The Condensation of Acetonitrile with Formaldehyde

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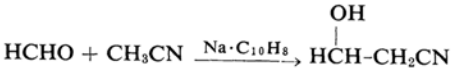
(Received June 3, 1963)

The condensations of nitriles with aldehydes have been reported with both acidic and basic catalysts. Examples of an acid-catalyzed condensation are the formation of methylenebisamides or that of triacyltrihydrotriazines.[1,2] In base-catalyzed condensations, the nitriles with an active methylene group, such as cyanoacetic acid,[3] ethyl cyanoacetate[4,5] and malononitrile[6], can easily be converted to the corresponding α, β-unsaturated nitriles. It has been shown that the reaction of acetonitrile with aldehyde is difficult with ordinary base catalysts, but that it reacts with benzaldehyde or benzophenone, using sodium amide as a catalyst, yielding β-hydroxynitriles, i. e., β-hydroxy-β-diphenylpropionitrile, respectively.[7] However, the aldol-type condensation of acetonitrile with such aliphatic aldehydes as formaldehyde has not yet been reported.

The present paper will describe the aldol-type condensation of acetonitrile with formaldehyde in tetrahydrofurane (THF), using as a base catalyst sodium naphthalene complex, which has been proved to be effective for the alkylation of nitriles with aldehydes.[8] Although the reaction was complicated by side reactions, β-hydroxynitrile (ethylene cyanohydrin) was identified in the reaction product by gas chromatography and spectrography.



$$HCHO + CH_3CN \xrightarrow{Na\cdot C_{10}H_8} H\overset{OH}{C}H\text{-}CH_2CN$$

In the reaction product, 2, 4, 6-trimethyltriazine was also detected. A similar reaction using a SiO_2-NaOH catalyst[8a] at 280~300°C was unsuccessful.

Experimental

Materials.—Acetonitrile (first grade) was dried over anhydrous potassium carbonate and fractionally distilled (b. p. 81~82°C). Naphthalene was of the first grade. THF (first grade) was dried over sodium for a few days and distilled over sodium hydroxide in an all-glass apparatus protected from the moisture in the air by a calcium chloride tube (b. p. 66°C).

Preparation of Sodium Acetonitrile.—Sodium acetonitrile was prepared according to the Horner-Güsten method;[8] 5.0 g. (0.2 mol.) of sodium was added to a solution of 25.6 g. (0.21 mol.) of naphthalene in 200 ml. of THF, and the mixture was stirred at room temperature for about 3 hr. in an atmosphere of nitrogen. The solution was then added slowly to a solution of 25.6 ml. (0.2 mol.) of acetonitrile in 100 ml. of THF at −8 and −10°C.

Reaction of Sodium Acetonitrile with Formaldehyde.—Gaseous formaldehyde was preparaed by dropping liquid paraffin slurry, containing 12 g. of paraformaldehyde, into a preheated flask at 115~140°C. The gaseous formaldehyde was bubbled into the THF solution of sodium acetonitrile for one hour at room temperature and then for an additional 0.5 hr. to ensure the completion of the reaction. The resulting yellow and viscous liquid was carefully neutralized with concentrated hydrochloric acid. Instead of gaseous formaldehyde, paraformaldehyde and trioxane could be used, but the yields were poorer (see Table I).

Ehtylene cyanohydrin in the products was isolated according to the following scheme:

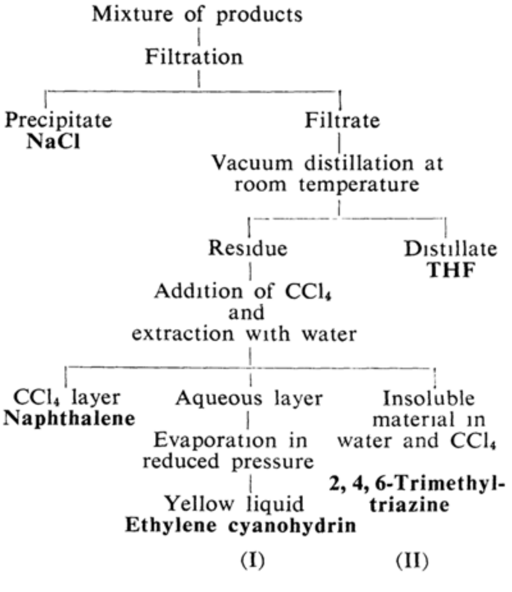


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TABLE I. REACTION OF ACETONITRILE WITH FORMALDEHYDE

Aldehyde	Reaction time hr.	Reaction temp. °C	$HOCH_2CH_2CN$ yield, %
Gaseous formaldehyde	2(1)[a]	0∼5	6.0
Gaseous formaldehyde	2(1)[a]	15	6.4
Gaseous formaldehyde	2(1)[a]	20	7.7
Paraformaldehyde	2	30	0
Paraformaldehyde	2	50	1.0
Trioxane	2	50	2.8

a) The figures in the parenthesis are the bubbling time (hr.) of gaseous formaldehyde.

Identification of Ethylene Cyanohydrin.—Both infrared spectrography and gas chromatography showed that the main component in the products (I) was identical with an authentic sample of ethylene cyanohydrin, prepared from ethylene chlorohydrin and sodium cyanide. The wave numbers (cm^{-1}) of the characteristic absorption bands of ethylene cyanohydrin and the product sample are as follows: 3400 (ν_{OH}), 2920 (ν_{CH_2}), 2260 (ν_{CN}), 1410 ($\delta_{CH_2(CN)}$), 1060 (ν_{CO})cm^{-1}.[9]

Figure 1 presents the gas chromatography curves on the authentic and resulting ethylene cyanohydrin; these also support our findings.

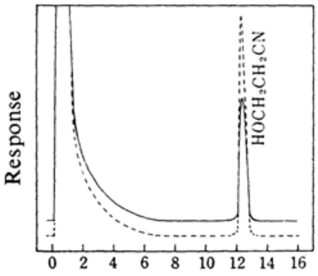


Fig. 1. Gas chromatography curves on ethylene cyanohydrin.
Partition liquid: PEG 4000, 25 wt.%/ Celite 545, 80∼100 mesh
Column length: 2 m.
Column temp.: 203°C
Carrier gas: He 49 ml./min.
Detection current: 150 mamp.
——: EtOH solution of I
- - -: Addition of pure ethylene cyanohydrin to the above solution.

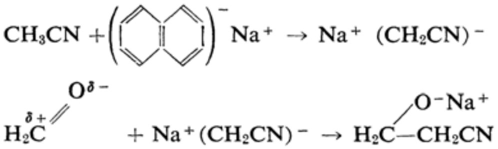
It was found both by a qualitative test of nitrogen (alkali fusion) and by ultraviolet absorption spectrography that the insoluble material (II) in water and carbon tetrachloride contained 2, 4, 6-trimethyltriazine, since it has the characteristic absorption band at 254 mμ (256 mμ[10]) in ethanol.

The yields on the basis of used acetonitrile, together with the reaction conditions, are presented in Table I.

The yields of ethylene cyanohydrin in these experiments were estimated by gas chromatography. The yields, high (6.0∼7.7 %) with gaseous formaldehyde, tended to be lower (1.0∼2.8%) with paraformaldehyde and trioxane.

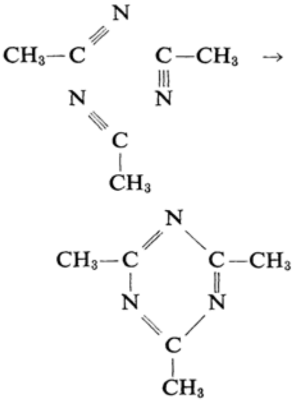
Discussion

The present fiindings show that formaldehyde can be reacted with acetonirile through the aldol-type condensation to form ethylene cyanohydrin. The reaction appeares to proceed by way of the attack of the carbanion of acetonitrile on the carbonyl carbon of formaldehyde.



$$H_2\overset{\delta+}{C}=O^{\delta-} + Na^+(CH_2CN)^- \rightarrow H_2C(O^-Na^+)-CH_2CN$$

The above reaction was successful with a strong base catalyst such as sodium naphthalene, but it appears that the reaction does not occur with a weaker base because of the difficulty of forming carbanion. The base-catalyzed polymerizations of acetonitrile may also occur—for instance, the trimerization of acetonitrile:



2, 4, 6-Trimethyltriazine

In fact, we could identify 2, 4, 6-trimethyltriazine.

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The poor yield of ethylene cyanohydrin may be due to the formation of such polymers of acetonitrile as cyamethine, *N*-(2, 6-dimethyl-*N*-(2, 6-dimethyl-4-pyrimidyl)-acetamidine, and 2, 4, 6-trimethyltriazine, the hydrolysis of acetonitrile and/or the base-catalyzed condensation of formaldehyde.[10)] The other aliphatic aldehydes, e. g., acetaldehyde, are easily subject to aldol condensation by themselves; hence, the reaction with acetonitrile was found to be difficult.

Summary

The condensation of acetonitrile with formaldehyde using sodium naphthalene as a base catalyst has been studied. The results showed that formaldehyde reacted with acetonitrile through the aldol-type condensation to form ethylene cyanohydrin (1.0∼7.7%). 2, 4, 6-Trimethyltriazine was detected as one of the by-products.

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