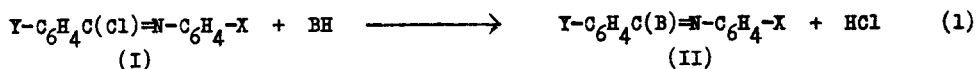


NUCLEOPHILIC ATTACKS ON CARBON-NITROGEN DOUBLE BONDS. PART I. SUBSTITUTION
OF DIARYLIMIDOYL CHLORIDES WITH AMINES IN BENZENE

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While several substitution mechanisms of a leaving group attached to a >C=C< bond are known,¹ those at a >C=N- bond were little studied. The kinetics of the hydrolysis of the -C(Cl)=N- system was studied only by Ugi² and that of the -C(X)=N-N- system by Scott and coworkers.³ Intermediate nitrilium halide ion pairs ($\text{-C}^+\text{=N- X}^-$) were suggested, based on the kinetic dependence on the nucleophile and the leaving group, the solvent effect, and the negative ρ values for both C-Ar and N-Ar substituents.^{2,3} Not all the data are easily accommodated by this mechanism,⁴ and competing routes are unknown. We studied therefore by a spectrophotometric method the substitution of diarylimidoyl chlorides (Ia-Ik) by morpholine and piperidine (BH) in benzene (eqn. 1) which gave the following results:



- | | |
|-------------------|-----------------------------------|
| (Ia) X=p-MeO, Y=H | (If) X=p-CN, Y=H |
| (Ib) X=p-Me, Y=H | (Ig) X=p-NO ₂ , Y=H |
| (Ic) X=H, Y=H | (Ih) X=H, Y=p-MeO |
| (Id) X=p-Cl, Y=H | (Ii) X=H, Y=p-NO ₂ |
| (Ie) X=m-Cl, Y=H | (Ij) X=p-MeO, Y=p-NO ₂ |

(Ik) X=p-NO₂, Y=p-NO₂

(a) With excess amine, the first order coefficient k_{obs} increases with the amine concentration according to eqn. 2, i.e., the reaction is overall a combination of a

$$k_{\text{obs}} = k_2 [\text{BH}] + k_3 [\text{BH}]^2 \quad (2)$$

second and third order processes. k_3 is always significant with morpholine (Table)

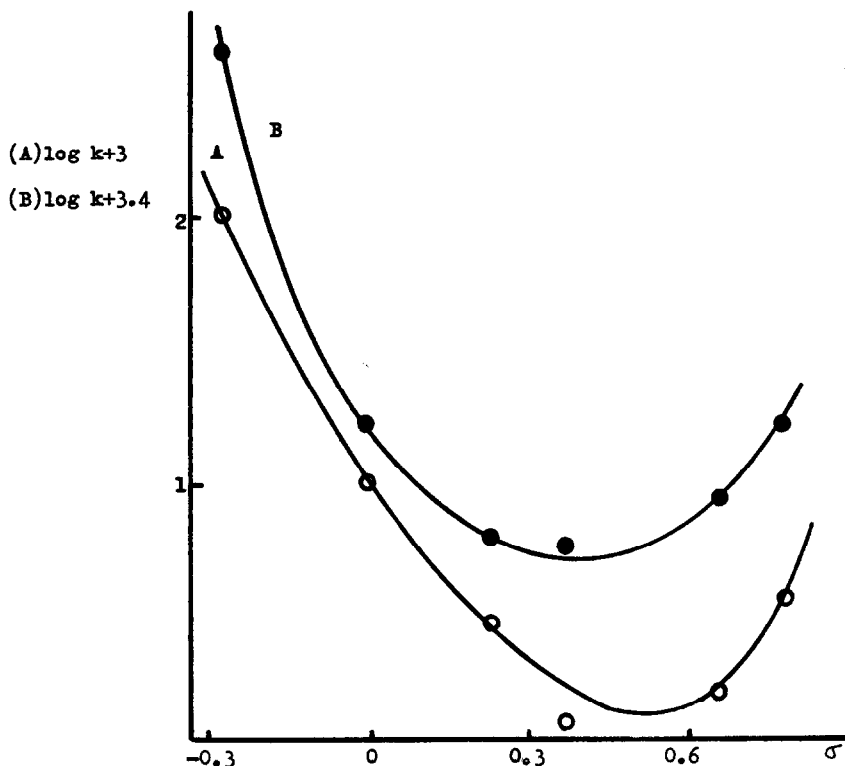


Figure: Plots of (A) $\log k_2$ and (B) $\log k_3$ vs. σ for the morpholine-(Ia-Ig) reaction.

Table. Kinetic data for the reaction of $\text{PhC}(\text{Cl})=\text{NC}_6\text{H}_4\text{X}$ with morpholine in benzene at 30° .^a

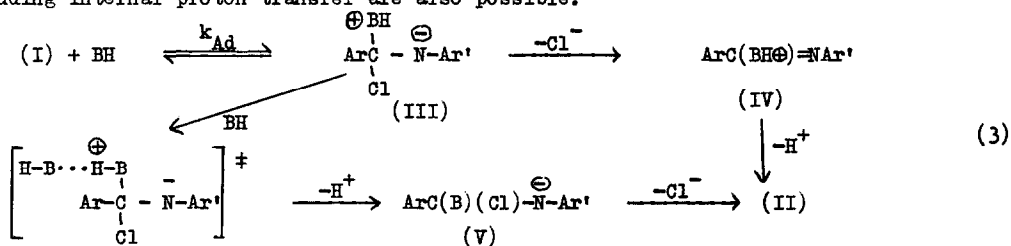
X	$10^5 k_2$, l/mole.sec	$10^5 k_3$, l ² /m ² .sec	k_3/k_2 , l/m	Bronsted α ^b	$k_2^{\text{pip}}/k_2^{\text{morph}}$
p-MeO	173 ± 5	287 ± 26	1.65	0.024	1.16 ^c
H	19.7 ± 0.3	10.8 ± 0.86	0.55	0.069	1.54
p-Cl	6.0 ± 0.3	4.16 ± 0.25	0.82	0.23	4.15
m-Cl	2.1 ± 0.8	4.05 ± 0.1	1.94	0.38	11.0
p-CN	3.6 ± 0.15	5.9 ± 0.15	1.62	0.47	18.8
p-NO ₂	6.1 ± 0.43	11.1 ± 0.63	1.81	0.49	22.0
	15.3 ± 1.1 ^d	23.2 ± 2.8 ^d	1.51	0.49	

^a The correlation coefficients of eqn. 1 are 0.97-0.999, except for m-Cl ($r=0.88$).

^b Calculated by using the pKa's of the two amines in water. ^c $k_1 \sim 75 \cdot 10^{-5} \text{ sec}^{-1}$ for aniline as nucleophile at room temperature. ^d At 45° ; $E_2 = 11.5 \text{ Kcal/mole}$, $\Delta S_2^\ddagger = -33.5 \text{ e.u.}$; $E_3 = 9.3 \text{ Kcal/mole}$ and $\Delta S_3^\ddagger = -40 \text{ e.u.}$

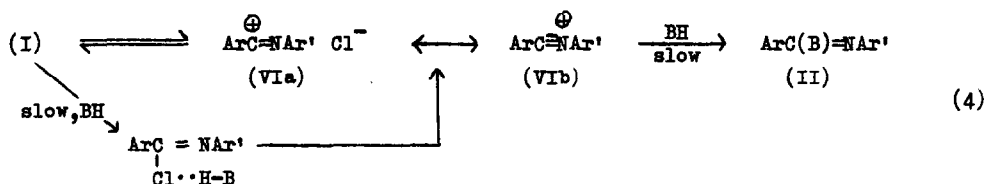
but contributes only with electron-attracting X with piperidine. (b) When $Y=H$ a $\log k_2$ or $\log k_3$ vs. Hammett's σ_X plot is a parabola (Figure) with a minimum for *m*-Cl with morpholine and for *p*-Cl with piperidine. For k_2 , with piperidine at 30° the use of σ^+ values gives two intersecting lines with ρ 's of -1.04 and ca. $+1.9$, while for morpholine σ^- gave a better correlation with ρ 's of -3 and ca. $+1.6$. (c) At 30° with piperidine $k_2(Ij):k_2(Ii):k_2(Ik)$ are $1:1.07:24.2$, suggesting curved $\sigma-\rho$ plot also when $Y=p-NO_2$. (d) With piperidine $k_2(Ih):k_2(Ic):k_2(Ii)$ are $5.4:1.15:1$ suggesting a curved $\sigma-\rho$ plot for C-Ar substituents, and a substituent effect in the same direction but with higher sensitivity to X than to Y. (e) For both reactions $\Delta H^\ddagger = 8.5-11.5$ Kcal/mole and $\Delta S^\ddagger = -24$ to -40 e.u. (f) The ratio $k_{\text{piperidine}}/k_{\text{morpholine}}$ is very small for (Ia) but increases on increasing σ_X (Table). A Bronsted α value for the two amines vs. σ_X is approximately linear. (g) In acetonitrile, for compounds (Ic), (Id), (Ig), (Ii) and (Ih) k_{obs} is given by: $k_{\text{obs}} = k_1 + k_2[\text{BH}]$, i.e., the reaction order is between zero and one in the amine.

In benzene, from the shape of the Hammett plot and (c) and (d) above, the substitution mechanism changes with both the X and the Y substituents. For substituents with $\sigma_X > 0.3$ which give a positive ρ , the most likely mechanism is a nucleophilic addition-elimination ($\text{Ad}_{\text{Nu}}-\text{El}$) of the amine to (I) to form the zwitterion (III) (eqn. 3). (III) either expels Cl^- in an overall second order uncatalyzed process (leading to IV), or participates in a third order process in which an amine-catalyzed N-H bond cleavage (leading to V) precedes the C-Cl bond cleavage. The scheme is similar to that suggested for nucleophilic vinylic substitution of chlorine by amines,⁵ and leads to the kinetics of eqn. 2. Other variants including internal proton transfer are also possible.



This route which operates when X is capable of spreading a negative charge, is in line with the positive ρ 's (which are probably governed by the k_{Ad} step)^{1,5} and with the increasing importance of k_3 with morpholine, since Cl^- expulsion is more difficult from the more electron-attracting morpholinium ion.

The competing mechanism for substituents with $\sigma_X < 0.3$ has a negative ρ and probably involves an intermediate azocarbonium ion, as suggested for the hydrolysis of (I).² The first order dependence in the amine is in line with the $S_N2(C^+)$ variant⁶ where an ion pair is formed in a fast pre-equilibrium and attacked slowly by the amine. The higher importance of the third order process with morpholine and with the increase in σ_X suggests an electrophilic catalysis by the second amine molecule (eqn. 4). Further discussion on other alternatives must wait until data for the corresponding imidoyl bromides will be available.⁷



Our results in acetonitrile and the previous ones in aqueous solvents^{2,3} show that the S_N1 route becomes dominant in a higher dielectric solvent with weak nucleophiles. Indeed, (Ik) is the slowest solvolyzing compound,² but the fastest one with morpholine in benzene.

The higher response to X than to Y in the $S_N2(C^+)$ reaction shows the importance of structure (VIb).^{2,3} In the $\text{Ad}_{\text{Nu}}\text{-E1}$ route the higher response to X reflects the higher importance of resonative negative-charge dispersal from the N-Ar, while C-Ar disperses the charge inductively. This is compatible with data on nucleophilic vinylic reactions.^{1,8}

REFERENCES

1. Z. Rappoport, *Adv. Phys. Org. Chem.*, **7**, 1 (1969).
2. I. Ugi, F. Beck and U. Fetzer, *Chem. Ber.*, **95**, 126 (1962).
3. F.L. Scott and D.A. Cronin, *Tet. Lett.*, 715 (1963); F.L. Scott and J.B. Aylward, *ibid.*, 841 (1965); F.L. Scott, J.A. Cronin and J. Donovan, *ibid.*, 4615 (1969); F.L. Scott and J.K. O'Halloran, *ibid.*, 4083 (1970); J.B. Aylward and F.L. Scott, *J.C.S. (B)*, 1080 (1969).
4. E.g., the high $k(\text{O-Me})/k(\text{O-Ph})$ reactivity ratio deserves further study.
5. Z. Rappoport and R. Ta-Shma, *J.C.S. (B)*, 871 (1971).
6. C.K. Ingold, "Structure and Mechanism in Organic Chemistry", Cornell University Press, 2nd Ed., 1969, p. 470.
7. A possible unified mechanism is an addition-elimination for which bond-forming is important when $\sigma_X > 0.3$, while bond breaking is important when $\sigma_X < 0.3$. See R.F. Hudson and G. Klopman for a relevant analogy.
8. H. Shenhav, Z. Rappoport and S. Patai, *J.C.S. (B)*, 469 (1970).