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STUDIES OF PYRAZINES. IV. PYROLYSIS OF 2-ALKOXYPYRAZINES

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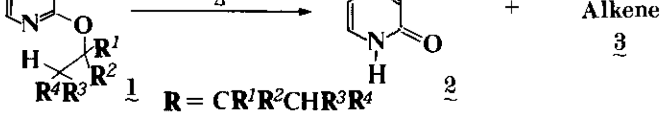
Abstract — A pyrolysis of 2-alkoxypyrazine (**1**) has been performed to give 2-pyrazinol (**2**) and alkene (**3**) and to obey first-order kinetics. The reaction proceeds through a 6-membered cyclic transition state analogous to that of ester pyrolysis. The activation parameters, $\log(A/s^{-1})$ and $E_a/(\text{kcal mol}^{-1})$, and the relative rate constants were determined in the pyrolysis of eight 2-alkoxypyrazines **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 alkoxyl group were discussed on the basis of the kinetic data.

Previously, the pyrolysis of isopropoxypyrazine 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 benn observed in the mass spectra of 2-alkoxypyrazines.[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-ethoxypyrazine.[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-alkoxypyrazines (**1**). As mentioned above, **1** was decomposed to 2-pyrazinol (**2**)



(Eq. 1)

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-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-tublar reactor coupled with a gas chromatograph aparatus in series. The decrease of **1** obeyed good first-order kinetics. The activation parameters ($\ln A$ and E_a) in the pyrolysis of eight 2-alkoxypyrazines (**1a** ∿ **1h**) were determined and shown in Table. The values change drastically with substituents at the α- or β-position in the alkoxyl group. 2-Octyloxypyrazine (**1i**) did not yield isomers except for 1-octene, and 2-neopentyloxypyrazine (**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-ethoxypyridine 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 nitrogene, 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 abstructs 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 <u>tertiary</u> > <u>secondary</u> > <u>primary</u>. This is the same order as Taylor has previously reported in a pyrolysis of acetates.[8] The k_{rel} values for isopropoxy- and t-butoxypyrazine, (**1c**) and (**1f**), are 18.8 and 758, respectively.

Table. Activation Parameters and Relative Rate Constants in Pyrolysis of 2-Alkoxypyrazines (**1a** ∿ **1h**)

Compd.	$\log(A/s^{-1})$	E_a/(kcal mol^{-1})	Temp. range t/°C	k_{rel} [a)]
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.* $\log(k_{rel})_{2\text{-}alkoxypyrazine}$ gives a straight line (Figure). The fact suggests that the transition state in the pyrolysis of **1** is similar to that of acetate.

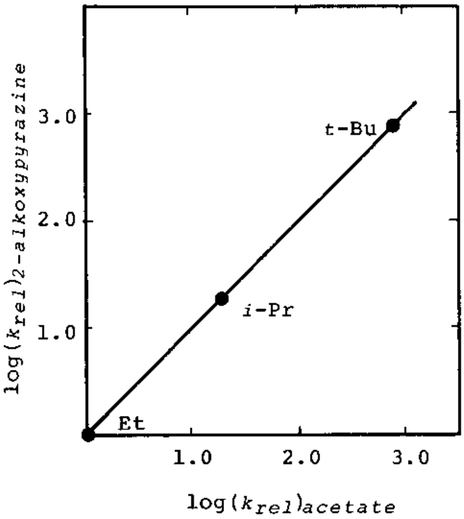


Figure. Correlation of relative rates of 2-alkoxypyrazine **1** and ester pyrolysis at 520 °C.

The effects on the rate by methyl branching at the α-position in the pyrolysis of **1** at 520 °C were clarified by a comparison of k_{rel} for **1c** with that for **1f**; or that for **1e** with that for **1g**. The accelerating effects in **1c** and **1f** are 18.8 and 40.3; and those in **1e** and **1g** are 17.1 and 83.0, respectively. These results imply that the electronic effect is important in the pyrolysis of the α-substituted **1** and that the α-carbon in **1** posesses 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* alkoxyl groups was substituted with one methyl group. Although an pronounced accelerating effect was not observed in the pyrolysis of **1h** (1.1 times relative to **1e**), the reaction of isobutoxypyrazine (**1d**) was suppressed (0.25 times relative to **1b**). These deaccelerating effects in the pyrolysis of **1d** and **1h** result from a steric hindrance between the 2-pyrazinyl group and the bulky isopropyl one attached to the α-carbon.[10]

The tublar 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 **1** and an appropriate internal standard (quinoline, o-xylene or mesitylene) was injected with a micro injector into the reactor. The 2-alkoxypyrazines **1** were prepared by the method reported previously.[1]

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5. When **1j** was heated at 555.6 °C for 3.68 s, most of **1j** 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]
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9. R. Taylor, G. G. Smith and W. H. Wetzel, *J. Am. Chem. Soc.*, 1962, **84**, 4817.
10. Most of the hydrogen abstruction in the reaction of **1h** may occur at the 1-methyl group in the 1,2-dimethylpropyl one.

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