

Significant peaks are also found at  $m/e$  175 and  $m/e$  160 ( $M-\text{COCH}_2\text{R}$  and  $M-15-\text{COCH}_2\text{R}$ ).

The molecular compositions of all peaks are proved by accurate mass measurements and the loss of HR is confirmed by metastable peaks at  $m^*$  155 and  $m^*$  140, respectively.

*E. glandulosum* H.B. & K. (syn. *E. adenophorum* Spr.) contained none of the above mentioned chromenes, but an oily component  $\text{C}_{14}\text{H}_{16}\text{O}_3$  (Found: 232.1101. Calc. 232.1099). Its spectral properties were identical to methyleupatoriochromene A (2) formed on methylation of eupatoriochromene A (1) with dimethylsulphate and potassium carbonate.

NMR spectra were recorded on a Varian A-60-A spectrometer with  $\text{CDCl}_3$  (Merck) as solvent. Mass spectral measurements were done on an AEI MS 902 instrument.

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## Equilibrium Protonation of a Carbon Base Prior to its Hydrolysis. The Acid-catalyzed Cleavage of the Furan Ring

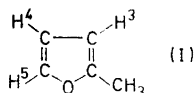
ALPO KANKAANPERÄ and SIRKKA KLEEMOLA

*Department of Chemistry, University of Turku, Turku, Finland*

In a previous study<sup>1</sup> of the hydronium ion-catalyzed hydrolysis of furan and 2,5-dimethylfuran, two alternative mechanisms were shown to be in accord with the experimental results. First, a rate-determining proton transfer with a Brønsted  $\alpha$  of almost unity. Second, a protonation pre-equilibrium and subsequent heterolysis of the protonated substrate. Although the lack of detectable general acid catalysis and the measured solvent deuterium isotope effect,  $k_{\text{D}_2\text{O}^+}/k_{\text{H}_3\text{O}^+}=2.15$ , were best interpreted in the terms of the latter mechanism, the rate-determining proton transfer mechanism could not be wholly excluded.

Stamhuis *et al.*<sup>2</sup> have proposed that proton transfer is the rate-determining stage in the hydrolysis of furans. Unfortunately, this assumption is mainly based on the reported value of the solvent deuterium isotope effect,  $k_{\text{D}_2\text{O}^+}/k_{\text{H}_3\text{O}^+}=0.59$ , which greatly differs from the value determined by Salomaa and Kankaanperä.<sup>1</sup> (An explanation for this discrepancy is photochemical side reactions that take place when the reaction system is exposed to ultraviolet light.<sup>1</sup>)

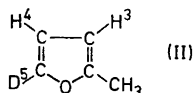
The above problem can be solved if it is possible to measure the rate of proton (or its isotopic equivalent) uptake by the substrate and the rate of ring cleavage, both under the same conditions. This paper presents such data. The kinetics of the deuterium uptake by 2-methylfuran (I) and the hydrolytic cleavage of the ring were studied in solutions of hydrochloric acid in a dioxane- $\text{D}_2\text{O}$  mixture (3:1 w/w).



*Experimental.* The used 2-methylfuran was a product of Koch and Light Ltd. To check the purity of the compound, its NMR spectrum was recorded (10 % solution in carbon tetrachloride with TMS as the internal standard): 1 H at  $\delta$  5.85 ppm (3-hydrogen), 1 H at  $\delta$  6.13 ppm (4-hydrogen), 1 H at  $\delta$  7.18 ppm (5-hydrogen), and 3 H at 2.27 ppm (2-methyl). Other signals were not detected.

The hydrolysis of the furan derivative was studied in 0.1 M solution of DCl in a dioxane-D<sub>2</sub>O mixture (3:1 w/w). About 15 vol. % of 2-methylfuran was added to the acid solution and after vigorous shaking the reaction mixture was sealed in the NMR tube which was placed in the variable temperature probe. The temperature of the block was adjusted to 70°C. The NMR spectrum of 2-methylfuran was recorded at suitable intervals during the hydrolysis reaction. A Perkin Elmer R 10 spectrometer was used in the measurements.

By following the hydrolysis of 2-methylfuran by NMR spectroscopy, a detailed picture of the kinetics of the reaction can be obtained. The measured spectra revealed that in the early stage of the hydrolysis, only the area of the peak for H<sup>5</sup> diminishes. A comparison of the multiplicity of the different peaks revealed that the signal of H<sup>4</sup> is transformed from a triplet to a doublet. Both of these observations indicate that 2-methylfuran-*d*<sub>5</sub> (II) was formed

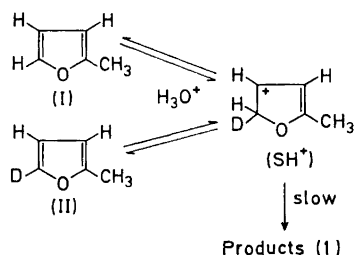


in the reaction mixture. The rate of formation of II can be estimated from the spectra measured at suitable intervals. To eliminate the variation in the sensitivity of the spectrometer, a standard must be used. We found that the signal of H<sup>4</sup> is an excellent standard because it remains unaltered in this stage of the hydrolysis and, in addition, lies in the same region of the magnetic field as the peak of H<sup>5</sup>, the disappearance of which is followed. The ratio of the areas of these peaks is proportional to the extent

of the proton uptake reaction and thus the first-order rate coefficient  $k^{70} = (3.0 \pm 0.2) \times 10^{-4} \text{ s}^{-1}$  (0.1 M DCl in a 3:1 w/w dioxane-D<sub>2</sub>O mixture) could be calculated.

To measure the rate of hydrolysis in the above-mentioned conditions, the progress of the reaction was followed until the cleavage was complete. We found that the peaks of H<sup>3</sup>, H<sup>4</sup>, and 2-CH<sub>3</sub> disappeared at the same rate in the hydrolysis. The rate of this stage was calculated from the disappearance of the bands of the 2-methyl protons using tetramethylsilane as an internal standard. A value of  $(1.2 \pm 0.2) \times 10^{-6} \text{ s}^{-1}$  was obtained for the first order rate coefficient.

The above kinetic data show that the rate of deuteron uptake by the 5-carbon atom of the furan ring is more than two powers of ten higher than the rate of cleavage of the ring (see scheme (1)). It is thus evident that the mechanism



proposed by Stamhuis *et al.*<sup>2</sup> for the hydrolysis of the furan ring, *i.e.* a rate-determining proton transfer to the  $\alpha$ -carbon atom, does not conform with the new results presented here.

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