JMS-D300 spectrometer. Preparative thin-layer chromatography (TLC) was carried out on precoated plates of silica gel (Merck, Silica gel F-254).

General Procedure for Synthesis of 1-Alkynylbenziodoxolones 3. To a stirred suspension of 1-alkynyltrimethylsilane (3 mmol) and commercially available 1-hydroxybenziodoxolone 4 (6.6 mmol) in freshly distilled dichloromethane (30 mL) was added dropwise $BF_3{\cdot}Et_2O$ (6.6 mmol) at room temperature under nitrogen, and the mixture was stirred for 2 days. A pale yellow color developed. After the removal of the solvent under reduced pressure, diethyl ether (30 mL) was added. A pale yellow precipitate was collected, washed with diethyl ether, and dried in vacuo. A mixture of the precipitate in methanol (60 mL) was heated at 60 °C for 45 min to give a clear solution. After the removal of the solvent under reduced pressure, dichloromethane (100 mL) was added. The resulting precipitate was filtered off, and the filtrate was concentrated to give an oil, which was purified by silica gel column chromatography or by preparative TLC to give 1-alkynyliodoxolone 3.

1-(Cyclohexylethynyl)-1,2-benziodoxol-3(1*H*)-one (3a). The benziodoxolone 3a was prepared from (cyclohexylethynyl)-trimethylsilane in 34% yield according to the general procedure: colorless prisms (recrystallized from dichloromethane–hexane); mp 70–73 °C dec; IR ($CHCl_3$) 3430, 3000, 2940, 2860, 2160, 1645, 1440, 1320, 1290, 830, 585 cm^{-1}; ^1H NMR (400 MHz, CD_2Cl_2) δ 8.30 (dd, J = 7.1, 2.0 Hz, 1 H), 8.21 (dd, J = 7.9, 1.3 Hz, 1 H), 7.81–7.72 (m, 2 H), 2.79 (tt, J = 9.2, 3.9 Hz, 1 H), 1.98–1.88 (m, 2 H), 1.82–1.70 (m, 2 H), 1.67–1.51 (m, 3 H), 1.46–1.32 (m, 3 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 166.7, 134.6, 132.3, 131.6, 131.4, 126.1, 115.6, 113.6, 39.0, 32.2, 30.7, 25.5, 24.7; MS m/z (relative intensity) 354 (2, M^+), 351 (8), 248 (13), 231 (100), 203 (20), 76 (33); HRMS calcd for $C_{15}H_{15}O_2I$ (M^+) 354.0118, found 354.0097. Anal. Calcd for $C_{15}H_{15}O_2I{\cdot}H_2O$: C, 48.40; H, 4.60. Found: C, 48.10; H, 4.35.

1-(1-Decynyl)-1,2-benziodoxol-3(1*H*)-one (3b). The benziodoxolone 3b was prepared from 1-decynyltrimethylsilane in 22% yield according to the general procedure: colorless oil; ^1H NMR (270 MHz, $CDCl_3$) δ 8.44–8.38 (m, 1 H), 8.22–8.15 (m, 1 H), 7.80–7.72 (m, 2 H), 2.60 (t, J = 7.1 Hz, 2 H), 1.73–1.20 (12 H), 0.89 (t, J = 6.8 Hz, 3 H); ^{13}C NMR (68 MHz, $CDCl_3$) δ 166.6, 134.6, 132.3, 131.5, 131.4, 126.1, 115.6, 109.7, 39.2, 31.7, 29.1, 28.9, 28.9, 28.2, 22.6, 20.4, 14.0; MS m/z (relative intensity) 384 (<1, M^+), 351 (4), 248 (10), 231 (100), 203 (18), 76 (25).

1-(3,3-Dimethyl-1-butynyl)-1,2-benziodoxol-3(1*H*)-one (3c). The benziodoxolone 3c was prepared from (3,3-dimethyl-1-butynyl)trimethylsilane in 35% yield according to the general procedure: colorless needles (recrystallized from dichloromethane–hexane); mp 206–208 °C dec; IR ($CHCl_3$) 2980, 2900, 2160, 1645, 1440, 1320, 1290, 1210, 830 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.45–8.38 (m, 1 H), 8.16–8.10 (m, 1 H), 7.80–7.72 (m, 2 H), 1.38 (s, 9 H); MS m/z (relative intensity) 313 (1, M^+ – Me), 269 (35), 248 (14), 231 (40), 208 (54), 193 (91), 142 (88), 141 (73), 81 (100), 76 (53); HRMS calcd for $C_{12}H_{10}O_2I$ (M^+ – Me) 312.9728, found 312.9768.

Registry No. 3a, 135226-07-2; 3b, 135226-08-3; 3c, 135226-09-4; 4, 131-62-4; (cyclohexylethynyl)trimethylsilane, 66270-60-8; 1-decynyltrimethylsilane, 54559-17-0; (3,3-dimethyl-1-butynyl)-trimethylsilane, 14630-42-3.

Supplementary Material Available: Tables of crystallographic details, atomic coordinates and isotropic temperature factors, anisotropic thermal parameters, bond lengths, and bond angles of 3a; ^1H and ^{13}C NMR spectra of 3a and 3b; and ^1H NMR spectrum of 3c (12 pages). Ordering information is given on any current masthead page.

Reactions of (*E*)-*O*-Arylbenzaldoximes with Secondary Amines in Acetonitrile. Competition between E2 and S_NAr Reactions

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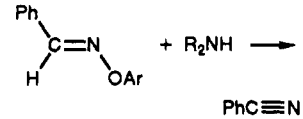
Reactions of (*E*)-*O*-arylbenzaldoximes in which the *O*-aryl group is 2,4-dinitrophenyl (1) and picryl (2) with secondary amines in acetonitrile have been studied kinetically. The reactions proceed via competing E2 and S_NAr mechanism. The second rate-determining step of the S_NAr reactions involves both uncatalyzed and base-catalyzed pathways. The sensitivity of the S_NAr reaction to base catalysis was greater for 2 and increased with base strength. The rates of E2 and S_NAr reactions increased by approximately 10^3 and 10^4 fold, respectively, with the variation of the substrate from 1 to 2. The yield of S_NAr product increased with base concentration, electron-withdrawing ability of *O*-aryl group, and base strength. From these results, factors that influence the competition between E2 and S_NAr reaction pathways are assessed.

Recently we reported a competition between base-promoted elimination and nucleophilic aromatic substitution reactions of (*E*)-*O*-arylbenzaldoximes 1 and 2 under various conditions. Thus, when hydroxide ion in 60% aqueous DMSO was used as the promoting base, 1 produced elimination products, whereas 2 yielded S_NAr products exclusively.[1] On the other hand, the reactions of both 1 and 2 with tertiary amines proceeded by an E2 mechanism.[2] It appears that the nature of attacking base and the electron-withdrawing ability of the *O*-aryl substituent play important roles in these reactions.

To understand the factors that influence the competition between these two reactions, it seems necessary to conduct the reactions under conditions where both of these processes proceed at comparable rates. We found that the reactions of 1 and 2 with secondary amines in acetonitrile produced both elimination and substitution products (eq 1). To probe these two competing mechanisms, we have investigated the effects of varying base concentration, base strength, and steric bulk, as well as *O*-aryl substituents. The results of these studies are reported here.



$$PhC{\equiv}N + PhCH{=}NOH + ArO^- + R_2NAr \quad (1)$$

Ar	R_2NH
1 2,4-dinitrophenyl	pyrrolidine
2 picryl	piperidine
	tetrahydroisoquinoline
	morpholine

(1) Cho, B. R.; Lee, J. C.; Cho, N. S.; Kim, K. D. *J. Chem. Soc., Perkin Trans. 2* **1989**, 489.
(2) Cho, B. R.; Kim, K. D.; Lee, J. C.; Cho, N. S. *J. Am. Chem. Soc.* **1988**, *110*, 6145.

0022-3263/91/1956-5513$02.50/0 © 1991 American Chemical Society

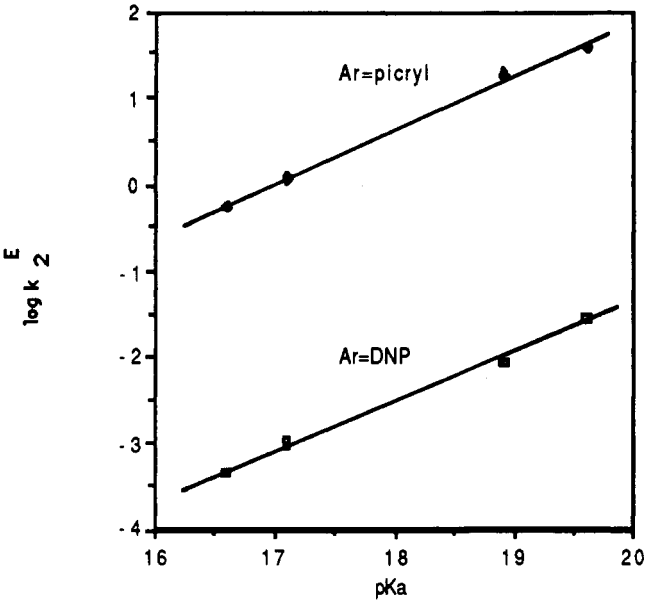


Figure 1. Bronsted plots for elimination from (*E*)-*O*-(2,4-dinitrophenyl)benzaldoxime (Ar = DNP, 1) and (*E*)-*O*-picrylbenzaldoximes (2) promoted by R_2NH in MeCN.

Table I. Transition-State Parameters for Eliminations from (*E*)-*O*-(2,4-Dinitrophenyl)benzaldoxime Promoted by R_2NH in MeCN at 25.0 °C

base	Et_3N	piperidine
pK_a[a]	18.5	19.6
rel rate	1	11.3
ρ	2.0[b]	
β	0.57[b]	0.58 ± 0.03
ρ_{lg}	2.6[b]	2.7
β_{lg}	−0.59[b]	−0.63

[a] Reference 3. [b] Reference 2.

Results

(*E*)-*O*-(2,4-Dinitrophenyl)benzaldoxime (1) and (*E*)-*O*-picrylbenzaldoxime (2) were prepared by reactions of (*E*)-benzaldoxime with aryl halides as reported previously.[1] Reactions of 1 and 2 with R_2NH in MeCN produced benzonitrile, aryloxides, benzaldoxime, and *N*-arylamines. The rates of reactions were followed by monitoring the increase in the absorption at the λ_{max} for the aryloxides. The rate of reaction between 2 and pyrrolidine was too fast to follow with the UV–vis spectrophotometer when the base concentration was higher than 1.50×10^{-3} M. For reactions of 1 with R_2NH, the rate constants were determined at amine concentrations less than 0.20 M to avoid complications caused by change in solvent properties. The observed rate constants were multiplied by the product yields to determine the rate coefficients for the S_NAr and elimination processes. The k^S and k_2^E values were calculated by dividing the corresponding rate constants by the base concentration. Except for a few cases, the rate coefficients for the reactions with greater than 50% yield of one of the products were used to minimize the error involved in the yield determination. The rate constants are summarized in Table SI–SIV in the supplementary material.

Bronsted plots for eliminations from 1 and 2 promoted by R_2NH in MeCN are presented in Figure 1. The rate data exhibit excellent correlation with the pK_a values of the base. The β values are 0.58 ± 0.03 and 0.63 ± 0.02 for 1 and 2, respectively. The β_{lg} value was calculated from the rate constants for eliminations from 1 and 2 and the pK_{lg} values of aryloxides.[3] The β_{lg} value is −0.63 (Tables I and II).

For all substrates, plots of k^S vs base concentration gave straight lines (plots not shown). The k_3/k_2 values were calculated by dividing the slope by the intercept (vide

Table II. Effect of Leaving Group upon Eliminations from (*E*)-PhCH=NOAr Promoted by Piperidine in MeCN

	Ar	
	2,4-dinitrophenyl	picryl
pK_{lg}[a]	16.0	11.0
rel rate	1	18×10^3
β	0.58 ± 0.03	0.63 ± 0.02
β_{lg}	−0.63	

[a] Reference 3.

Table III. Relative Rate, β, and k_3/k_2 Values for S_NAr Reactions of (*E*)-PhCH=NOAr with Piperidine in MeCN

	Ar	
	2,4-dinitrophenyl	picryl
rel rate[a]	1	2.7×10^5
β[b]	1.05 ± 0.10	1.05 ± 0.11
k_3/k_2	3.53×10^2	2.32×10^3

[a] k^S values of 1.26×10^{-4} and 33.7 M^{-1} s^{-1} for 1 and 2, respectively, determined at [piperidine] = 2.00×10^{-3} M were used in the calculation. [b] Slope of the plot of log k_A vs pK_a.

Table IV. Effect of Base Strength upon the k_3/k_2 Values for the Reactions of (*E*)-PhCH=NOAr with R_2NH in MeCN at 25.0 °C

		k_3/k_2 value when Ar =	
base	pK_a[a]	2,4-dinitrophenyl	picryl
pyrrolidine	19.6	387	3990
piperidine	18.9	353	2320
tetrahydroisoquinoline	17.1	311	2120
morpholine	16.6	297	1190

[a] Reference 3.

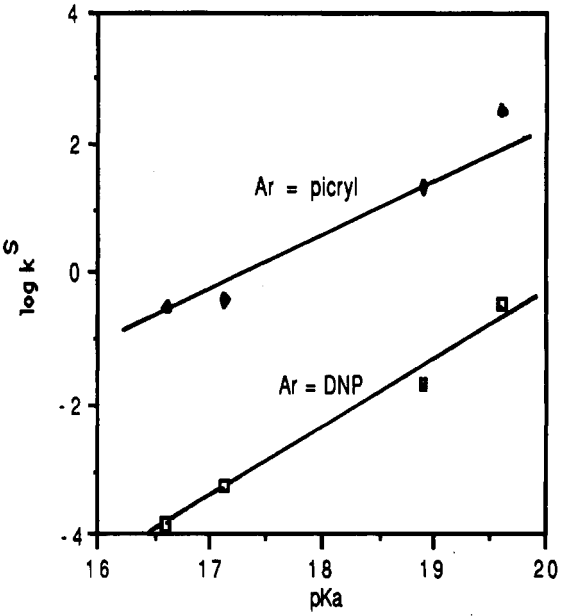
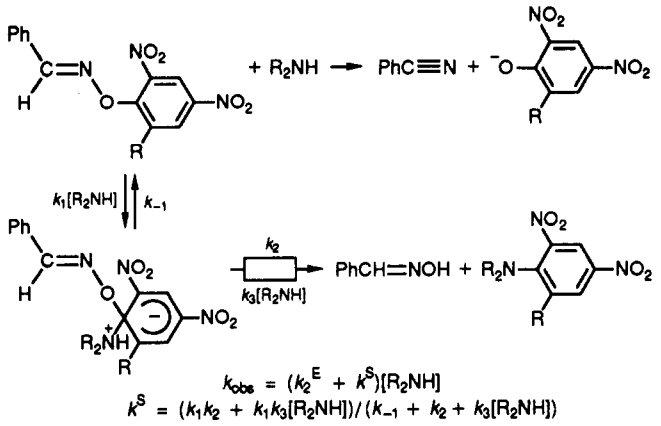


Figure 2. Plots of log k^S vs pK_a values of the bases for reactions of (*E*)-*O*-(2,4-dinitrophenyl)benzaldoxime (Ar = DNP, 1) and (*E*)-*O*-picrylbenzaldoxime (2) with R_2NH in MeCN. Base concentrations are 5.00×10^{-2} and 1.00×10^{-3} M for 1 and 2, respectively.

(3) Coetzee, J. F. *Prog. Phys. Org. Chem.* **1965**, *4*, 45.

Scheme I



infra). The k_3/k_2 values are listed in Tables III and IV.

Plots of log k^S vs pK_a values of the base are shown in Figure 2. Since the k^S value is a function of base concentrations (Scheme I), the values at base concentrations of 5.00×10^{-2} and 1.00×10^{-3} M for **1** and **2**, respectively, were used in the plot. The slopes of the plots are listed in Table III.

Yields of S_NAr and E2 products for the reactions of **1** and **2** with R_2NH in MeCN were determined at four base concentrations by comparing the absorption of the reaction products with those for authentic samples of the products. The yields of S_NAr product increased with base concentration, electron-withdrawing ability of *O*-aryl substituent, and base strength. The results are summarized in Table V.

Table V. Yields of S_NAr Products for Reactions of (E)-PhCH=NOAr with R_2NH in MeCN

			% yield of S_NAr product[a] for Ar =	
base	pK_a[b]	10^3[BH]	2,4-dinitrophenyl	picryl
pyrrolidine	19.6	30	80	
		10	63	
		5.0	57	98
		1.5	32	95
piperidine	18.9	30	57	95
		10	33	90
		5.0	31	89
		1.5		71
tetrahydroisoquinoline	17.1	30	26	86
		10		74
		5.0		54
		1.5		26
morpholine	16.6	30	22	84
		10		66
		5.0		49
		1.5		35

[a] Yields lower than 20% are not included in the table because of the uncertainties involved in the yield determination (see text). Reference 3.

Discussion

Mechanism and Transition-State Structure for the Elimination Reactions. Results of kinetic investigations and product studies clearly establish that the reactions of **1** and **2** with secondary amines produce the elimination products via an E2 mechanism. Since the reactions exhibited second-order kinetics, all but bimolecular pathways can be ruled out. In addition, an E1cb mechanism is negated by the substantial values of β and β_{lg} (Table I).[4,5]

The rate and transition-state parameters for eliminations from **1** promoted by piperidine in MeCN are compared with those observed with tertiary amines[2] in Table I. The values are very similar except for the 11-fold increase in the rate, which can be attributed to the base strength effect.[3] When the leaving group is changed from 2,4-dinitrophenoxide to picrate, the elimination rate increased by a factor of 1.8×10^3 and β increased from 0.58 to 0.63 (Table II). Similar results were observed for the tertiary amine promoted elimination reactions with the same leaving group variation.[2] Since it was demonstrated that the reactions of **1** and **2** with tertiary amines proceed via an E2-central type of transition state with significant cleavage of C_β–H and N_α–OAr bonds and extensive triple-bond formation,[2] the structure of the transition state for reactions of **1** and **2** with secondary amines can also be assumed to be E2-central.

Mechanism and Structure–Reactivity Relationship for the S_NAr Reactions. Nucleophilic aromatic substitution reaction is known to proceed via a Meisenheimer complex.[7-9] For reactions of **1** and **2** with secondary amines in MeCN, the k^S values increased linearly with base concentration. This indicates that $k_{-1} \gg k_2 + k_3[R_2NH]$ and the k^S expression in Scheme I can be simplified to $k^S = (k_1k_2 + (k_1k_2 + k_1k_3[R_2NH])/k_{-1}$. Therefore, the reaction must proceed by an addition–elimination mechanism in which the second step is rate determining (Scheme I). A similar mechanism was proposed for the reactions of *O*-(2,4-dinitrophenyl)-substituted cyclohexanone oxime, acetophenone oxime, and benzophenone oxime with piperidine in DMSO.[10]

The β and k_3/k_2 values obtained for these reactions are consistent with this mechanism (Table III). The slope of the plot of log k^S vs pK_a of the nucleophiles is very close to 1.0 for reactions of both **1** and **2**, indicating that the nucleophile–carbon bonds are completely formed in the transition states.[11] In addition, the k_3/k_2 ratios are 10^2–10^3 for both reactions. Thus the product-forming step must involve both uncatalyzed (k_2) and base-catalyzed (k_3) pathway. On the other hand, if the first step were rate determining, β should be less than 1 because the nucleophile–carbon bond would be only partially formed, and no

(4) Cockerill, A. F.; Harrison, R. G. *The Chemistry of Double-Bonded Functional Group*, Supplement A, Part 1; Patai, S., Ed.; Wiley-Interscience: New York, 1973; p 725.

(5) A reviewer has suggested the possibility of a multistep or an E1cb mechanism for the elimination pathway. However it can be ruled out by the transition-state parameters. For tertiary amine promoted eliminations from **1**, the ρ value increased with base strength and the $-\beta_{lg}$ value decreased with the electron-withdrawing ability of the β-aryl substituent.[2] The results correspond to $p_{xy'} = 0.096$ and $p_{yy'} = -0.32$, which are consistent with an E2 mechanism.[6] Since the transition-state parameters for R_2NH- and R_3N-promoted eliminations from **1** are very similar, it is not unreasonable to assume that the former reaction also proceeded by the same E2 mechanism.

(6) Gandller, J. R. In *The Chemistry of Double Bonded Functional Group*; Patai, S., Ed.; Wiley: Chichester, 1989; Vol. 2, Part 1.

(7) Miller, J. *Aromatic Nucleophilic Substitution*; Elsevier: New York, 1968.

(8) Bernasconi, C. F. *Acc. Chem. Res.* **1978**, *11*, 147.

(9) Bacaloglu, R.; Bunton, C. A.; Orgeta, F. *J. Am. Chem. Soc.* **1988**, *110*, 3495.

(10) Jain, A. K.; Kumar, A.; Sarma, K. N. *J. Chem. Soc., Perkin Trans 2.* **1989**, 153.

(11) Although k^S is a function of base concentration, the k^S value determined at given base concentration should reflect the relative rates of the S_NAr reactions. Therefore, the slope of Figure 2 could be taken as the susceptibility of the S_NAr rate to the base strength, i.e., δ in $\Delta G^\circ = \delta \Delta G$, which is the general expression of a linear free energy relationship such as the Bronsted equation.[12]

(12) Lowry, T. H.; Richardson, K. S. *Mechanism and Theory in Organic Chemistry*, Harper & Row: New York, 1987; pp 289–291.

base catalysis should be observed.

The rate of nucleophilic aromatic substitution was increased by a factor of 2.8×10^4 by changing of the substrate from 1 to 2. This can be attributed to the anion-stabilizing ability of the additional nitro group. Since the reaction is assumed to proceed through a Meisenheimer complex, which will be stabilized further by the additional nitro group of 2, the rate should be enhanced.[13] The increase in the k_3/k_2 value with the same variation of the substrate can also be explained similarly. If the energy of the intermediate for 2 is lower than that for 1, the activation energy of the second step of the former reaction is anticipated to be higher because the nitro group would stabilize the intermediate more than the transition state. Therefore, it is not surprising to observe that 2 is more strongly catalyzed by the base than 1 in the product-determining step.

For reactions of 1 and 2, the k_3/k_2 value increased with base strength (Table IV). A similar trend was observed in the reactions of 2,4-dinitrofluorobenzene with amine bases.[15] An increase in the base strength would stabilize the intermediate, increasing the activation energy of the k_2 step (vide supra). This is expected to decrease the rate. On the other hand, a stronger base should increase the rate of the k_3 step. A combination of these two effects would be an increase of the k_3/k_2 ratio for a stronger base as observed.

Competition between E2 and S_NAr Reactions. The yields of S_NAr product for the reactions of 1 and 2 with R_2NH in MeCN are summarized in Table V. The yield increased with base concentration, electron-withdrawing ability of *O*-aryl substituent, and base strength.

The increase in the S_NAr product yields with the base concentration is as expected from the rate equation. The E2 reaction is first order to the base concentration, whereas the rate equation for the S_NAr reaction consists of two terms that are first and second order to the base concentration (vide supra). Therefore, the S_NAr reaction should predominate at higher base concentration.

The yield of S_NAr product increased dramatically with the change of the substrate from 1 to 2 under the same conditions. The change of the substrate from 1 to 2 would increase the rates of both E2 and S_NAr reactions by stabilizing the partial negative charge developed in both transition states. However, since the transition state for the elimination reaction is assumed to be E2-central and that for the S_NAr reaction should closely resemble the Meisenheimer complex, more negative charge is expected to be developed in the latter. Thus the S_NAr reaction would be enhanced more than the E2 reaction by the additional nitro group. This interpretation is supported by the much greater increase in k^S than k_2^E with the same variation of the substrate (Tables II and III).

The effect of base strength upon the yield of S_NAr product can also be explained similarly. A stronger base would enhance the rates of both E2 and S_NAr reactions by forming stronger base–proton and base–carbon bonds in the respective transition states. However, the degree of bond formation would be greater for the latter as indicated by the greater β value (Tables VI and VII). Therefore, a stronger base should facilitate the S_NAr reaction more than the E2 reaction. This is expected to increase the yield of S_NAr product with a stronger base.

The yield of the S_NAr product obtained from 1 increases more rapidly with the base strength than does that of 2. The result can be attributed to the different sensitivity of the E2 and S_NAr reactions to the base strength. The sensitivity of the k^S values to the base strength is the same for both substrates (Table III). On the other hand, the β value for the E2 reaction of 1 is slightly smaller than that of 2 (Table II). Therefore, the percent yield of S_NAr reaction product from 1 must change more steeply with the base strength than does that of 2.

The competition between E2 and S_NAr reactions was also influenced by a steric effect. For reactions of 1 and 2 with R_2NH, the increase in the S_NAr product yield with the change of base from piperidine to pyrrolidine is much greater than when the base is varied from morpholine to tetrahydroisoquinoline. The result can be attributed to the smaller steric requirement of the pyrrolidine base. Since the transition state of the S_NAr reaction is sterically more congested than that for the E2 reaction, a sterically less hindered base would enhance the rate of the former more than the latter. This would increase the S_NAr product yield to a higher value than that expected from the basicity. A similar interpretation was advanced to explain the rate difference in the reactions of 2,4-dinitro-1-naphthyl ethyl ether with pyrrolidine and piperidine bases.[16-18] The steric effect of tetrahydroisoquinoline, the most bulky base employed in this study, was observed when sterically more hindered 2 was used as a substrate. Thus, although the yield of S_NAr reaction product from 2 with tetrahydroisoquinoline is higher than that with morpholine at a higher base concentration, the trend is reversed at a lower base concentration. A sterically hindered base would retard the rate of S_NAr reaction more than that of the E2 reaction because the susceptibility of the former to the base steric effect is greater than that of the latter (vide supra). Moreover, since the transition state for the k_1 step is more endothermic and thus more product-like than that of the second step, a bulkier base is expected to decrease the k_1 without much affecting the k_2 and k_3 values (Scheme I). Therefore, the rate retardation caused by the base steric effect would become more important as the base concentration decreases. This would predict that the yield of S_NAr product with tetrahydroisoquinoline base could be lower than that with morpholine at a low base concentration. The base steric effect may be more clearly seen in the Bronsted-type plots for the S_NAr reactions of 1 and 2 (Figure 2). The data for pyrrolidine showed positive deviations for both substrate, whereas tetrahydroisoquinoline showed a negative deviation only for 2.

Experimental Section

(*E*)-*O*-Arylbenzaldoximes were prepared by reactions of (*E*)-benzaldoximes with appropriate aryl halides. Reagent-grade MeCN was distilled from CaH_2. The secondary amines were purified by a literature method.[19] The base–solvent solution was prepared by adding the appropriate amines to MeCN.

Kinetic Studies of Reactions between 1 and 2 and R_2NH in MeCN. Kinetics of reactions between 1 and 2 and R_2NH in MeCN were followed by monitoring the increase in the absorbance of the aryloxides with time as described previously.[2]

Product Studies of Reactions between 1 and 2 and R_2NH in MeCN. The products of reactions between 1 and 2 and R_2NH

(13) The steric effect of the nitro group upon the S_NAr reaction was found to be relatively unimportant.[14]

(14) Cho, B. R.; Chung, J. H. Manuscript in preparation.

(15) Bernasconi, C. F.; Becker, G.; Zollinger, H. *Helv. Chim. Acta* **1967**, *50*, 10.

(16) Bunnett, J. F.; Cartano, A. V. *J. Am. Chem. Soc.* **1981**, *103*, 4861.

(17) Bunnett, J. F.; Sekiguchi, S.; Smith, L. A. *J. Am. Chem. Soc.* **1981**, *103*, 4865.

(18) Bunnett, J. F.; Sekiguchi, S. *J. Am. Chem. Soc.* **1981**, *103*, 4871.

(19) Coetzee, Z. F.; Padmanabahn, G. R. *J. Am. Chem. Soc.* **1965**, *87*, 5005.

in MeCN were determined as described previously.[2] The products were benzonitrile, benzaldoxime, aryloxides, and *N*-arylamines.

Control Experiment. The stabilities of **1** and **2** in MeCN were demonstrated as described previously.[2]

Acknowledgment. This investigation was supported by grants from KOSEF and KOSEF-OCRC.

Registry No. **1**, 75735-29-4; **2**, 115828-60-9; pyrrolidine, 123-75-1; piperidine, 110-89-4; tetrahydroisoquinoline, 91-21-4; morpholine, 110-91-8; *N*-(2,4-dinitrophenyl)pyrrolidine, 14552-00-2; *N*-(2,4-dinitrophenyl)piperidine, 839-93-0; *N*-(2,4-dinitrophenyl)tetrahydroisoquinoline, 135226-10-7; *N*-(2,4-dinitrophenyl)morpholine, 39242-76-7; *N*-picrylpyrrolidine, 77379-02-3; *N*-picrylpiperidine, 67263-27-8; *N*-picryltetrahydroisoquinoline, 135226-11-8; *N*-picrylmorpholine, 77379-03-4.

Supplementary Material Available: Listing of rate constants for E2 and S_NAr reactions of (*E*)-*O*-(2,4-dinitrophenyl)-benzaldoxime (**1**) and (*E*)-*O*-picrylbenzaldoxime (**2**) with R_2NH in MeCN at 25.0 °C (3 pages). Ordering information is given on any current masthead page.

Stereoelectronic Effects in Ionization Reactions of Cyclic Ortho Thioesters

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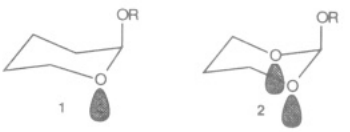
The objective of this work was to determine whether stereoselectivity observed in certain condensed-phase ionic reactions of ortho thioesters was also evident in related gas-phase reactions. Ionization of the C-2 epimers of *cis*-4,6-dimethyl-2-(methylthio)-1,3-dithianes **6** and **7** under FT-ICR conditions produced gaseous ions of m/z 147 corresponding to the *cis*-4,6-dimethyl-1,3-dithian-2-yl cation. Kinetics of ionization were followed by using mixtures of each epimer with 2-methylpropane or with 2-(ethylthio)ethanol. Kinetic parameters were calculated from the rates of decay of the precursor ions (m/z 43 from 2-methylpropane and m/z 75 from 2-(ethylthio)ethanol) at different pressures of reactants. Within experimental error, the specific rates of reaction of each epimer with m/z 43 and with m/z 75 were equal. Ionization is not therefore sensitive to stereochemical configuration at the C-2 reaction site in the gas phase. Solution-phase methylthiolation and methylation of the equatorial epimer (4*c*,6*c*-dimethyl-2*r*-(methylthio)-1,3-dithiane, **7**) led to reversible cleavage at C-2 to produce the *cis*-4,6-dimethyl-1,3-dithian-2-yl cation. Addition of sodium methanethiolate quenched the equilibrium and led irreversibly to a mixture of epimers **6** and **7** in which the axial epimer **6** was in modest excess. The control of reaction stereoselectivity in the formation and trapping of 1,3-dithian-2-yl cations from ortho thioesters is discussed.

Introduction

The reported selectivity for dissociation of *axial* substituents in polar displacement reactions of cyclic acetals **1** and ortho esters **2** has been attributed to stereoelectronic effects whereby reaction stereochemistry is controlled by the orientation of the reacting bond with nonbonding electron pairs on neighboring heteroatoms. The comprehensive studies of Deslongchamps reveal that the effect is operative only when the orbitals in question are antiparallel, which allows for their maximum interaction.[1,2] For example, the antiparallel orientation of the axial OR substituent of **1** and **2** with lone pair orbitals on the ring heteroatoms is believed to enhance the reactivity of the axial bond (over that of the equatorial epimer) through n $\rightarrow \sigma^*$ delocalization.[3] An alternative interpretation attributes a kinetic preference for axial cleavage to the principle of least nuclear motion, which is to say that the amount of reorganization at the reaction site is minimized (and the rate maximized) when the reacting bond is axial.[4,5] In addition, medium effects (due to solvent and counterions) and differences in leaving-group abilities undoubtedly influence reactivity. Because the relative importance of each effect in a given situation is not well understood and is difficult to determine,[3,6] any conclusion that reaction selectivities are due primarily to stereoelectronic effects would seem tenuous at best.



In an earlier paper we described an attempt to test for stereoelectronic effects in the gas-phase ionic dissociation of epimeric ortho esters **3** and **4** under conditions that eliminated solvent and counterions and hence ion-pairing effects.[7] The experiment used electron-impact ion cyclotron resonance (ICR) techniques for the generation of organic ions and the observation of their ensuing ion–molecule reactions at low pressure. We anticipated that, if stereoelectronic effects were significant factors in controlling ionic cleavage of ortho esters **3** and **4**, the cyclic ion **8** (m/z 115) would be produced more rapidly from the axial isomer **3** than from the equatorial isomer **4** (eq 1). The study showed that m/z 115 was indeed the major product ion of reaction of both esters with a variety of

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