

HYDROLYSIS OF AROMATIC NITRILES BY ALKALINE HYDROGEN PEROXIDE

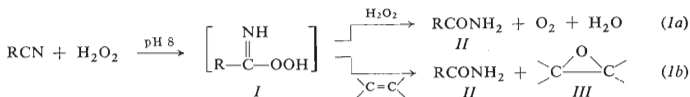
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Alkaline hydrogen peroxide (30%) at pH 8 was used to hydrolyse benzonitrile to benzamide, terephthalonitrile to *p*-cyanobenzamide and diamide of terephthalic acid, and isophthalonitrile to *m*-cyanobenzamide and diamide of isophthalic acid. The reaction carried out in the presence of an olefin yielded corresponding epoxide as an additional product.

Hydrolysis of nitriles to amides by water proceeds relatively reluctantly, and in general, the reaction requires elevated temperatures and pressures¹. This is due to the low reactivity of the hydroxyl anion in its addition to the nitrile group. If alkaline hydrogen peroxide is used in place of water, the reaction proceeds best at pH 8 already under mild conditions, since perhydroxyl anion adds to the nitrile group much easier than hydroxyl anion. The reaction of organic nitriles with alkaline hydrogen peroxide is known as Radziszewski reaction². The intermediate product of this reaction is generally assumed to be peroxycarboximidic acid (*I*) which reacts with another molecule of hydrogen peroxide to give amide (*II*), oxygen, and water (equation (*Ia*)) (ref.³).



Peroxy-carboximidic acid has not as yet been isolated, its solutions show, however, typical properties of peracids and react, for instance, with an olefin, which is stronger reducing agent than hydrogen peroxide, to give amide *II* and olefin epoxide⁴ *III* (equation (*Ib*)). Aromatic nitriles are in general more reactive than aliphatic nitriles, and their conversion by alkaline hydrogen peroxide was used to prepare amide of *o*-toluic acid⁵ and veratrylamide⁶. Apart from one report published in the year 1917 (ref.⁷), no data are available on hydrolysis of aromatic dinitriles by alkaline hydrogen peroxide. In connection with preparation of diamides of aromatic carboxylic acids or of cyanobenzamides, which could be obtained from corresponding dinitriles, we have subjected this reaction to a more detailed study, both in the presence and absence of an olefinic hydrocarbon.

Hydrolysis of benzonitrile, terephthalonitrile, and isophthalonitrile by alkaline hydrogen peroxide was carried out in methanol at 40°C and pH 8 in the presence or absence of cyclohexene. The formation of cyclohexene oxide in the course of

the reaction was followed by gas chromatography and the formation of oxygen by means of a bubble burette. Optimum reaction conditions were checked with a benzonitrile–hydrogen peroxide–cyclohexene system. In methanol and in the absence of the nitrile, only negligible spontaneous decomposition of hydrogen peroxide to oxygen and water occurred at 40°C. Formation of oxygen during hydrolysis of the nitrile in the presence of cyclohexene corresponded to 10–15% conversion of hydrogen peroxide according to Eq. (1a). In order to maintain the alkalinity of the reaction mixture at pH 8 during the reaction, potassium hydrogen carbonate was added at once in the amount of 10 mol % with respect to benzonitrile. With lower concentrations of potassium hydrogen carbonate the reaction rate depended on its concentrations; further increase of its concentration (up to 30 mol %) did not affect the reaction rate. The commonly used sodium hydroxide has to be added intermittently in small portions during the reaction, while continuously checking the pH of the reaction mixture, since an eventual increase of pH would lead to a spontaneous decomposition of hydrogen peroxide.

Hydrolysis of benzonitrile by alkaline hydrogen peroxide gave benzamide in 80% yield. Products of hydrolysis of aromatic dinitriles were corresponding diamides and cyanobenzamides. The yields of diamides depended on the ratio of starting substances, on reaction time, and on the base used. Diamides of terephthalic and isophthalic acids were obtained in maximum yields 80 and 71%, respectively (Table I). The

TABLE I

Effects of Molar Ratio of Reaction Components, Reaction Time, Type of the Base and Its Concentration on the Yield of Diamide in Hydrolysis of Terephthalonitrile and of Isophthalonitrile by Hydrogen Peroxide in Methanol at 40°C in the Absence of Olefin

Molar ratio of reaction components				Reaction time, h	Yield of diamide, %
Terephthalonitrile	isophthalonitrile	hydrogen peroxide	KHCO ₃		
1	—	1	0.1	5.5	33
1	—	2	0.1	5.5	33
1	—	4	0.25	7.5	33
1	—	4	0.5	12	67
1 ^a	—	4	— ^b	7.5	80
—	1.5	2	0.1	5.5	21
—	1	4	0.5	14.5	52
—	1 ^a	4	— ^c	7.5	71

^a Instead of KHCO₃ 0.5M-NaOH was added gradually during the reaction. ^b A total of 10 ml 0.5M-NaOH was added. ^c A total of 6 ml 0.5M-NaOH was added.

product yields of dinitrile hydrolysis for the reaction carried out in the presence of cyclohexene were compared with those obtained in the absence of this olefin under the same reaction conditions and are presented in Table II. As follows from these results, the presence of cyclohexene in the reaction mixture favourably affects the yields of the diamides. The product of hydrolysis obtained by partial conversion of dinitriles contained cyanobenzamide which is the reaction intermediate.

In the presence of cyclohexene the additional reaction product was cyclohexene oxide. At the ratio of reaction components: cyclohexene : benzonitrile : hydrogen peroxide = 1 : 1.2 : 1.2, 65% conversion of cyclohexene was achieved after 5 h. Using a 2.4-fold excess of hydrogen peroxide the conversion of cyclohexene increased to 93%. In hydrolysis of terephthalonitrile and of isophthalonitrile cyclohexene was converted to cyclohexene oxide to a lesser extent (max. 90 and 77%, respectively). The course of epoxidation reaction, which in the hydrolysis of nitriles has not yet been studied, is shown in Fig. 1. The higher molar ratio of hydrogen peroxide in the reaction mixture increased the conversion of cyclohexene to cyclohexene oxide, while the higher molar ratio of dinitrile with respect to the other reaction components did not affect this conversion.

These results demonstrate that hydrolysis of aromatic nitriles by alkaline hydrogen peroxide is a simple method for preparing aromatic amides and diamides. The yields of diamides obtained in this way are comparable to or even higher than those obtained by water hydrolysis of nitriles at elevated temperatures and pressures, performed

TABLE II

Hydrolysis of Terephthalonitrile and of Isophthalonitrile by Hydrogen Peroxide in the Presence and Absence of Cyclohexene in Methanol at 40°C

Molar ratios of reaction components: cyclohexene: terephthalonitrile: hydrogen peroxide = 1 : 2 : 2; cyclohexene : isophthalonitrile : hydrogen peroxide = 1 : 1.5 : 2; reaction time 3 h.^a

Dinitrile	Cyclohexene		Over-all yield of hydrolytic products mol. %	Composition of hydrolytic products mol. %	
	mol/l ^b	conversion %		cyanobenzamide	diamide
Terephthalonitrile	0.025	77	61	38	62
Terephthalonitrile	0	—	57	42	58
Isophthalonitrile	0.025	67	79	40	60
Isophthalonitrile	0	—	60	60	40

^a Concentration of KHCO_3 was 10 mol % with respect to dinitriles. ^b Initial concentration.

in the case of terephthalonitrile in the presence of magnesium oxide⁸, ammonia⁹, and formic acid¹⁰. Hydrolysis of aromatic dinitriles by alkaline hydrogen peroxide can also be used to prepare corresponding cyanobenzamides, and the reaction therefore offers an alternative method for their preparation by hydrolysis in the presence of ion exchangers¹¹. Another advantage of the nitrile hydrolysis by alkaline hydrogen peroxide is the formation of epoxy compounds when the reaction is carried out in the presence of olefins.

EXPERIMENTAL

Chemicals. Benzonitrile (99.7%), a product of toluene amoxidation (Research Institute of Organic Syntheses, Pardubice - Rybitví), was distilled prior to using; b.p. 190–191°C. Terephthalonitrile, a product of *p*-xylene amoxidation (Research Institute of Organic Syntheses, Pardubice - Rybitví) was crystallised twice from dioxane; m.p. 222–223°C (ref.¹² m.p. 224°C). Isophthalonitrile, a product of *m*-xylene amoxidation (Research Institute of Organic Syntheses, Pardubice - Rybitví) was crystallised twice from dioxane; m.p. 162°C (ref.¹² m.p. 161°C). Cyclohexene was prepared by dehydration of cyclohexanol on alumina and was rectified prior to using; b.p. 81.5–82°C. Hydrogen peroxide, analytical purity (30%, Chemical Works, Sokolov), methanol, analytical purity, (Lachema, Brno), potassium hydrogen carbonate, analytical purity (Loba-Chemie, Wien) and cyclohexene oxide, pure (>95%, Fluka Basel), were used without further purification.

Determination of cyclohexene oxide in the reaction mixture. Conversion of cyclohexene to cyclohexene oxide was followed by gas chromatography. Conditions of chromatographic analysis:

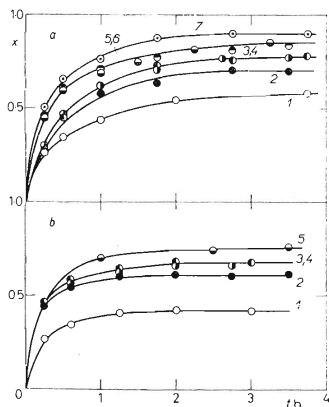


FIG. 1

Time Dependence of Conversion (x) of Cyclohexene to Cyclohexene Oxide in Methanol at 40°C for Varying Molar Ratios of Hydrogen Peroxide to Dinitrile

a Cyclohexene: terephthalonitrile: hydrogen peroxide 1 1:1:1; 2 1:1.5:1.5; 3 1:2:2; 4 1:1:2; 5 1:1:3; 6 1:2:3; 7 1:2:4; *b* Cyclohexene: isophthalonitrile: hydrogen peroxide 1 1:1:1; 2 1:1:1.5; 3 1:1:2; 4 1:1.5:2; 5 1:1:3.

a 3.6 m-column filled with diglycerol (15%) on Chromaton N (0.16—0.20 mm); column temperature 104°C, nitrogen flow rate 11 ml/min. Analyses were performed with a Chrom 31 instrument (Laboratorní přístroje, Prague) equipped with an integrator and using calibration by authentic samples of cyclohexene and cyclohexene oxide.

Hydrolysis of benzonitrile by hydrogen peroxide in the presence of cyclohexene. A three necked flask equipped with a reflux condenser, a regulating thermometer, a bubble burette, and a magnetic stirrer, was charged with 5.15 g of benzonitrile (0.05 mol), 3.3 g cyclohexene (0.04 mol), and 40 ml of methanol. The mixture was heated to 39°C, and 5.6 g of 30% hydrogen peroxide (0.05 mol) containing 0.5 g of freshly dissolved potassium hydrogen carbonate were added. The mixture temperature was maintained at $40 \pm 0.5^\circ\text{C}$ and in the samples taken at fixed time intervals cyclohexene was determined by gas chromatography. After completion of the reaction (5 h) the reaction mixture was evaporated by heating *in vacuo* until benzamide began to crystallise. The residue was diluted with water and cooled, the solid substance was filtered off and washed successively with water and light petroleum. The yield of benzamide was 4.85 g (80%), m.p. 127—128°C. Isolation of cyclohexene oxide was not attempted.

Hydrolysis of terephthalonitrile and of isophthalonitrile by hydrogen peroxide. A mixture of 6.4 g of the appropriate dinitrile (0.05 mol), and 2 g of cyclohexene (0.025 mol) in 60 ml of methanol was heated at 39°C, and a freshly prepared solution of 0.5 g of potassium hydrogen carbonate (0.005 mol) in an appropriate volume of 30% hydrogen peroxide (0.05—0.20 mol) was added. The reaction mixture was maintained at a temperature of $40 \pm 0.5^\circ\text{C}$. From the reaction mixture which became homogenous (in the case of terephthalonitrile not completely) shortly after beginning of the reaction a white precipitate gradually began to set down. The precipitate was filtered off and extracted twice with 15 ml of hot acetone. The solid substance so isolated was identified as the diamide of the corresponding acid. The filtrate from the amide isolation was freed of unreacted hydrogen peroxide by addition of silver powder, evaporated to dryness, and the solid residue was extracted thrice with 15 ml of hot acetone; the extracts were combined with the acetone extracts obtained in the isolation of the diamides and were evaporated to dryness. The solid unreacted dinitrile and the product were easily separated by fractional sublimation. Terephthalonitrile or isophthalonitrile sublimed at normal pressure at 150—170°C and the *meta*- or *para*-cyanobenzamide sublimed at 190—220°C/20 Torr. The isolation of cyclohexene oxide was not attempted. Hydrolysis of dinitriles by hydrogen peroxide in the absence of cyclohexene, the work-up of the reaction mixture as well as the isolation of products were carried out in a similar fashion. The yields of the above reactions are presented in Tables I and II. Isolated products were characterized as follows: Diamide of terephthalic acid, m.p. 332°C, dec. (ref.¹¹ m.p. 300°C, dec.). For $\text{C}_8\text{H}_8\text{N}_2\text{O}_2$ (164.2) calculated: 58.53% C, 4.91% H, 17.07% N; found: 58.29% C, 4.82% H, 17.16% N.

p-Cyanobenzamide, m.p. 222—223°C (ref.¹¹ m.p. 223°C). For $\text{C}_8\text{H}_6\text{N}_2\text{O}$ (146.2) calc. 65.75% C, 4.14% H, 19.17% N; found: 66.00% C, 4.29% H, 19.20% N.

Terephthalonitrile, m.p. 222—223°C (ref.¹² m.p. 224°C). For $\text{C}_8\text{H}_4\text{N}_2$ (128.1) calc. 74.99% C, 3.15% H, 21.87% N; found: 75.12% C, 3.23% H, 21.97% N.

Diamide of isophthalic acid, m.p. 279—280°C (ref.¹³ m.p. 280°C). For $\text{C}_8\text{H}_8\text{N}_2\text{O}_2$ (164.2) calc. 58.53% C, 4.91% H, 17.07% N; found: 58.29% C, 4.85% H, 17.12% N.

m-Cyanobenzamide, m.p. 222°C (ref.¹¹ m.p. 222°C). For $\text{C}_8\text{H}_6\text{N}_2\text{O}$ (146.2) calc. 65.75% C, 4.14% H, 19.17% N; found: 65.71% C, 4.13% H, 19.31% N.

Isophthalonitrile, m.p. 162°C (ref.¹² m.p. 161°C). For $\text{C}_8\text{H}_4\text{N}_2$ (128.1) calc. 74.99% C, 3.15% H, 21.87% N; found: 75.10% C, 3.23% H, 21.99% N.

REFERENCES

1. Farkas A., Szonyi G.: US-Pat. 3 113 964 (1963); Chem. Abstr. 60, 6792 (1964).
2. Radziszewski B.: Ber. 17, 1389 (1884).
3. Wiberg K. B.: J. Am. Chem. Soc. 75, 3961 (1953).
4. Payne G. B., Deming P. H., Williams P. H.: J. Org. Chem. 26, 659 (1961).
5. Noller C. R.: Org. Syn., Coll. Vol. 2, 586 (1943).
6. Buck J. S., Ide W. S.: Org. Syn., Coll. Vol. 2, 44 (1943).
7. McMaster L., Langreck F. B.: J. Am. Chem. Soc. 39, 103 (1917).
8. Gasson E. J., Hadley D. J.: Brit. Pat. 801 125 (1958); Chem. Abstr. 53, 8080 (1959).
9. Archipova I. A., Rafikov S. R., Suvorov B. V.: Ž. Obšč. Chim. 33, 637 (1963).
10. Becke F., Gnad J.: German Pat. 1 283 220 (1968); Chem. Abstr. 70, 47131 (1969).
11. Berther C.: Chem. Ber. 92, 2616 (1959).
12. Ikeda T., Kibatake M., Ito M., Noguchi I.: Bull. Chem. Soc. Japan 41, 1158 (1968).
13. Aschan O.: Ann. 387, 36 (1912).

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