

The Dehydration Reactions of Aldoximes

By Teruaki MUKAIYAMA and Tsujiaki HATA

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The dehydration reactions of nitroparaffin and aldoxime with isocyanate, carbodiimide, acetylenic ether and ketene acetal have been described in the previous papers^{1,2)}. In one of the preceding papers, it was proposed that compounds containing a triple bond or a twinned double bond may be used as a useful dehydrating reagent. In addition, the dehydration reaction of aldoxime with ketene acetal containing a double bond and two alkoxyl groups turns out to be also successful. It is

also known that iminochloride³⁾ containing a double bond and a chlorine atom reacts with water much more easily, yielding acid amide rather than nitrile containing a triple bond. These results lead to conclusion that not only the compounds containing a triple bond or a twinned double bond but also the compounds containing a double bond and an atom or atomic group, such as halogen alkoxyl or acyloxyl groups, would become effective dehydrating reagents.

Referring to the above results it appears

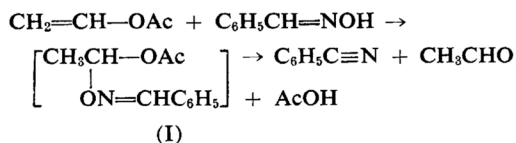
1) T. Mukaiyama and T. Hoshino, *J. Am. Chem. Soc.*, **82**, 5339 (1960).

2) T. Mukaiyama and T. Hata, This is now presented to this Bulletin.

3) J. v. Braun, F. Jostes and W. Münch, *Ann.*, **453**, 113 (1927).

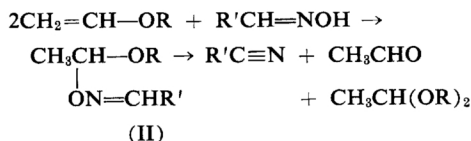
feasible to extend the dehydration reactions of nitroparaffin and aldoxime by using vinyl ether or vinyl acetate in place of acetylenic ether described in the preceding paper. Firstly, the reaction of vinyl *n*-butyl ether and aldoxime is tested in the presence of tertiary alkyl amine, but no reaction occurs and the starting materials are recovered quantitatively. The dehydration reaction is also not observed, when vinyl acetate is treated with benzaldoxime under the same condition.

It is known that the addition reaction⁴⁾ of vinyl acetate with an alcohol to form an acetal is well conducted in the presence of boron trifluoride and mercuric oxide. Accordingly, vinyl acetate and benzaldoxime are reacted in the presence of a catalytic amount of boron trifluoride and yellow mercuric oxide in place of a basic catalyst. A violent reaction takes place and benzonitrile, acetaldehyde and acetic acid are obtained in good yields.



Analogous to the explanation used for the dehydration with acetylenic ether, it is reasonable to consider that the reaction proceeds through an intermediate I which gives nitrile and hemiacetal. The latter decomposes to give acetaldehyde and acetic acid.

By the same method, the reaction of vinyl ether and aldoxime gives nitrile in equally good yield along with acetaldehyde and acetal.

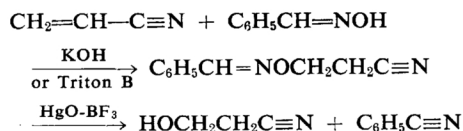


In order to evaluate experimentally the intermediate of the reaction, namely the addition compound of vinyl ether and aldoxime, the isolation of the compound II is tried. Since the catalysts, boron trifluoride and mercuric oxide, may accelerate both the initial addition reaction and the subsequent decomposition reaction, an equimolar amount of triethyl amine to neutralize boron trifluoride is added to the reaction system of vinyl ether and aldoxime immediately after the liberation of heat ceases. By this method the addition compound is isolated in high yield. And the addition compound is observed to decompose on heating in the presence of a catalytic amount of boron trifluoride and mercuric

oxide to give 82% yield of nitrile. Consequently, it can be concluded that the coexistence of boron trifluoride and mercuric oxide is effective in accelerating the decomposition of the associated addition compounds with vinylogs, and conducts the dehydration of aldoximes. The decomposition of the adduct II cannot be observed in the absence of the said catalysts and it is recovered quantitatively after refluxing for 7 hr. in benzene.

Further, it is confirmed that benzaldoxime is recovered unchanged, when it is refluxed for 6 hr. in the presence of a catalytic amount of boron trifluoride in benzene. It can be concluded that the dehydration reaction of benzaldoxime is conducted with vinyl ether or vinyl acetate.

In order to examine the possibility of dehydration of aldoximes with vinylogs having an electron-withdrawing substituent which usually show different reactions from vinyl ether or vinyl acetate, acrylonitrile is reacted with benzaldoxime in the presence of a catalytic amount of boron trifluoride and mercuric oxide. No reaction is then observed and the starting materials are recovered. On the other hand, the addition reaction of acrylonitrile with aldoxime is known as an example of cyanoethylation⁵⁾ when strong bases are used. The addition compound of acrylonitrile and benzaldoxime is synthesized initially according to the method of Bruson and Riener and it is successfully decomposed to give nitrile and ethylene cyanohydrin on heating in the presence of a catalytic amount of boron trifluoride and mercuric oxide.

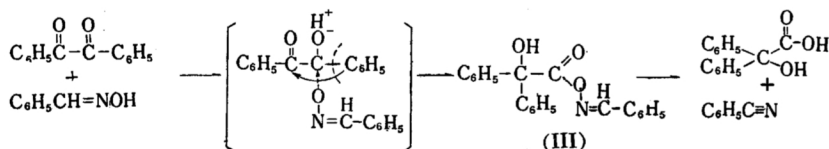
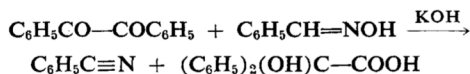


In the next place, the dehydration reaction of aldoxime with a compound containing carbon-oxygen double bond is studied. It is generally shown that carbonyl compounds react with water to form unstable *gem*-dihydroxy compounds which exist in equilibrium with the starting materials and can scarcely be isolated. On this basis, it is said that these compounds cannot be used as a dehydrating reagent in the present type of reaction. It is, however, known that benzil containing two carbonyl groups reacts with water to form a stable benzilic acid and this is considered to be an example of carbonyl compounds as a dehydrating reagent. The reaction of benzil with aldoxime in the presence of a small

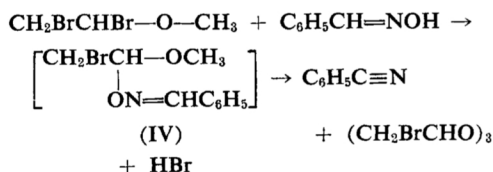
4) W. J. Croxall, F. J. Glavis and H. T. Neher, *J. Am. Chem. Soc.*, **70**, 2805 (1948).

5) H. A. Bruson and T. W. Riener, U. S. Pat., 2352514 (*Chem. Abstr.* **38**, 5506 (1944)).

amount of potassium hydroxide is tried and nitrile and benzoic acid are obtained as expected.

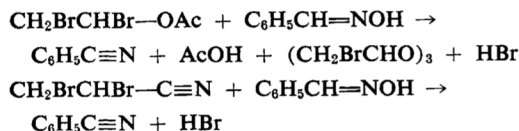


Further, in the course of preparing acetylenic ether according to the method of Arens⁶⁾, it is found that the intermediate, α, β -dibromoethyl methyl ether, reacts violently with water to form bromoacetaldehyde and hydrogen bromide. On the consideration that such compounds which readily react with water can be used as a dehydrating reagent of the present type of dehydration, the reaction of α, β -dibromoethyl methyl ether with aldohime is tried and nitrile results quantitatively along with hydrogen bromide.



This reaction can be explained by introducing the intermediate IV which is yielded by the reaction of aldohime and the ether. The IV, which is similar to the addition compound of vinyl ether and aldohime, decomposes to give nitrile and hemiacetal. The latter decomposes to aldehyde and alcohol.

Similarly, nitrile is obtained quantitatively when aldohime is reacted with α, β -dibromoethyl acetate and α, β -dibromopropionitrile respectively as shown in the following equations.

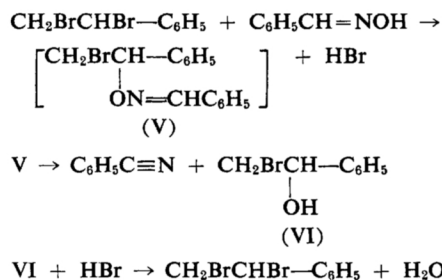


These reactions are carried out in the absence of a catalyst, and the initially formed hydrogen bromide may be considered to accelerate the reactions.

On the other hand, the treatment of benzoaldohime with α, β -dibromoethylbenzene yields

The reaction can be shown by the following scheme which involves the initial formation of the addition compound of benzil and aldohime, and the subsequent rearrangement of the phenyl group to form III. This decomposes to nitrile and benzoic acid by transferring its hydrogen atom.

the dehydrated product of benzonitrile and water in high yields, and the starting material of dibromo compound is unexpectedly recovered. The recovery of the dibromo compound can be satisfactorily explained by considering the replacement reaction of initially formed β -hydroxy- β -phenylethylbromide with hydrogen bromide, as shown in the following equations. The unexpected isolation of water is considered to be due to the low reactivity of α, β -dibromoethylbenzene with water as compared with α, β -dibromoethylmethyl ether and α, β -dibromoethyl acetate.



Experimental

Reaction of α -Benzaldohime with Vinyl Acetate.

—A solution of 10 drops of boron trifluoride (40% ether solution) and 0.6 g. of yellow mercuric oxide in 10 ml. dry benzene was added dropwise over a 30-min. period to a solution of vinyl acetate (16 g., 0.186 mol.) and α -benzoaldohime (11.3 g., 0.093 mol.) in 20 ml. dry benzene with continuous stirring. Then acetaldehyde and benzene were distilled into a 2,4-dinitrophenylhydrazine solution. The yield of acetaldehyde 3.6 g., (44% of theoretical) was calculated from the yield of acetaldehyde 2,4-dinitrophenylhydrazone thus obtained. The liquid residue was distilled to give acetic acid 8.1 g., (72% of theoretical), b. p. 55°C (61 mmHg) and benzonitrile 8.7 g., (91% of theoretical), b. p. 85–87°C (23 mmHg) was obtained.

Reaction of n -Heptanaldohime with Vinyl Methyl Ether.—To a solution of n -heptanaldohime (5 g., 0.039 mol.) and methyl vinyl ether (5 g., 0.089 mol.) were added 2 drops of boron trifluoride (40% ether solution) and 0.1 g. of yellow mercuric

6) J. F. Arens, *Rec. trav. chim. Pays-Bas*, **74**, 271 (1955).

oxide. After shaking the mixture for 30 min., it became clear, and then it was heated under reflux for 5 hr. After removing acetaldehyde and benzene, acetaldehyde dimethyl acetal 3.5 g., (89% of theoretical), b. p. 64~66°C and heptanitrile 1.7 g., (40% of theoretical), b. p. 54°C (8 mmHg) were obtained.

Reaction of α -Benzaldoxime with Vinyl Methyl Ether.—To a solution of α -benzaldoxime (15 g., 0.123 mol.) and methyl vinyl ether (15 g., 0.268 mol.) in 20 ml. dry benzene were added 5 drops of boron trifluoride (40% ether solution) and 0.3 g. of yellow mercuric oxide. After shaking the mixture for 30 min., it was heated under reflux for 6 hr. After removal of acetaldehyde and benzene, acetaldehyde dimethyl acetal 4.0 g., (34% of theoretical), b. p. 62~64°C and benzonitrile 10.2 g., (80% of theoretical), b. p. 48~50°C (3 mmHg) were obtained.

Addition Compound of α -Benzaldoxime and Ethyl Vinyl Ether.—To a solution of ethyl vinyl ether (3.6 g., 0.05 mol.) and 0.05 g. of yellow mercuric oxide in 10 ml. dry benzene was added dropwise a solution of α -benzaldoxime (6.1 g., 0.05 mol.) and 2 drops of boron trifluoride (40% ether solution) in 5 ml. dry benzene with continuous stirring over a 10-min. period at room temperature. The reaction mixture became warm and clear soon. After rapid cooling, 4 drops of triethyl amine was added to the solution. After removal of benzene, an attempt was made to distil the liquid residue. Addition compound of benzaldoxime and ethyl vinyl ether 7.8 g., (80% of theoretical), b. p. 92~93°C (4.5 mmHg) was obtained.

Found: C, 68.62; H, 7.86; N, 7.41. Calcd. for $C_{11}H_{15}O_2N$: C, 68.37; H, 7.82; N, 7.25%.

Decomposition of the Addition Compound of α -Benzaldoxime and Ethyl Vinyl Ether.—To a solution of the addition compound of α -benzaldoxime and ethyl vinyl ether (1.9 g., 0.01 mol.) in 10 ml. dry ether were added 5 drops of boron trifluoride (40% ether solution) and yellow mercuric oxide (0.05 g.). Then the mixture was heated under reflux for 7 hr. After removal of acetaldehyde and ether, ethanol 0.4 g., (87% of theoretical), b. p. 77~78°C and benzonitrile 0.85 g., (83% of theoretical), b. p. 69°C (10 mmHg) were obtained.

Reaction of α -Benzaldoxime with Acrylonitrile.—To a solution of α -benzaldoxime (8 g., 0.066 mol.) and acrylonitrile (3.5 g., 0.066 mol.) in 15 ml. dry benzene was added 0.2 g. of potassium hydroxide. The mixture was heated under reflux for 5 hr. After removal of benzene, the addition compound of α -benzaldoxime and acrylonitrile 5.2 g., (45% of theoretical), b. p. 150°C (6 mmHg) was obtained.

Found: N, 16.12. Calcd. for $C_{10}H_{10}N_2O$: N, 16.09%.

The same result was obtained when Triton B was used in place of potassium hydroxide.

Decomposition of the Addition Compound of α -Benzaldoxime and Acrylonitrile.—To a solution of the above mentioned addition compound (5.2 g., 0.03 mol.) in 10 ml. dry benzene were added 10 drops of boron trifluoride (40% ether solution) and 0.1 g. of yellow mercuric oxide. The mixture was heated under reflux for 12 hr. After removal of benzene, benzonitrile 1.6 g., (44% of theoretical), b. p. 188~189°C and ethylene cyanohydrin 0.7 g.,

(33% of theoretical), b. p. 221~223°C were obtained.

Reaction of α -Benzaldoxime with Benzil.—To a mixture of α -benzaldoxime (1.2 g., 0.01 mol.) and benzil (2.1 g., 0.01 mol.) was added 0.1 g. of well-ground potassium hydroxide. After the mixture was heated on the water-bath for 30 min., it was left on stand for 5 days at room temperature and a large amount of benzoic acid was separated. It was filtered and washed with light petroleum ether and recrystallized from 95% ethanol, 0.5 g., (22% of theoretical), m. p. 150°C. After removal of the low boiling point fractions from the filtrate, benzonitrile 0.2 g., (20% of theoretical), b. p. 78~80°C (18 mmHg) was obtained.

Reaction of α -Benzaldoxime with α , β -Dibromoethyl Methyl Ether.— α -Benzaldoxime (6.7 g., 0.055 mol.) was added dropwise to a solution of α , β -dibromoethyl methyl ether in 10 ml. dry benzene with continuous stirring at room temperature. A large amount of white precipitate separated, and then it dissolved with evolving hydrogen bromide, when the mixture was heated under reflux. After heating the mixture for 6 hr., the resulting solution was distilled under reduced pressure and benzonitrile 5.3 g., (93% of theoretical), b. p. 75° (17 mmHg) was obtained. From the residue a small amount of bromoacetaldehyde trimer, m. p. 102~104°C, was obtained.

Reaction of α -Benzaldoxime with α , β -Dibromoethyl Acetate.— α -Benzaldoxime (9.9 g., 0.081 mol.) was added dropwise to a solution of α , β -dibromoethyl acetate (20 g., 0.081 mol.) in 20 ml. dry benzene with continuous stirring. After the mixture was heated under reflux for 2 hr., the resulting solution was worked up in the usual manner and acetic acid 2.2 g., (46% of theoretical), b. p. 118°C and benzonitrile 4.8 g., (57% of theoretical), b. p. 61~63°C (7 mmHg) were obtained. From the residue a small amount of bromoacetaldehyde trimer, m. p. 103~104°C, was obtained.

Reaction of α -Benzaldoxime with α , β -Dibromopropionitrile.— α -Benzaldoxime (11.4 g., 0.094 mol.) was added dropwise to a solution of α , β -dibromopropionitrile (20 g., 0.094 mol.) in 20 ml. dry benzene with continuous stirring. After heating the mixture under reflux for 3 hr., the resulting solution was worked up in the usual manner, benzonitrile 9.7 g., (98% of theoretical), b. p. 77~78°C (15 mmHg) was obtained.

Reaction of α -Benzaldoxime with α , β -Dibromoethylbenzene.— α -Benzaldoxime (2.4 g., 0.05 mol.) was added to a solution of α , β -dibromoethylbenzene (5.3 g., 0.05 mol.) in 15 ml. dry benzene. The mixture was heated under reflux for 5 hr. After removal of benzene, water and benzonitrile were distilled and water 2.0 g., (56% of theoretical) and benzonitrile 1.3 g., (65% of theoretical), b. p. 76~78°C (15 mmHg) were obtained. α , β -Dibromoethylbenzene 3.7 g., (70% of theoretical), b. p. 137~139°C (15 mmHg) was recovered.

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*Department of Chemistry
Tokyo Institute of Technology
Meguro-ku, Tokyo*