the reaction mixture, a condenser connected to the reactor with a short Hempel column to reduce spray, and a 250ml. dropping funnel. The sulfur dioxide formed in the reaction was allowed to escape through the condenser into a caustic solution. A slight vacuum was kept on the system to prevent sulfur dioxide from escaping into the atmosphere.

the system to prevent sum the set of the system to prevent sum divide from escaping into the atmosphere. In the reactor flask were placed 1030 grams of sclenium dioxide. A mixture of 1030 grams of concentrated sulfuric acid, 4 grams of sclenium dioxide, and 121 grams of aldehydine was placed into the dropping funnel. The reactor charge was heated to about 300° C. The mixture in the dropping funnel was added to the reactor while maintaining a temperature of 300° to 310° C. About $1^{1/2}$ hours were required for this addition, after which the mass was heated until the temperature reached 350° C. The reactor mass (approximately 200 grams) was transparent and had a red color. The distillate of approximately 450 grams was 60 to 70% sulfuric acid. It was badly discolored with amorphous sclenium. The diameter of the condenser system had to be large enough to prevent being plugged by the sclenium, which sublimed out of the reaction mixture. The reaction mass in the reactor was diluted with an equal volume of water and neutralized to a pH of 3.5 with 33% sodium hydroxide. The purpose of using the concentrated solutions was to have a solution saturated with sodium sulfate at the end of the neutralization.

RECOVERY OF CRUDE NICOTINIC ACID BY SOLVENT EXTRAC-TION. The equipment consisted of a solvent boiler, a condenser, and an extractor vessel, the latter so fitted that the vapors for the boiler condensed and percolated through the neutralized sodium sulfate-nicotinic acid solution to extract the nicotinic acid and then overflowed into the boiler for concentration. The boiler was a 3-liter flask and the extractor was a flask of 3- or 5-liter volume, depending on the size of the charge. It was found desirable to have the aqueous layer filling about two thirds of the capacity of the extractor.

shape to have the addeduct layer fining about two thirds of the capacity of the extractor. The extractor was charged with the aqueous solution and then filled with *n*-butyl alcohol. The boiler was filled about two thirds full of butyl alcohol and then heated to boiling with a Glas-col electric heater. The extractor was maintained at about 93° C. with a hot water bath. The extraction was continued until the butyl alcohol extract showed no nicotinic acid on evaporating to dryness. To recover the product the butyl alcohol was distilled off and the solid dried in a vacuum oven. The yield

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		TABL	EI. Ox	IDATION OF	ALDEHYDE	WITH SULFI	JRIC ACID	
Run No.	Cat Com- pound	G./mole of alde- hydine	Alde- hydine, G.	Reaction Temp., °C.	Reaction Time, HrMin.	Melting Pt., Crude Nicotinic Acid, °C.	Yield, Crude Nicotinic Acid, % of Theory	Remarks
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17	CuO HgSO4 NiSO4 CoSO4 SeO2 SeO2 SeO2 SeO2 SeO2 SeO2 SeO2 SeO2	6 24 24 24 24 10 10 10 10 10 8 6 4 4 6 6 6 6 6	$\begin{array}{c} 60.5\\ 60.5\\ 60.5\\ 121\\ 121\\ 121\\ 121\\ 60.6\\ 60.5\\ 60.5\\ 60.5\\ 60.5\\ 60.5\\ 60.5\\ 121\\ 242\\ 121\\ \end{array}$	$\begin{array}{r} 290-310\\ 300-328\\ 300-323\\ 311-325\\ 311-323\\ 270-360\\ 305-356\\ 307-360\\ 305-360\\ 305-360\\ 305-360\\ 309-355\\ 301-352\\ 309-348\\ 300-352\\ 309-348\\ 300-352\\ 305-360\\ \end{array}$	3 0 2 8 2 45 2 15 1 30 2 30 2 10 1 43 2 30 2 30 2 38 2 38 2 38 2 30 1 00 5 15 5 00	$\begin{array}{c} 218-214\\ 210-212\\ 209-214\\ 214-216\\ 214-216\\ 213-217\\ 173-177\\ 182-190\\ 158-164\\ 202-209\\ 195-200\\ 214-216 \end{array}$	82 81 78.71.5 74.8 78.8 78.8 78.1 84.5 62 82 67 80	Tar only Tar only Tar only Tar only Tar only Tar only Very dark product Very dark product Very dark product

of crude product, which had a melting point above 200° C., was 90 to 100 grams. This material was purified by carbon treatment and recrystallization from water. A product with a melting point of 234° C. and containing less than 1 p.p.m. of selenium was usually obtained.

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In Table I it is obvious that copper, mercury, nickel, cobalt, and manganese were ineffective as catalysts and were no improvement over sulfuric acid alone. A study of runs 9 to 14 shows that 4 grams of selenium dioxide per mole of aldehydine were definitely too little, 6 grams were on the borderline, and 10 grams were definitely sufficient. A reaction time of $2^{1}/_{2}$ hours was generally sufficient but as much as 5 hours appeared to show no harmful effects. Below approximately 300° C. little, if any, reaction took place as evidenced by little or no evolution of gases and water until after 300° C. was reached. A final temperature of 340° C. seemed desirable but as high as 360° C. was not harmful. Runs 6, 7, and 8 are believed typical of what can be expected under normal reaction conditions.

SUMMARY

Using selenium dioxide as a catalyst and sulfuric acid as the oxidizing agent, aldehydine can be converted into nicotinic acid in good yields.

Allyl Ethers of Methylolmelamines

S PART of a study of methylolmelamines and their ethers the preparation and properties of the allyl ethers of several methylolmelamines have been examined. Particular attention has been given to the fully allylated ether of that methylolmelamine prepared by condensing 4.5 moles of formaldehyde with 1 mole of melamine, referred to hereafter as tetramethylolmelamine. These allyl ethers were of particular interest in view of the drying properties which they might possess, by analogy with allyl ethers of other series (1, 4, 5, 7).

The fully allylated ether of tetramethylolmelamine has been isolated as a hydrophobic gum and exhibits typical drying properties. By reacting this material with additional formaldehyde approximately two additional nonetherified methylol groups were introduced; the drying properties of this material were less pronounced. The hexaallyl ether of hexamethylolmelamine was also prepared but no drying study was made. It was impossible to avoid the formation of gels during an attempt to etherify a

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LITERATURE CITED

- (1) Cislak, U. S. Patent 2,396,-457 (1946).
- (2) Cislak and Wheeler, Can. Patent 424,546 (1944); Brit. Patent 568,889 (1945); U. S. Patent 2,-437,938, 2,456,380 (1948).
- (3) Dean and King, U. S. Patent 2,409,345 (1946).
- (4) Ibid., 2,410,254 (1946).
- (5) Fox, U. S. Patent 2,413,615 (1946).
- (6) Frank, Blegen, Dearborn, Meyers, and Woodward, J. Am. Chem. Soc., 68, 1368 (1946).
- (7) Hawkinson and Elston, U. S. Patent 2,371,691 (1945).
- (8) Henze, Ber., 67B, 750 (1934).
- (9) Luxema, Soc. anon., Sté. Holding Luxembourgeoise, Belg. Patent 473,726 (1947).
- (10) Mueller, U. S. Patent 2,436,660 (1948).
- (11) Ibid., 2,449,906 (1948).
- (12) Ogilvie and Sweet, U. S. Patent 2,371,691 (1945).
- (13) Screenivasan and Sadasivan, IND. ENG. CHEM., ANAL. ED., 11, 314 (1939).
- (14) Shive and Glenn, U. S. Patent 2,409,806 (1946).
- (15) Stitz, Österr. Chem.-Ztg., 45, 159 (1942).
- (16) Teeters, U. S. Patent 2,476,004 (1949).
- (17) Tisza and Duesel, Ibid., 2,406,972 (1946).
- (18) U. S. Dept. of Commerce, Washington 25, D. C., Office of Technical Service, PB602, Ludwigshafen II, A-4 (1941), PB718, Leverkusen III, B-12 (1942).
- (19) U. S. Dept. of Commerce, Washington 25, D. C., Office of Technical Service, PB639, Ludwigshafen II, B-10 (1942), PB705, Leverkusen III, A-20 (1941).
- (20) Van de Kamp and Sletzinger, U. S. Patent 2,392,437 (1946).
- (21) Vosyunina, Beer, and Preohrazheuskii, J. Applied Chem. (U.S.S.R.), 16, 206 (1943).
- (22) Wejland, Messerly, and Tishler, U. S. Patent 2,381,794 (1945).
- (23) Woodward, Badgett, and Kaufman, IND. ENG. CHEM., 36, 544 (1944).
- (24) Woodward, Badgett, and Willaman, Ibid., 36, 540 (1944).

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commercial spray-dried, water-soluble methylolmelamine (3) containing approximately 2.5 methylol groups per molecule. In contrast with the above allyl ethers, a sample of the *n*-propyl ether of tetramethylolmelamine prepared as a control exhibited no drying characteristics.

Clear water dispersions of the ethers listed above have been prepared by the action of sulfur dioxide or sulfite. In the authors' opinion the process is that described earlier for saturated ethers (x) and does not involve addition of sulfite to the unsaturated allyl radicals. A survey of the literature showed that the conditions necessary for this type of addition reaction are radically different from those used in the present investigation; their application to the problem at hand is impossible because of the certain polymerization they would promote with any ether of a polymethylolmelamine.