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CHARACTERIZATION OF THE PRIMARY PRODUCTS FROM DISPLACEMENT REACTIONS OF 2-(CHLOROMETHYL)FURANS

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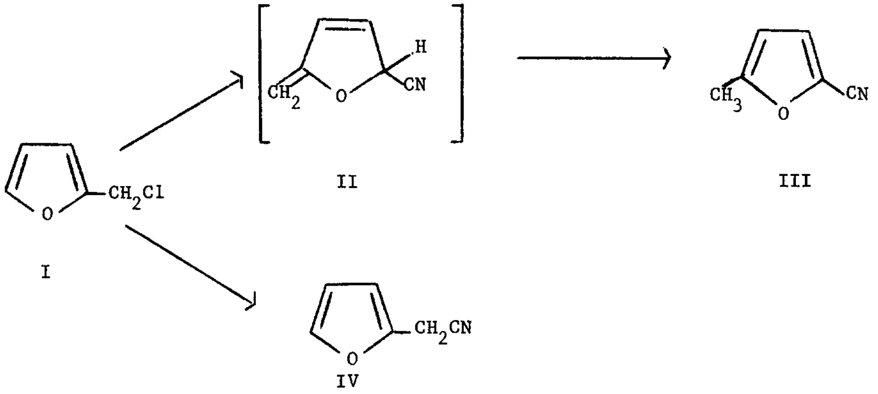
Earlier investigators[1-3] postulated that the formation of 5-methyl-2-furonitrile (III) in the reaction of 2-(chloromethyl)furan (I) and aqueous KCN solution, should occur through an intermediate, 5-methylene-2,5-dihydro-2-furonitrile (II). However, no experimental evidence was provided to support the existence of such an intermediate. Recently some support for this theory was put forward, when analogous exomethylene compounds were isolated from the alcoholysis of I, and from the reactions of 2,5-bis(chloromethyl)furan with cyanides.[4-6]



In the course of the present investigation, an unexpected set of resonances were found in the NMR spectrum of the crude product mixture obtained from the reaction of I and aqueous potassium cyanide solution at 0°. These resonances disappeared in about fifteen minutes while the intensity of the resonances assigned to III increased proportionally. The amount of IV present in the reaction mixture remained unchanged. These observations indicated the presence of a transient species preceding the formation of III.

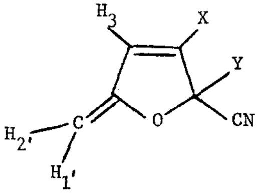
Subsequent experiments proved that the compound responsible for these resonances could be sufficiently stabilized and partially isolated for further studies. These studies had to be carried out on an approximately 1 : 1 mixture of the unknown and IV, since the latter could not be removed even by vapor phase chromatography.

The IR spectrum of the unknown showed the absence of the C-H stretching vibrations characteristic for the aromatic furan ring. A new absorption at 3120cm^{-1}, and the bands at 1665, 1632, 880, and 690cm^{-1} were diagnostic for the presence of vicinal and geminal vinyl hydrogens. The two strong absorptions at 1215 and 1098cm^{-1} could be identified with a vinyl ether structure. These features are consistent with the structure of the proposed intermediate II.

The NMR spectrum of the mixture was taken neat, in 25% CCl_4, and in CH_3SOCH_3 solutions, using TMS as the internal standard. The chemical shifts of the resonances attributed to the unknown are shown in Table I, as well as the spectral data of some analogous compounds.

TABLE I.

NMR Spectra of Some 5-Methylene-2,5-Dihydro-2-Furonitriles.[a]



X	Y	Solvent	H_3 and H_4	H_5	$H_{1'}$	$H_{2'}$
$-H_4$	$-H_5$	neat	6.26	5.67	4.43	4.20
$-H_4$	$-H_5$	CCl_4	6.27	5.68	4.42	4.18
$-H_4$	$-H_5$	$(CH_3)_2SO$	6.59	6.07	4.45	4.27
$-C(CH_3)$	$-H_5$	CCl_4	6.03	5.60	4.27	4.02
$-H_4$	$-CH_3$[b]	CCl_4	6.06	-	4.42	4.15

[a] Values are given in ppm (δ); given δ values represent the center of a multiplet. [b] The CH_3 resonance is found at δ 1.66.

The NMR spectrum of the unknown is consistent with the proposed structure of II. The validity of this assumption was confirmed by its similarity to the NMR spectrum of 2-methylene-2,5-dihydro-5-methoxyfuran, obtained by L. A. Hill[5], and to the spectra of 2-methylene-2,5-dihydrofuran derivatives obtained by J. Ficini.[7] The assignment of the individual resonances to the corresponding protons was based on comparisons to the spectra of analogous molecules.[8-14]

A neutralized sample containing about 50% each of II and IV proved to be surprisingly stable. It could be stored at room temperature for 24 hours without observable deterioration. It could be kept for weeks in the refrigerator. It withstood temperatures up to 80° without noticeable decomposition. Our observations indicate that pure II is more stable than IV. Its stability is comparable to that of III.

A crude sample of II, containing probably some dissolved KCN and/or HCN, was aromatized thermally at 14°, and the progress of the reaction was monitored through NMR spectra taken at regular intervals. From the data thus obtained, the rate of disappearance of II was calculated using a first-order approach, and a rate constant $k_1 = 6.5 \times 10^{-4}$ sec $^{-1}$ was obtained. Other experimental evidence indicated that this was a pseudo first-order rate constant.

A purified sample containing about 50% of II was treated with aqueous potassium cyanide solution for one hour at 0°. The NMR spectrum of the product showed no traces of II. Quantitative measurements indicated that II was transformed into III quantitatively.

A similar sample was heated with a buffered solution of acetic acid and sodium acetate for one hour. After this period, the starting material was quantitatively recovered.

When the aromatization of II was attempted in 80% ethanolic potassium hydroxide solution, at room temperature, the NMR spectrum of the product showed the presence of about 7% of III. However, the principal product was identified as 2-ethoxy-5-methylfuran. Although this result was unexpected, the reaction seems to be analogous to those of substituted 2,5-dihydro-2-furonitriles reported by Belogorodskii and his associates.[15]

The results of these experiments show that II may be considered either an isolable intermediate or a primary product unstable under the usual reaction conditions. If one considers II to be a product, then the formation of III from I should take place in two distinct steps: the reaction of I with the cyanide ion to give II as the major product and IV as the secondary product. This process appears to be monomolecular. When II is unstable under the reaction conditions, it is converted immediately to the usually isolated product, III. Experimental evidence supports a bimolecular mechanism for this step.

The formation of a substituted analog of II was also observed, when 4-t-butyl-2-(chloromethyl)furan was treated with KCN in aqueous solution. The NMR spectrum of 3-t-butyl-5-methylene-2,5-dihydro-2-furonitrile is shown in Table I. Although this compound was not isolated, it appeared to be somewhat more stable than its unsubstituted analog.

2-Methyl-2,5-dihydro-5-methylene-2-furonitrile was obtained as the minor product (21%) from the reaction of 5-methyl-2-(chloromethyl)furan with aqueous potassium cyanide. The NMR spectrum of this compound is also shown in Table I. Although this dihydro derivative cannot react further through aromatization, it decomposes rapidly under the reaction conditions.

The implications of these results on the mechanism of the reaction between 2-(chloromethyl)-furan and aqueous cyanide solutions will be discussed in a later publication.

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