

STUDIES OF PYRAZINES. IV. PYROLYSIS OF 2-ALKOXYPYRAZINES

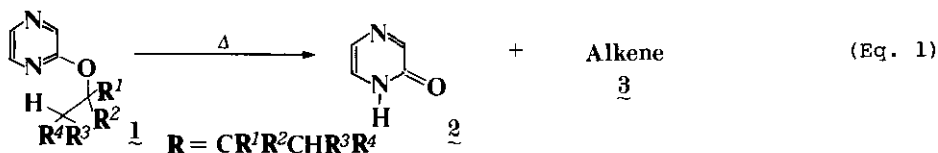
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Abstract — A pyrolysis of 2-alkoxy pyrazine (1) has been performed to give 2-pyrazinol (2) and alkene (3) and to obey first-order kinetics. The reaction proceeds through a 6-membered cyclic transition state analogous to that of ester pyrolysis. The activation parameters, $\log(A/s^{-1})$ and $E_a/(kcal\ mol^{-1})$, and the relative rate constants were determined in the pyrolysis of eight 2-alkoxy pyrazines 1 ($R = C_2H_5, n-C_3H_7, i-C_3H_7, i-C_4H_9, s-C_4H_9, t-C_4H_9, t-C_5H_{11}$, and 1,2-dimethylpropyl). Substitution effects on the reaction rate at the α - and β -position in the alkoxy group were discussed on the basis of the kinetic data.

Previously, the pyrolysis of isopropoxy pyrazine was reported to give 2-pyrazinol and propene.¹ This was the first reaction which was a nitrogen analogue of ester pyrolysis, and an analogous reaction has also been observed in the mass spectra of 2-alkoxy pyrazines.² In the progress of the kinetic study on the reaction by us,³ Taylor has independently reported a kinetics in an analogous type of reaction of 2-ethoxy pyrazine.⁴ In his report, he proposed that the reaction proceeded through a semi-conserted 6-centered cyclic transition state. However, the detailed nature of the transition state has not been described.

In this communication, we wish to report our findings on the pyrolysis of the 2-alkoxy pyrazines (1). As mentioned above, 1 was decomposed to 2-pyrazinol (2)



- a) $R = C_2H_5$ b) $R = n-C_3H_7$ c) $R = i-C_3H_7$ d) $R = i-C_4H_9$
 e) $R = s-C_4H_9$ f) $R = t-C_4H_9$ g) $R = t-C_5H_{11}$
 h) $R = 1,2\text{-dimethylpropyl}$ i) $R = n-C_8H_{17}$ j) $R = neo-C_5H_{11}$

and alkene (3) at 360 ~ 585 °C (Eq. 1). The reaction was performed in a silver-tubular reactor coupled with a gas chromatograph apparatus in series. The decrease of k obeyed good first-order kinetics. The activation parameters ($\ln A$ and E_a) in the pyrolysis of eight 2-alkoxy-pyrazines ($1a \sim 1h$) were determined and shown in Table. The values change drastically with substituents at the α - or β -position in the alkoxy group. 2-Octyloxy-pyrazine ($1i$) did not yield isomers except for 1-octene, and 2-neopentyloxy-pyrazine ($1j$) resisted stubbornly to the pyrolysis.⁵ These facts imply that the reaction (1) proceeds through the 6-membered cyclic transition state analogous to that of ester pyrolysis. The activation energy in the pyrolysis of $1a$ is 63.8 kcal mol⁻¹ and larger than that of 2-ethoxy-pyridine reported by Taylor (46.8 kcal mol⁻¹).⁴ The rate of the former is about 2.3 times slower than that of the later. The deactivation effect results from the decrease in the electron density on the pyrazine-ring nitrogen, which shows lower pK_a values than that of pyridine ring.⁶ This is the first observation on the electronic effect at the trigger atom which abstracts β -hydrogen in the unimolecular thermal elimination of alkene analogous to ester pyrolysis.

If the compound $1a$ is selected as a logical standard, the relative rate constants, k_{rel} , are calculated as shown in Table 1. The reactivity order in each compounds studied is tertiary > secondary > primary. This is the same order as Taylor has previously reported in a pyrolysis of acetates.⁸ The k_{rel} values for isopropoxy- and *t*-butoxy-pyrazine, ($1c$) and ($1f$), are 18.8 and 758, respectively.

Table. Activation Parameters and Relative Rate Constants in Pyrolysis of 2-Alkoxy-pyrazines ($1a \sim 1h$)

Compd.	$\log(A/s^{-1})$	$E_a/(kcal\ mol^{-1})$	Temp. range	$k_{rel}^{a)}$
			$t/^{\circ}C$	
$1a$	16.55	63.8	550 ~ 585	1.00
$1b^{b)}$	14.60	56.3	533 ~ 571	1.3
$1c$	13.22	47.1	465 ~ 525	18.8
$1d^{b)}$	27.79	106.4	527 ~ 553	0.32
$1e^{b)}$	12.91	45.3	468 ~ 495	22.3
$1f$	12.65	39.2	357 ~ 387	758
$1g^{b)}$	13.70	41.6	357 ~ 389	1850
$1h^{b)}$	14.07	49.8	459 ~ 487	24.3

a) At 520 °C. b) Relative rate method.

In comparison with relative rate constant in a pyrolysis of the corresponding acetate at the same temperature,⁸ a plot of $\log(k_{rel})_{acetate}$ vs. $\log(k_{rel})_{2-alkoxy-pyrazine}$ gives a straight line (Figure). The fact suggests that the transition state in the pyrolysis of $\underline{1}$ is similar to that of acetate.

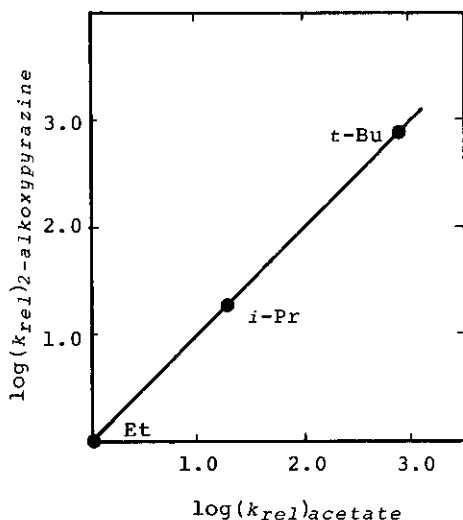


Figure. Correlation of relative rates of 2-alkoxy-pyrazine $\underline{1}$ and ester pyrolysis at 520 °C.

The effects on the rate by methyl branching at the α -position in the pyrolysis of $\underline{1}$ at 520 °C were clarified by a comparison of k_{rel} for $\underline{1c}$ with that for $\underline{1f}$; or that for $\underline{1e}$ with that for $\underline{1g}$. The accelerating effects in $\underline{1c}$ and $\underline{1f}$ are 18.8 and 40.3; and those in $\underline{1e}$ and $\underline{1g}$ are 17.1 and 83.0, respectively. These results imply that the electronic effect is important in the pyrolysis of the α -substituted $\underline{1}$ and that the α -carbon in $\underline{1}$ possesses the same carbonium ion character in the transition state of the pyrolysis as proposed in a pyrolysis of esters.⁹

On the other hand, the effects at the β -position is very different from those at the α -position. The reaction rates were accelerated by the factors of 1.2 ~ 2.4 when the β -position in each of the primary, secondary and tertiary alkoxy groups was substituted with one methyl group. Although an pronounced accelerating effect was not observed in the pyrolysis of $\underline{1h}$ (1.1 times relative to $\underline{1e}$), the reaction of isobutoxypyrazine ($\underline{1d}$) was suppressed (0.25 times relative to $\underline{1h}$). These deaccelerating effects in the pyrolysis of $\underline{1d}$ and $\underline{1h}$ result from a steric hindrance between the 2-pyrazinyl group and the bulky isopropyl one attached to

the α -carbon.¹⁰

The tubular reactor used in this work was made in our laboratory and coupled with a Shimadzu GC-4CPF gas chromatograph apparatus in series. In a typical procedure, a mixture of I_2 and an appropriate internal standard (quinoline, o-xylene or mesitylene) was injected with a micro injector into the reactor. The 2-alkoxy-pyrazines I_2 were prepared by the method reported previously.¹

References

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2. T. Konakahara, K. Kuwata and Y. Takagi, Abstr. No. 2-3, 12th Symposium of Organic Mass Spectrometry, Tokyo, November 1977.
3. T. Konakahara, Y. Takagi and T. Kuwana, Abstr. No. 3K07, 35th National Meeting of the Chemical Society of Japan, Sapporo, August 1976; T. Konakahara and Y. Takagi, Abstr. No. 2R14, 36th National Meeting of the Chemical Society of Japan, Osaka, April 1977; T. Konakahara, K. Kuwata and Y. Takagi, Abstr. No. 1I27, 38th National Meeting of the Chemical Society of Japan, Nagoya, October 1978.
4. R. Taylor, J. Chem. Soc. Chem. Comm., 1978, 732.
5. When I_2 was heated at 555.6 °C for 3.68 s, most of I_2 was recovered (>98%).
6. The pK_a values of pyrazine itself are 0.65 and -5.8, and that of pyridine is 5.17.⁷
7. W. H. Cheeseman and E. S. G. Werstiuk, "Advances in Heterocyclic Chemistry," Vol. 14, ed. A. R. Katritzky and A. J. Boulton, Academic Press, New York (1972), p.99.
8. R. Taylor, J. Chem. Soc. Perkin Trans. 2, 1975, 1025.
9. R. Taylor, G. G. Smith and W. H. Wetzal, J. Am. Chem. Soc., 1962, 84, 4817.
10. Most of the hydrogen abstraction in the reaction of I_2 may occur at the 1-methyl group in the 1,2-dimethylpropyl one.

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