The Effect of Alkali Metal Ions on Rate

Bull. Korean Chem. Soc. **1994**, *Vol. 15, No. 2* 161

References

1. (a) Kanaoka, Y. *Acc. Chem. Res.* **1978**, *11*, 407; (b) Coyle, J. D. *Synthetic Organic Photochemistry*; Horspool, W. M. ed.; Plenum Press: New York, 1984; p 259; (c) Mazzocchi, P. H. *Organic Photochemistry*; Padwa, A. ed.; Marcel Dekker: New York, **1981**, Vol. 5, p 421, and references therein.

2. (a) Brumfield, M. A.; Quillen, S. L.; Yoon, U. C.; Mariano, P. S. *J. Am. Chem. Soc.* **1984**, *106*, 6855; (b) Brumfield, M. A.; Yoon, U. C.; Hasegawa, E.; Mariano, P. S. *J. Org. Chem.* **1988**, *53*, 5435; (c) Ohga, K.; Yoon, U. C.; Mariano, P. S. *J. Org. Chem.* **1984**, *49*, 213.

3. Yoon, U. C.; Kim, H. J.; Mariano, P. S. *Heterocycles* **1989**, *29*, 1041.

4. Yoon, U. C.; Oh, J. H.; Lee, S. J.; Kim, D. U.; Lee, J. G.; Kang, K. T.; Mariano, P. S. *Bull. Korean Chem. Soc.* **1992**, *13*, 166.

5. (a) Yoon, U. C.; Kim, J. U.; Hasegawa, E.; Mariano, P. S. *J. Am. Chem. Soc.* **1987**, *109*, 4421; (b) Hasegawa, E.; Xu, W.; Mariano, P. S.; Yoon, U. C.; Kim, J. U. *J. Am.*

Chem. Soc. **1988**, *110*, 8099.

6. Heyon, E.; Ibata, T.; Lichtin, N. N.; Simic, M. *J. Phys. Chem.* **1972**, *76*, 2072.

7. (a) Yoshida, Y.; Isoe, S. *Chem. Lett.* **1987**, 631; (b) Yoshida, Y.; Isoe, S. *Tetrahedron Lett.* **1987**, *28*, 6621.

8. Kanaoka, Y.; Migita, Y.; Koyama, K.; Sato, Y.; Nakai, H.; Mizoguchi, T. *Tetrahedron Lett.* **1973**, *14*, 1193.

9. Yoon, U. C.; Cho, S. J.; Oh, J. H.; Lee, J. G.; Kang, K. T.; Mariano, P. S. *Bull. Korean Chem. Soc.* **1991**, *12*, 241.

10. Mazzocchi, P. H.; Minamikawa, S.; Bowen, M. *J. Org. Chem.* **1978**, *43*, 3079.

11. (a) Kanaoka, Y.; Migita, Y.; Sato, Y.; Nakai, H. *Tetrahedron Lett.* **1973**, 51; (b) Nakai, H.; Sato, Y.; Ogiwara, H.; Mizoguchi, T.; Kanaoka, Y. *Heterocycles* **1974**, *2*, 621; (c) Kanaoka, Y.; Migita, Y. *Tetrahedron Lett.* **1974**, 3693. 131.

12. Yoon, U. C.; Kim, Y. C.; Choi, J. J.; Kim, D. U.; Mariano, P. S.; Cho, I. S.; Jeon, Y. T. *J. Org. Chem.* **1992**, *57*, 1422.

13. Sato, Y.; Nakai, H.; Mizoguchi, T.; Kawanishi, M.; Hatanaka, Y.; Kanaoka, Y. *Chem. Pharm. Bull.* **1982**, *30*, 1263.

14. (a) Machida, M.; Takechi, H.; Kanaoka, Y. *Chem. Pharm. Bull.* **1982**, *30*, 1579; (b) Kormendy, K.; Volford, J. *Acta Chim. Acad. Sci. Hung.* **1962**, *32*, 121; (c) Dirscherl, W.; Weingarten, F. W. *Ann. Chem.* **1951**, *574*, 131.

15. Trost, B. M.; Mignani, S. *J. Org. Chem.* **1986**, *51*, 3435.

The Effect of Alkali Metal Ions on Nucleophilic Substitution Reactions of Aryl Substituted Benzenesulfonates

Ik-Hwan Um*, Seok-Joo Lee, Hee-Sun Park, and Dong-Sook Kwon

Department of Chemistry, Ewha Womans University, Seoul 120-750
Received October 5, 1993

Rate constants have been measured spectrophotometrically for the nucleophilic substitution reactions of aryl substituted benzenesulfonates (3) with alkali metal ethoxides (EtO⁻M⁺) and butane-2,3-dione monoximates (Ox⁻M⁺) in ethanol at 25°C. The reactivity of the alkali metal ethoxides decreases in the order EtO⁻K⁺>EtO⁻>EtO Li⁺, indicating that K⁺ ion behaves as a catalyst and Li⁺ ion acts as an inhibitor for all the substrates studied. For the corresponding reactions of 3 with Ox⁻M⁺, Li⁺ ion also exhibits inhibitory effect for all the substrates, while, K⁺ ion shows catalytic or inhibitory effects depending on the nature of substituents on the acyl and phenyl moieties. A study of substituent effect on rate has revealed that both EtO⁻ and Ox⁻ systems have the same reaction mechanism. The different behavior shown by K⁺ ion for the reaction of 3 with EtO⁻ and Ox⁻ would be attributed to a difference in charge polarization of S=O bond in the transition state between the two systems and/or a change in conformation of Ox⁻K⁺.

Introduction

Studies of metal ion effect on organic reactions have attracted a great deal of attention due to the important role of metal ions in biological processes[1-3]. However, the studies have mostly been confined to multivalent metal ions which could exert catalytic effect by acting as Lewis acids[4]. Investigation of the effect of alkali metal ions on organic reactions has been initiated only recently[5].

In recent studies alkali metal ions in various organic reactions have been demonstrated to exhibit catalytic or inhibitory effects depending on the type of substrates (phosphinic, carboxylic, or sulfonic esters) and nucleophiles, and on the size of alkali metal ions. Buncel and his coworkers have reported that alkali metal ions exhibit significant catalytic effect in the reaction of a phosphinic ester (1) with alkali metal ethoxides (EtO⁻M⁺) in ethanol[5-7]. On the contrary, we have found that alkali metal ions show significant inhibitory effect

in the reaction of **1** with alkali metal phenoxides (PhO⁻M⁺) as well as in the reaction of a carboxylic ester (**2**) with EtO⁻M⁺ in ethanol[8,9]. For the reaction of a sulfonic ester (**3a**) with EtO⁻M⁺, it has been reported that Li^+ ion behaves as an inhibitor, while K^+ ion acts as a catalyst[10].

Although many theories have been advanced to explain the catalytic or inhibitory effects shown by alkali metal ions, their roles in chemical reactions are not completely understood. Therefore, we have chosen the following reaction system for a better understanding of metal ion effect. The present structural changes both in the substrate and nucleophile would be considered to give us important informations concerning reaction mechanism as well as the role of alkali metal ions in the organic reaction.
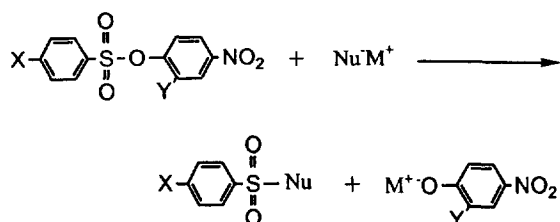
X = H, 4-CH₃O, 4-CH₃, 4-Cl, 3-NO₂, 4-NO₂
Y = H, NO₂
Nu⁻ = C₂H₅O⁻ (EtO⁻) ; CH₃C(O)C(CH₃)=NO⁻ (OX⁻)
M⁺ = K⁺, Li⁺, K⁺ + 18-C-6 ether

Experimental

Materials. The aryl benzenesulfonates in the present study were prepared by a known procedure using corresponding nitrophenols and benzenesulfonyl chlorides in the presence of triethylamine in dried ether. Their purity was checked by means of melting points and spectral data such as IR and ¹H-NMR characteristics. Absolute ethanol was prepared by the method described in the literature[11] under a nitrogen atmosphere. Alkali metal ethoxides solutions were

prepared by dissolving the corresponding alkali metal in the absolute ethanol under a nitrogen atmosphere. The concentration of the stock solutions of EtO⁻M⁺ were titrated against potassium hydrogen phthalate. Other chemicals used were of the highest quality available (Aldrich) and were generally recrystalized or distilled before use.

Kinetics. The kinetic study was performed with a Hitachi U-2000 model UV-VIS spectrophotometer equipped with a Neslab RTE-110 model constant temperature circulating bath to keep the temperature in the UV cell at 25.0±0.1℃. The reaction was monitored by measuring the appearance of the leaving nitrophenoxides at a fixed wavelength (λ_{max} of ArO⁻). All the reactions were carried out under pseudo-first-order conditions in which the concentration of ethoxides was generally 20 to 100 times greater than that of the substrate (2-4×10^{-5} M). Typically, reaction was initiated by adding 5 μl of 0.02 M solution of the substrate in CH₃CN by a Hamilton syringe to a 10-mm UV cell containing 2.50 m*l* of absolute ethanol and EtO⁻M⁺.

Results

All the reactions here obeyed pseudo-first-order kinetics up to over 90% of the total reaction. Pseudo-first-order rate constants (k_{obs}) were obtained from the Guggenheim equation, $\ln(A_{oo}$-$A_t) = -k_{obs}t + C$. Second-order rate constants (k_2) where possible, were calculated from the plots of k_{obs} versus the concentration of total base.

In Tables 1 and 2 are summarized pseudo-first-order rate constants for the reactions of nitrophenyl substituted benzenesulfonates (**3a-3e**) with alkali metal ethoxides (EtO⁻M⁺) and butane-2,3-dione monoximates (Ox⁻M⁺), respectively, in ethanol at 25.0±0.1℃. The kinetic data are demonstrated graphically in Figures 1-5.

In Table 3 are summarized second-order rate constants for the reaction of 4-nitrophenyl X-substituted benzenesulfonates (X-C₆H₄SO₂OC₆H₄-4-No₂) with ethoxide (EtO⁻) and the

Table 1. Kinetic Data for the Reactions of EtO⁻M⁺ with Aryl Substituted Benzenesulfonates (**3a-3e**) in Ethanol at 25.0±0.1℃

	[KOEt] ×10³, M	k_{obs} ×10², s⁻¹	[KOEt+18C6] ×10³, M	k_{obs} ×10², s⁻¹	[LiOEt] ×10³, M	k_{obs} ×10², s⁻¹
3a	10.4	0.0668	10.2	0.0330	10.3	0.0252
X=H	14.5	0.0992	14.4	0.0460	14.2	0.0312
Y=H	18.3	0.135	18.1	0.0582	18.0	0.0419
	22.7	0.187	22.3	0.0713	22.1	0.0501
	26.5	0.243	26.2	0.0842	26.0	0.0573
3b	0.731	0.591	1.09	0.852	0.921	0.730
X=H	1.45	1.42	2.16	1.76	1.83	1.38
Y=NO₂	2.16	2.41	3.20	2.79	2.72	2.09
	2.86	3.57	4.22	3.52	3.60	2.77
	3.54	4.66	5.21	4.50	4.47	3.29
3c	6.80	2.14	7.46	1.52	7.33	1.16
X=4-CH₃O	9.84	3.34	10.8	2.24	10.6	1.61
Y=NO₂	12.7	4.73	13.9	3.04	13.7	2.00
	15.3	5.89	16.8	3.66	16.5	2.43
	17.8	7.48			19.2	2.83

3d	3.88	1.08	3.88	0.810	3.81	0.622
X = 3-NO$_2$	7.47	2.38	7.47	1.68	7.33	1.27
Y = H	10.8	3.68	10.8	2.66	10.6	1.72
	13.9	4.89	13.9	3.30	13.7	2.22
	16.8	6.27	16.8	4.12	16.5	2.62
3e	3.54	1.25	3.54	1.10	3.81	1.01
X = 4-NO$_2$	6.81	2.70	6.81	2.29	7.34	1.75
Y = H	9.85	4.14	9.85	3.31	10.6	2.49
	12.7	5.83	12.7	4.40	13.7	2.95
	15.3	7.06	15.3	5.37	16.5	3.52

Table 2. Kinetic Data for the Reactions of Ox$^-$M$^+$ with Aryl Substituted Benzenesulfonates (3a-3e) in Ethanol at 25.0± 0.1°C.

	[OxK] ×10^3, M	k_{obs} ×10^3, s^{-1}	[OxK + 18C6] ×10^3, M	k_{obs} ×10^3, s^{-1}	[OxLi] ×10^3, M	k_{obs} ×10^3, s^{-1}
3a	13.9	0.239	10.3	0.172	16.5	0.204
X = H	16.8	0.290	13.3	0.226	19.2	0.233
Y = H	19.5	0.347	16.0	0.279	22.9	0.271
	23.3	0.422	18.6	0.312	25.7	0.299
	26.1	0.491	21.0	0.373	28.3	0.320
3b	1.20	34.5	0.800	21.0	1.17	13.9
X = H	1.59	48.8	1.20	35.2	1.94	38.8
Y = NO$_2$	1.98	64.5	1.59	52.0	2.32	59.3
	2.75	103	2.36	84.8	2.70	81.5
	3.50	136	3.13	117	3.44	115
3c	2.36	40.3	1.98	30.9	3.81	56.5
X = 4-CH$_3$O	3.88	73.6	3.88	71.0	4.54	68.8
Y = NO$_2$	5.35	103	5.71	110	5.96	91.2
	7.47	155	7.47	151	7.34	114
	8.83	189	9.17	191	8.67	134
3d	3.88	4.35	3.88	4.53	3.81	3.94
X = 3-NO$_2$	7.47	8.02	7.47	8.90	7.33	7.14
Y = H	10.8	12.1	10.8	13.0	10.6	9.74
	13.9	15.7	13.9	17.2	13.7	12.1
	16.8	19.2	16.8	21.3	16.5	14.8
3e	4.34	4.77	4.34	4.77	4.84	4.81
X = 4-NO$_2$	8.35	8.97	8.35	9.33	9.32	8.56
Y = H	12.1	13.0	12.1	13.7	13.5	11.7
	15.6	17.1	15.6	18.4	17.4	14.5
	18.8	20.5	18.8	22.3	21.0	16.8

oximate (Ox$^-$) in ethanol at 25.0± 0.1°C. The kinetic data are shown graphically in Figure 6.

1   **2**   **3a**
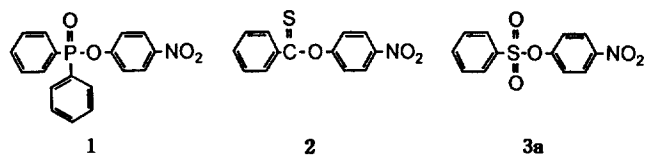
Discussion

Metal Ion Effect on Rate.   It is significant that the etho-

xides (EtO$^-$M$^+$) in the present system appear to have different reactivities depending on the counter cations as shown in Figures 1-5. Furthermore, the dependence of k_{obs} on the concentration of lithium and potassium ethoxides is not linear, regardless of the substituent on the substrate. EtO$^-$ K$^+$ exhibits upward curvatures, while EtO$^-$Li$^-$ shows downward curvatures. However, EtO$^-$K$^+$ with 3 equivalent of 18-crown-6 ether apparently gives linear lines.

It has been well known that alkali metal ethoxides (EtO$^-$M$^+$) in ethanol form ion paired species, and the degree of ion pair becomes stronger as the concentration of EtO$^-$M$^+$ increases or the size of M$^+$ decreases[12]. Since the ion pair
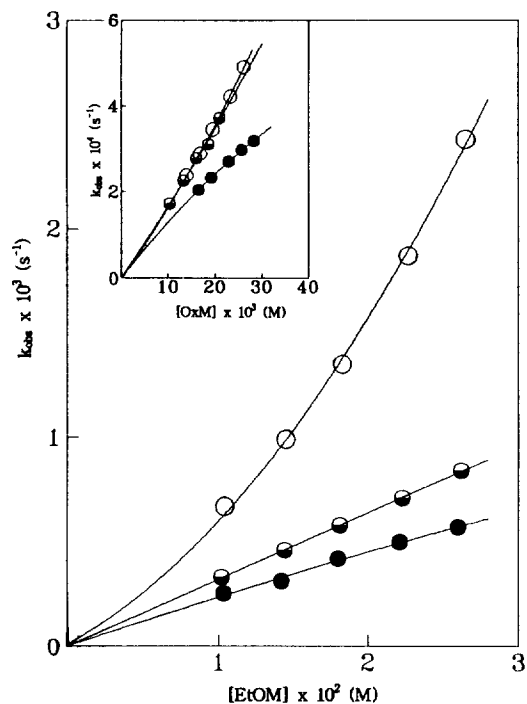
Figure 1. Kinetic data for the reaction of **3a** in EtOH at 25.0℃ with EtOK (○), EtOLi (●), EtOK + 18-crown-6 (◐). The inlet of the figure represents the corresponding reaction with OxM.
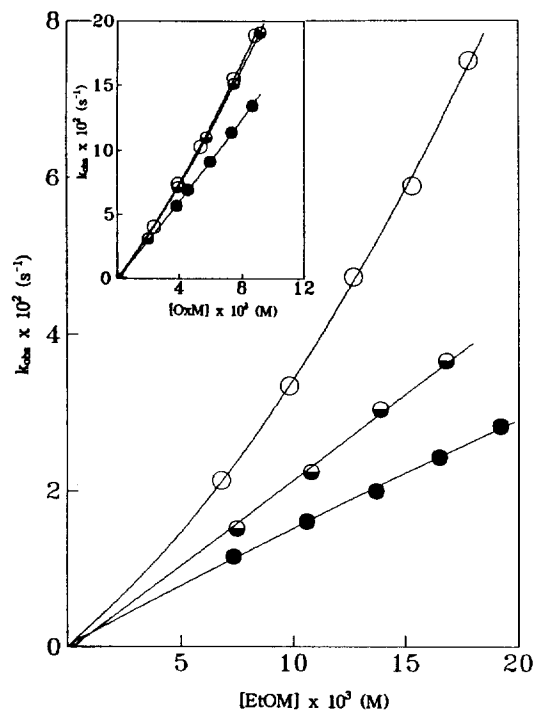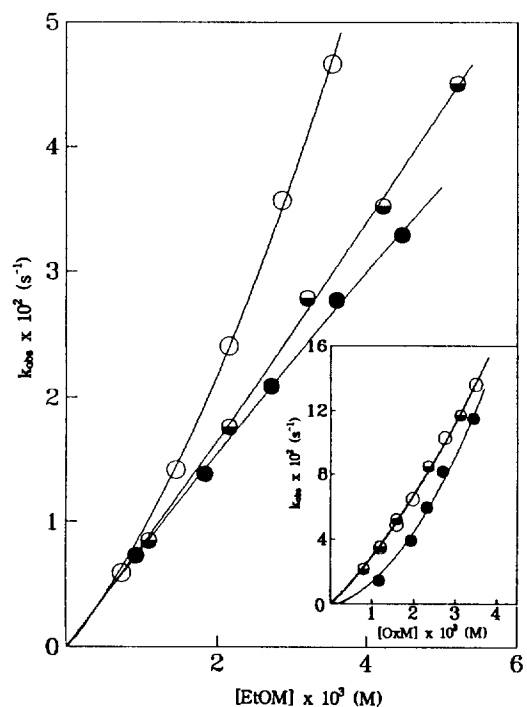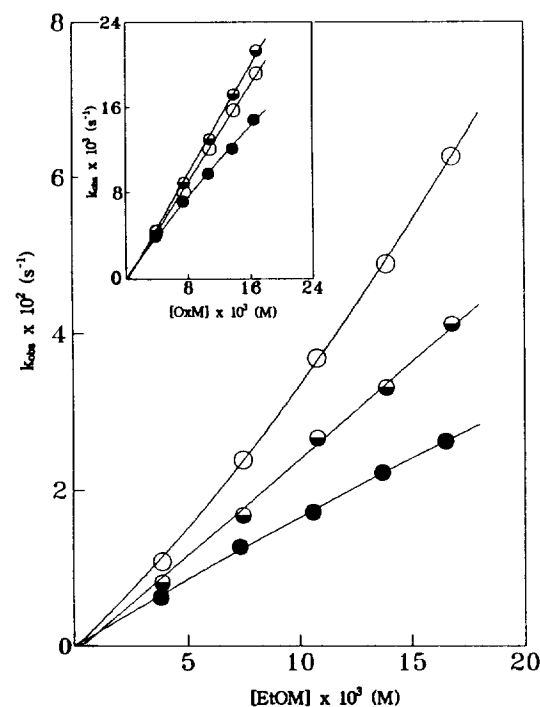

Figure 3. Kinetic data for the reaction of **3c** in EtOH at 25.0℃ with EtOK (○), EtOLi (●), EtOK + 18-crown-6 (◐). The inlet of the figure represents the corresponding reaction with OxM.

Figure 2. Kinetic data for the reaction of **3b** in EtOH at 25.0℃ with EtOK (○), EtOLi (●), EtOK + 18-crown-6 (◐). The inlet of the figure represents the corresponding reaction with OxM.

Figure 4. Kinetic data for the reaction of **3d** in EtOH at 25.0℃ with EtOK (○), EtOLi (●), EtOK + 18-crown-6 (◐). The inlet of the figure represents the corresponding reaction with OxM.

phenomenon would be eliminated by addition of complexing agents such as crown ethers and cryptands, metal ethoxide would exist as free ethoxide in the presence of a proper complexing agent[13]. The effect of 18-crown-6 ether (18C6)

added in the present system is clearly demonstrated in Figures 1-5, *i.e.* the depedence of k_{obs} on the concentration of EtO^-K^+ is linear in the presence of excess 18C6. Therefore, the upward curvature shown by EtO^-K^+ system indicates

The Effect of Alkali Metal Ions on Rate

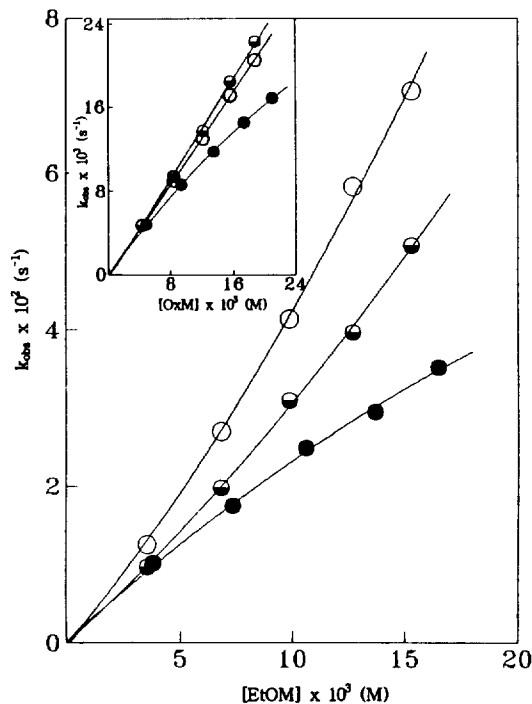*Bull. Korean Chem. Soc.* **1994**, *Vol. 15, No. 2* 165

Figure 5. Kinetic data for the reaction of **3e** in EtOH at 25.0℃ with EtOK (○), EtOLi (●), EtOK + 18-crown-6 (◐). The inlet of the figure represents the corresponding reaction with OxM.

Table 3. Summary of Second-Order Rate Constants k_2 (M^{-1} s^{-1}) for Reactions of p-Nitrophenyl X-Substitued Benzenesulfonates (X-C$_6$H$_4$SO$_2$OC$_6$H$_4$-4-NO$_2$) with Ethoxide (EtO$^-$) and Oximate (Ox$^-$) in Ethanol at 25.0± 0.1℃

X	$k_2 \times 10^2$, M^{-1}s^{-1}	
	EtO$^-$	Ox$^-$
4-NO$_2$	361	116
3-NO$_2$	255	124
4-Cl	11.5	5.98
H	2.87	1.76
4-CH$_3$	1.15	0.726
ρ_x	2.68	2.43

that the ion paired EtO$^-$K$^+$ is more reactive than the dissociated free ethoxide. On the contrary, the downward curvature shown by EtO$^-$Li$^+$ system suggests that ion paired EtO$^-$Li$^+$ is less reactive than the free ethoxide resulting in reactivity order EtO$^-$K$^+$>EtO$^-$K$^+$ with 18C6>EtO$^-$Li$^+$. Such a reactivity order does not change although the substituent on the substrate varies. However, the present reactivity of the ethoxides is quite different from the ones observed for the corresponding reactions of phosphorus centered (1) and carbon centered ester (2), in which the reactivity was reported to be in the order EtO$^-$Li$^+$>EtO$^-$K$^+$>EtO$^-$ for the former[7] and EtO$^-$>EtO$^-$K$^+$>EtO$^-$Li$^+$ for the latter reaction system[8].

For the reaction of **3a** with alkali metal oximates (Ox$^-$M$^+$), lithium oximate (Ox$^-$Li$^+$) is demonstrated to be less reactive than the free oximate as shown in the inlet of Figure 1.
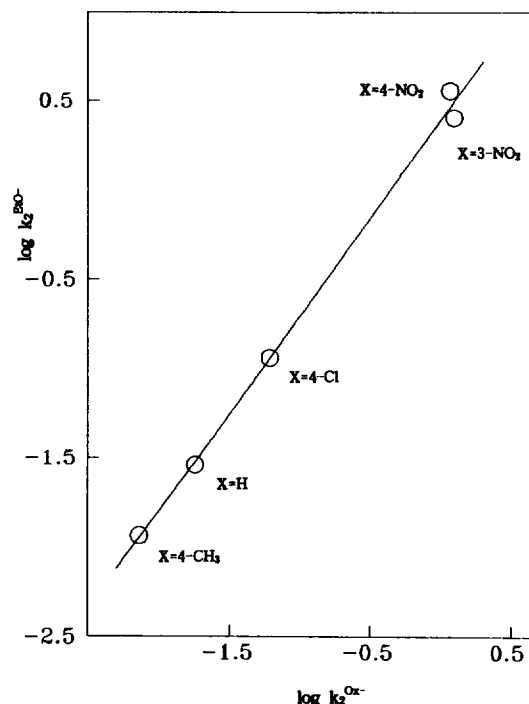

Figure 6. Plot of logarithmic second-order rate constants for the reactions of X-C$_6$H$_4$SO$_2$OC$_6$H$_4$-4NO$_2$ with butane-2,3-dione monoximate (log $k_2^{Ox^-}$) vs. logarithmic second-order rate constants for the corresponding reactions with ethoxide (log $k_2^{EtO^-}$).

The inhibitory effect shown by Li$^+$ ion does not change upon introducing of an electron withdrawing substituent (NO$_2$) on the leaving group or on the acyl moiety as shown in the inlets of Figures 1-5. However, K$^+$ ion in the oximate system shows different behaviors depending on the substrate. It exhibits catalytic effect but very small for the substrates **3a-3c**, and shows inhibitory effect for the reaction of the substrates containing NO$_2$ group on the acyl moiety (**3d-3e**), as shown in the inlets of Figures 1-5.

Therefore, metal ion effect on rate appears to be significantly dependent on the type of substrates and nucleophiles as well as the size of metal ion.

Reaction Mechanism. There have been conflicting arguments concerning the reaction mechanism of acyl-transfer reactions, *i.e.* one-step concerted mechanism versus stepwise (addition-elimination) mechanism[14,15]. Unlike the double bond in C=O bond, the one in S=O bond has been considered to be weak and significantly polarized to S$^+$-O$^-$ due to a large difference in size between the 3p orbital of S atom and 2p orbital of O atom. Therefore, sulfonyl-transfer reactions have often been suggested to proceed *via* a concerted mechanism[14a].

It was interesting whether the reaction of EtO$^-$ would proceed in a different manner from that of the oximate in the present reaction system, and any difference in reaction mechanism would be responsible for the difference in K$^+$ ion effect between the ethoxide and the oximate system. Thus, we have performed a Hammett type study in order to investigate reaction mechanism, *i.e.* reactions of EtO$^-$ and Ox$^-$ with 4-nitrophenyl X-substituted benzenesulfonates (X-C$_6$H$_4$SO$_2$OC$_6$H$_4$-4-NO$_2$) were studied in ethanol at 25.0± 0.1℃.

In Table 3 are summarized the kinetic results. As shown in the Table, the reactivity of EtO⁻ and Ox⁻ increases with increasing acid strengthening substituent on the acyl moiety. For a quantitative analysis of the substituent effect, a Hammett type plot has been constructed, and it has been found that the logarithmic second-order rate constant (log k_2) gives excellent Hammett correlations with Hammett σ constants for both EtO⁻ and Ox⁻ systems. The Hammett ρ_x values obtained are 2.7 and 2.4 for EtO⁻ and Ox⁻ system, respectively, indicating that the reactivity is very sensitive to the electronic effect of the substituent X on the acyl moiety of the substrate for both EtO⁻ and Ox⁻ system. Such large ρ_x values would not have been expected if the leaving group departure is involved in the rate-determining step[16]. This is consistent with the recent Buncel's proposal[17]. Buncel and his coworkers have studied the reaction of Y-substituted phenyl benzenesulfonates ($C_6H_5SO_2OC_6H_4$-Y) with ethoxide in ethanol, and found that σ° constants give a better Hammett correlation than σ⁻ constants[17]. Their results have led them to a conclusion that leaving group departure would not be advanced at the transition state of the rate-determining step, supporting a step-wise mechanism[17].

Therefore, it is considered that the present reaction would proceed *via* an addition-elimination mechanism for both EtO⁻ and Ox⁻ systems. This is further supported from the plot of logarithmic second-order rate constants for the reactions of X-$C_6H_4SO_2OC_6H_4$-4-NO_2 with EtO⁻ (log k_2^{EtO-}) against those for the corresponding reactions with the oximate (log k_2^{Ox-}). As shown in Figure 6, a good linearity is obtained in the plot. Such a good linearity clearly indicates that the two reaction systems proceed in the same reaction mechanism[18]. Therefore, one cannot attribute the different catalytic effect shown by K⁺ ion in the Ox⁻K⁺ and EtO⁻K⁺ system to any difference in the reaction mechanism between the two systems.

Origin of the Metal Ion Catalysis. The fact that Li⁺ ion exhibits inhibitory effect for both EtO⁻Li⁺ and Ox⁻Li⁺ systems indicates that the small Li⁺ ion would stabilize the ground state (GS) to a greater extent than the transition state (TS) by forming tighter ion-pair with the nucleophiles. This is consistent with the expectation that the degree of ion-pair would become stronger with increasing charge density of the ionic species. On the contrary, K⁺ ion shows catalytic effect for both EtO⁻K⁺ and Ox⁻K⁺ systems except for the reactions of **3d** and **3e** with Ox⁻K⁺. Therefore, the large K⁺ ion appears to stabilize the TS more significantly than the GS by forming effective chelation with the TS, although the negative charge of the TS would be considered to be more delocalized than that of GS.

It has often been reported that the reaction of **3b** and its analogues with anionic nucleophiles produces S-O and C-O bond cleaved products[19]. If K⁺ ion forms chelation I, the nucleofugality of 2,4-dinitrophenoxide and the degree of S-O bond cleavage would be increased. However, complexation of K⁺ ion by addition of 18C6 would prevent formation of I, and therefore, the reactivity and the degree of S-O bond cleavage would be significantly reduced.

The possibility of chelation I could be easily examined from the reaction of 2,4-dinitrophenyl benzenesulfonate (**3b**) with EtO⁻K⁺ in the absence and presence of excess 18C6. The results showed no difference in S-O/C-O bond cleavage

I   II
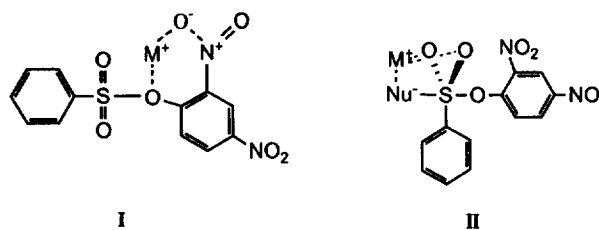
ratio, indicating that K⁺ ion does not form chelation I. Therefore, the catalytic effect shown by K⁺ ion is not considered to an enhanced nucleofugality. This argument is also consistent with the proposed reaction mechanism. If the leaving group departure occurs after the rate-determining step as discussed in the preceding section, the reaction rate would not be affected by increasing leaving group ability.

Chelation II would increase the charge polarization of S =O bond and lead to a rate enhancement by increasing the electrophilicity of S atom. Such a chelation by K⁻ ion would be expected to be more significant for the EtO⁻K⁻ than Ox⁻K⁺ system, since the charge polarization of the S=O bond would be more advanced in the former system than the latter based on the Hammett ρ_x values shown in Table 3 (2.7 *vs.* 2.4). This would account for the fact that K⁺ ion in the EtO⁻K⁺ system shows more catalytic effect than the one in the Ox⁻K⁺ system.
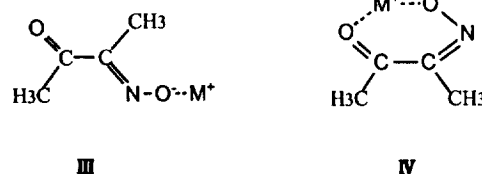
III   IV

Unlike EtO⁻K⁺, Ox⁻K⁺ can have two conformers (III, IV), and IV would be more stable than III due to an effective chelation in ethanol. The conformational change of III into IV would prevent complexation of K⁺ ion with the TS, and therefore, catalytic effect would disappear. This can be supported by the fact that K⁺ ion in Ox⁻K⁺ system exhibits only small catalytic effect or even inhibitory effect for the reaction of the substrates containing an electron withdrawing group (EWG) on the acyl moiety (**3d** and **3e**). Since the presence of a strong EWG such as NO_2 on the acyl moiety would reduce the degree of charge polarization of the S=O bond significantly, chelation by K⁺ ion with TS (chelation II) would be more difficult, leading to inhibitory effect. Therefore, the conformational change of Ox⁻K⁺ would be considered to be responsible for the inhibitory effect shown by K⁺ in the oximate system.

Conclusions

For the reactions of **3a-3e** with the alkali metal ethoxides and oximates, the inhibition effect shown by Li⁺ ion is attributed to a stronger ion-pair with GS than TS. An increase in charge polarization by complexation of K⁺ ion with the S=O bond in TS is considered to be responsible for the catalytic effect of K⁺. The different behavior shown by K⁺ ion for the reaction of **3** with EtO⁻K⁺ and Ox⁻K⁺ would be attributed to a difference in charge polarization of S=O

in the TS between the two systems and/or a change in conforrmation of Ox K⁺, but not to any mechanistic difference between the two reaction systems.

References

1. (a) Kraft, D.; Cacciapaglia, R.; Bohmer, V.; El-Fadl, A.; Harkema, S.; Mandolini, L.; Reinhoudt, D. L.; Verboom, W.; Vogt, W. *J. Org. Chem.* **1992,** *57,* 826; (b) Ercolani, G.; Mandolini, L. *J. Am. Chem. Soc.* **1990**, *112,* 423.

2. Fersht, A. *Enzyme Structure and Mechanism,* 2nd Ed.; W. H. Freeman and Company: New York, Chapter 12, **1985,** *12.*

3. Suh, J. *Acc, Chem. Res.* **1992,** *25,* 273.

4. (a) Breslow, R. *Adu. Enzymol.* **1986,** *58,* 1; (b) Herschlag, D.; Jencks, W. P. *J. Am. Chem. Soc.* **1987,** *109,* 4665; (C) Suh, J.; Park, T. H.; Hwang, B. K. *J. Am. Chem. Soc.* **1992,** *114,* 5141.

5. Buncel, E.; Dunn, E. J.; Bannard, R. A.; Purdon, J. G. *J. Chem. Soc., Chem. Commun.* **1984,** 162.

6. Dunn, E. J.; Buncel, E. *Can J. Chem.* **1989,** *67,* 1440.

7. Dunn, E. J.; Moir, R. Y.; Buncel, E.; Purdon, J. G.; Bannard, R. A. *Can. J. Chem.* **1990,** *68,* 1837.

8. Kwon, D. S.; Park, H. S.; Um, I. H. *Bull. Korean Chem. Soc.* **1991,** *12,* 93.

9. Um, I. H.; Yong, J. I.; Kwon, D. S.; Ahn, B. T.; Lee, I. *Tetrahedron Lett.* **1992,** *33,* 6483.

10. (a) Buncel, E.; Pregel, M. J. *J. Chem. Soc., Chem. Commun.* **1989,** 1566; (b) Pregel, M. J.; Dunn, E. J.; Buncel, E. *Can. J. Chem.* **1990,** *68,* 1846.

11. Vogel, A. I. *Practical Organic Chemistry,* Longman's Green and Co.: London, Eng., **1962**.

12. Lowry, T. H.; Richardson, K. S. *Mechanism and Theory in Organic Chemistry,* 3rd Ed.; Harper and Row: New York, **1987.**

13. (a) Lehn, J. M. *Acc. Chem. Res.* **1978,** *11,* 49; (b) De Jong, F.; Reinhoudt, D. N. *Adu. Phys. Org. Chem.* **1980,** *17,* 279.

14. (a) Ba-Saif, S.; Luthra, A. K.; Williams, A. *J. Am. Chem. Soc.* **1987,** *109,* 6362; (b) Williams, A. *Acc. Chem. Res.* **1989,** *22,* 387; (c) Blake, J. F.; Jorgensen, W. L. *J. Am. Chem. Soc.* **1987,** *109,* 3856.

15. (a) Buncel, E.; Um, I. H.; Hoz, S. *J. Am. Chem. Soc.* **1989,** *111,* 971; (b) Buncel, E.; Shaik, S. S.; Um, I. H.; Wolfe, S. *J. Am. Chem. Soc.* **1988,** *110,* 1275; (c) Kwon, D. S.; Lee, G. J.; Um, I. H. *Bull. Korean Chem. Soc.* **1990** *11,* 262.

16. Um, I. H.; Jeon, J. S.; Kwon, D. S. *Bull. Korean Chem. Soc.* **1991,** *12,* 406.

17. Pregel, M. J.; Dunn, E. J.; Buncel, E. *J. Am. Chem. Soc.* **1991,** *113,* 3545.

18. Um, I. H.; Choi, K. E.; Kwon, D. S. *Bull, Korean Chem. Soc.* **1990,** *11,* 362.

19. Tagaki, W.; Kurusu, T.; Oae, S. *Bull. Chem. Soc. Jpn.* **1969,** *42,* 2894.