Oxidation with Nickel Peroxide.[1] A New Synthesis of Amides from Aldehydes or Alcohols

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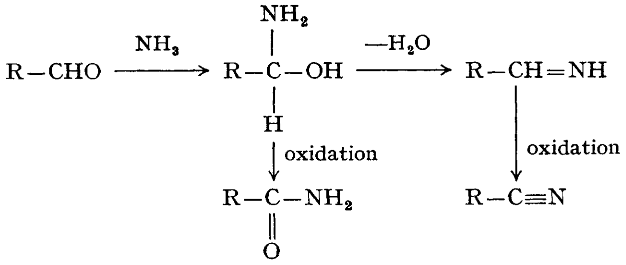
WHILE investigating oxidations effected by nickel peroxide, we found that aromatic or allylic aldehydes can be converted into amides in good yields by oxidation at −20° in an ether solution of ammonia. At higher temperatures, the yields of amides decreased and nitriles were produced as main products. The reaction mechanism may be envisaged as:



$$\begin{tikzcd} R{-}CHO \arrow[r, "NH_3"] & R{-}\overset{NH_2}{\underset{H}{C}}{-}OH \arrow[r, "-H_2O"] \arrow[d, "oxidation"] & R{-}CH{=}NH \arrow[d, "oxidation"] \\ & R{-}\underset{\underset{O}{\|}}{C}{-}NH_2 & R{-}C{\equiv}N \end{tikzcd}$$

TABLE I

Reaction temperature (° c)	Product (%)			
	p-Chlorobenzoic acid	*p*-Chlorobenzonitrile	Recovered *p*-chlorobenzaldehyde	*p*-Chlorobenzamide
−25	5·3	0	0	92·3
−20	8·6	0	0	89·4
0	17·4	0	0·6	72·2
10	29·0	4·6	3·0	56·6
20	27·9	13·8	16·0	36·5
35	14·8	34·2	42·0	4·8
78[a]	26·2	50·5	10·0	8·5

All oxidations were carried out with 0·05 mol. of aldehyde in 150 ml. of ether using nickel peroxide at 1·3 times the theoretical amount (available oxygen content in oxidant was determined by iodometry).
[a] Benzene was used as solvent.

The yields of products obtained from *p*-chlorobenzaldehyde at various temperatures are given in Table I. The general procedure was as follows. The solution of an aldehyde in freshly distilled ether was stirred under nitrogen, and dry ammonia gas was introduced until the solution was saturated at −20°. Then nickel peroxide was added in small portions over one hour, and ammonia was bubbled through the stirred reaction mixture for about 4 hr. at −20°. The mixture was filtered, the solid was washed with hot methanol, and the crude product obtained by removal of the solvent was recrystallized from ethyl acetate. This reaction was successfully applied to several kinds of aldehydes as shown in Table II.

In an earlier paper,[2] it was shown that allylic or benzylic alcohols were readily oxidized by nickel peroxide in organic solvents to give the corresponding carbonyl compounds in excellent yields. Therefore, it was thought that amides might be prepared directly from alcohols using nickel peroxide in a similar way. To test this possibility, benzyl alcohol and ammonia were treated with nickel peroxide by increasing the amount of oxidant in ether solution under the same conditions described for aldehydes, and a 71·2% yield of benzamide was obtained. Similarly cinnamamide (79·8%) and furfuramide (65·1%) were obtained from the corresponding alcohols.

TABLE II

Aldehyde	Yield (%) of amide
p-Chlorobenzaldehyde	89·4
o-Chlorobenzaldehyde	77·3
m-Nitrobenzaldehyde	88·0
Benzaldehyde	89·2
p-Cyanobenzaldehyde	76·8
p-Dimethylaminobenzaldehyde	57·6
p-Methoxybenzaldehyde	88·3
p-Methylbenzaldehyde	86·7
Piperonal	85·7
Cinnamaldehyde	84·7
Furfural	85·8

All oxidations were performed in ether at −20°.

It is known[3] that the oxidation of aldehyde and ammonia with lead tetra-acetate in benzene gives only a nitrile. The different results obtained with nickel peroxide are quite interesting and useful.

Further application of this reaction to other kinds of aliphatic and heteroaromatic alcohols and aldehydes is in progress, and the use of an alkylamine instead of ammonia is also being studied.

(*Received, December 2nd,* 1965; *Com.* 753.)

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[3] K. N. Parameswaran and O. M. Friedman, *Chem. and Ind.*, 1965, 988.