A Clear Demonstration of the Stereoelectronic Effect of Nitrogen in Chloride Ion loss by (*E*)- and (*Z*)-Hydroximoyl Chlorides

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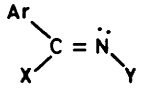
(*E*)-Benzohydroximoyl chlorides have been examined for the first time and are shown to react (as the conjugate ion) $>10^7$-fold more slowly than the corresponding (*Z*)-benzohydroximoyl chloride anions. This large rate difference is attributed to the favourable antiperiplanar lone pair on the adjacent nitrogen which facilitates Cl$^-$ loss from the (*Z*)-substrate. The (*Z*)-benzohydroximoyl chlorides were formed by direct chlorination of (*E*)- or (*Z*)-benzaldoximes while the (*E*)-chlorides were formed by acylation of these (*Z*)-isomers, photoisomerisation and separation, and then subsequent deacylation *in situ*.

The concept of stereoelectronic control, which ascribes a greater reactivity to an isomer or a conformation in which a leaving group is antiperiplanar to a lone pair on an adjacent heteroatom, has been used particularly by Deslongchamps[1] to rationalise a wide variety of reactions including eliminations and breakdown of tetrahedral intermediates. The generality of the idea has however been questioned as has some of the experimental evidence originally used to support its importance.

Sinnott[2] has urged that the idea should be reassessed. He has reported data on the non-enzymatic hydrolysis of glycosides and acetals from which it is apparent that these reactions involve 'late' transition states to highly unstable oxocarbocations. These reactions show little difference in rate whether the leaving group is antiperiplanar to the ring oxygen lone pair or not. Other attempts to freeze the possible conformations by incorporation of oxygen into a bicyclic or tricyclic system[3] are open to the criticism that ring strain effects, particularly at bridgeheads, may be the over-riding factor. Also central to the application of the theory to oxygen is the localisation of the two lone pairs on oxygen to defined areas of space. However there is little theoretical support for this[4] and in fact *ab initio* calculations show that the highest electron density may be *between* the tetrahedral orientations often associated with localised lone pairs.

The situation with regard to nitrogen should however be more clear-cut since the position of maximum electron density does not suffer from the same ambiguity. The imidoyl halide system **(1)**, **(2)** has the advantage that the relative orientations of the lone pair and the leaving group are fixed, and both syn- and anti-periplanar configurations are possible. However, the substrates must be chosen with care so that rapid interconversion of the (*E*)- and (*Z*)-isomers (by nitrogen inversion of whatever mechanism) occurs slowly, and both isomers are accessible. The latter restriction is a major one since when Y = OH, NMeAr [groups known to retard interconversion between **(1)** and **(2)**], the corresponding halides (X = Cl or Br) have been isolated as single isomers [probably with the structure **(1)**]. Attempts to photoisomerise these imidoyl halides to mixtures of **(1)** and **(2)** have also been unsuccessful.

We now report[5] that the introduction of an acyl protecting group ($Y = OCOR'$) permits the photoequilibration of isomers **(1)** and **(2)** of benzohydroximoyl chlorides. The acyl group can be removed *in situ*, giving the isomers **(1)** and **(2)** (X = Cl, Y = OH) both of which give nitrile oxides under mild conditions by Cl$^-$ loss from the corresponding anions.



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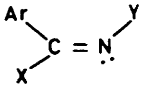

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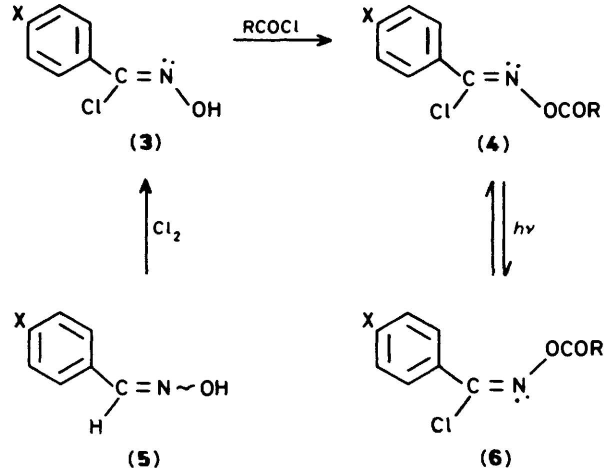
Results and Discussion

Synthesis and Structure of Substrates.—The benzohydroximoyl chlorides **(3)** were synthesised by direct chlorination of the parent aldoximes, using commercial-grade chloroform at 0 °C as the reaction medium. Rearrangement of a blue-green nitroso intermediate to the oxime occurs within 30 min. In the case of the unsubstituted oxime **(5a)** a yellow oily substance, which slowly converted into the hydroximoyl chloride **(3a)** on standing, was formed as a by-product.

Since photoisomerisation of oxime derivatives with a free –OH group does not appear to occur, it was necessary to use a suitable protecting group. A balance was also required between ease of separation of isomers and the lability of the protecting groups. The best characteristics were found with acetyl and substituted acetyl derivatives. Preliminary experiments established that the trimethylsilyl- and trifluoroacetyl-derivatives **(4e)** could be isolated and photoisomerised, but the isomers proved difficult to separate using chromatographic techniques. The benzoyl derivatives **(4d)** and **(6d)** were also formed but proved to be relatively stable towards hydrolysis; under the conditions required for the hydrolysis of **(6d)**, the (*E*)-chloride reacted too rapidly to be observed.

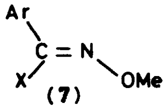
A range of acetyl, chloroacetyl, and dichloroacetyl derivatives of the hydroximoyl chlorides **(4)** were prepared (see Scheme 1) and photoisomerised to approximately 60:40 *Z*:*E* mixtures of the esters **(4)** and **(6)**. The esters were separated by preparative t.l.c.

Benzohydroximoyl chloride **(3a)** has the (*Z*)-configuration as established by *X*-ray crystallography.[6] The *O*-benzoyl derivative **(4d)** has also been assigned the (*Z*)-structure.[7] It is therefore likely that in all of the ester derivatives the (*Z*)-configuration of the starting chloride is retained. Correlations between n.m.r. chemical shifts and configuration are well established for oximes, and the n.m.r. spectra of the (*Z*)- and (*E*)-isomers **(4)** and **(6)** are quite distinctive. In all of the compounds examined, the acetyl protons were further downfield (by about 0.2 p.p.m.) in the series assigned the (*Z*)-configuration **(4)** than those assigned (*E*)-**(6)**. A downfield shift of similar magnitude was previously reported by Johnson[8] for the (*E*)- and (*Z*)-*O*-methylhydroximoyl chlorides **(7)** and **(8)** (X = Cl) and the *O*-methylbenzohydroximates **(7)** and **(8)** (X = *O*-alkyl). The chemical shifts of the *o*-hydrogens in the aryl group were also instructive. Thus, in **(4h)** the chemical shifts for the *o*- and *m*-hydrogens were almost identical. However, in the (*E*)-isomer **(6h)** the resonance position of the *o*-hydrogens is shifted upfield by 0.28 p.p.m. The *o*-hydrogens are equivalent due to rapid rotation about the C–Ar bond and the upfield shift can be



	X	R
a	H	Me
b	H	CH_2Cl
c	H	$CHCl_2$
d	H	Ph
e	H	CF_3
f	Cl	Me
g	Cl	CH_2Cl
h	NO_2	Me
i	NO_2	CH_2Cl
j	NO_2	Ph

Scheme 1.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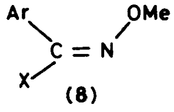

(8)

attributed to the influence of the *syn*-OCOMe group in (**6h**). A similar upfield shift (by 0.34 p.p.m.) is noted with (**6f**) relative to (**4f**).

Kinetic Results.—The rates of dehydrohalogenation of the (*Z*)-hydroximoyl chlorides (**3**) were studied directly at low pH, and followed the general pattern found for (**3a**) which was studied previously.[9] A typical result is shown in Figure 1 for (*Z*)-*p*-nitrobenzohydroximoyl chloride (**3h**) at 25 °C over the pH range 2—3.5 at 25 °C (μ = 1.0, $NaClO_4$). The reaction was found to be reversible under certain conditions due to the addition of Cl^- to the benzonitrile oxide formed (see Scheme 2) either by using added external Cl^- or even by using a large concentration of substrate ($>5 \times 10^{-2}$M) in a kinetic experiment. This is consistent with the result previously reported[10] by Armand of the observed rate of $1 \times 10^{-2}\ s^{-1}$ at $[Cl^-] = 0.01$M for the reaction of benzonitrile oxide with chloride ion. The forward reaction [(**10**) $\longrightarrow$ (**13**)] could however be measured at low substrate concentration in the absence of added $[Cl^-]$. The rate of dehydrohalogenation was inversely proportional to $[H^+]$ and became too fast to measure by conventional techniques at pHs >4 (see Figure 1).

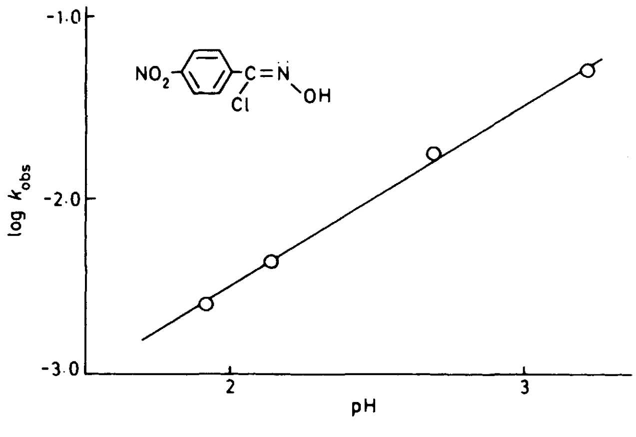


Figure 1. Plot of log of the observed rate of dehydrohalogenation of *p*-nitrobenzohydroximoyl chloride (**3h**) against pH (μ = 1.0, $NaClO_4$) at 25 °C in water

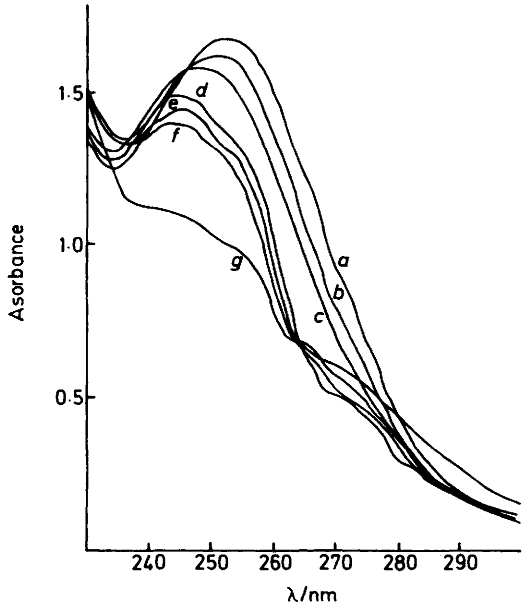


Figure 2. Repetitive scans of the u.v. spectrum for the reaction of (*Z*)-*O*-acetylbenzohydroximoyl chloride (**4a**) in water at 25 °C at pH 9.7. The time intervals are as follows: *a*, *t* = 0; *b*, +3 min; *c*, +6 min; *d*, +100 min; *e*, +120 min; *f*, +140 min, and *g*, ∞. The initial (ester hydrolysis) and subsequent (benzonitrile oxide hydrolysis) reactions are clearly seen

Removal of Protecting Groups.—Both (*E*)- and (*Z*)-esters (**4**) and (**6**) hydrolyse in basic buffer solutions. Repetitive scans of the u.v. spectra of the compounds buffered at pH 8—10 indicated successive reactions in each case. It was however possible to measure the initial reaction (ester hydrolysis) at an isosbestic point for the following reaction. For example, ester hydrolysis of (**4a**) was measured at 262 nm (Figure 2), an isosbestic point for the subsequent reaction (nitrile oxide reaction, see below).

In Figure 3 are plotted the log of the observed rate constants for the hydrolysis of the (*E*)- and (*Z*)-*O*-acetyl esters (**6a**) and (**4a**). The lines drawn have unit slope indicating hydroxide-mediated hydrolysis. The individual rate constants were obtained at low buffer concentrations. Initial experiments showed that catalysis by buffer species under these conditions was negligible.

The (*Z*)-ester hydrolyses about twice as fast as the (*E*)-isomer (this is a general result, see below). There is in addition a small increase in reactivity as the electron withdrawing power of the remote aryl substituent is increased (*p*-NO_2 > *p*-Cl > H).

With the more reactive chloroacetyl esters [and with the *O*-

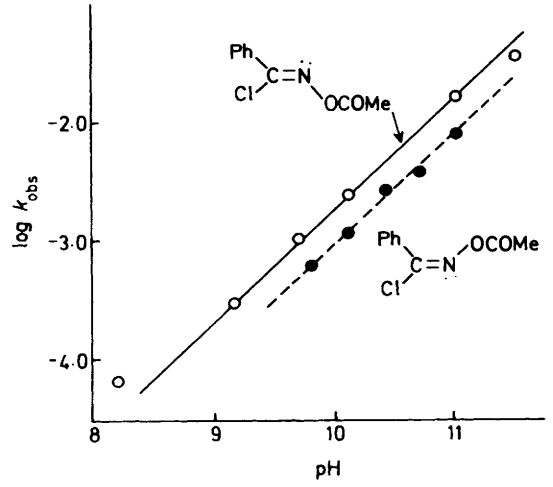


Figure 3. Plot of the log of the observed rate constants for the hydrolysis of the (*Z*)- and (*E*)-esters (**4a**) and (**6a**) against pH in water at 25 °C

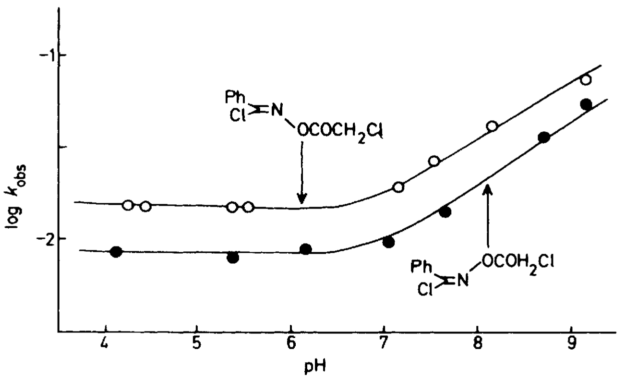


Figure 4. Plot of the log of the observed rate constants for the hydrolysis of the (*Z*)- and (*E*)-esters (**4b**) and (**6b**) against pH

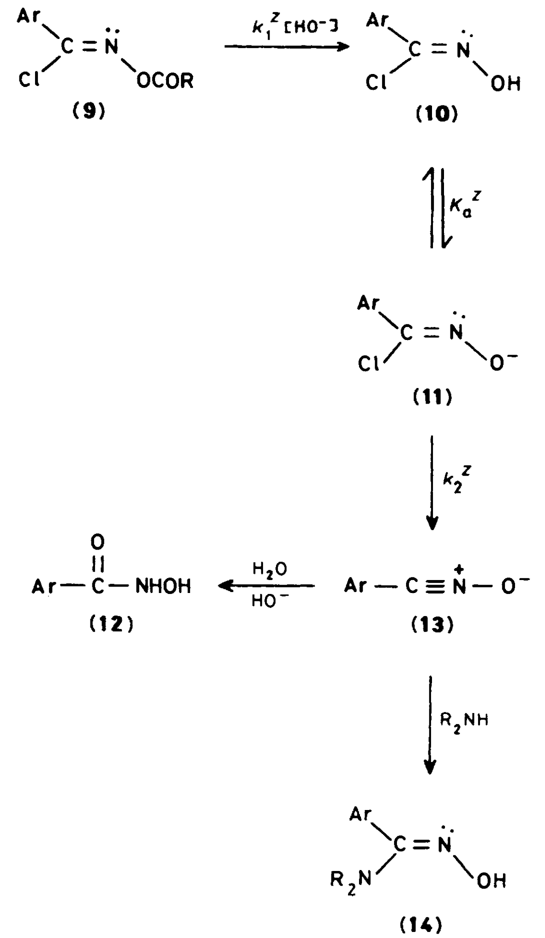
acetyl esters of *p*-nitrobenzohydroximoyl chloride], in addition to the (HO^-)-catalysed reaction, a pH-independent reaction occurs at pHs < 7 (see Figure 4). The rates of (HO^-)-catalysed and spontaneous rates of hydrolysis, correlated by equation (1), are summarised in Table 1.

$$k_{obs.} = k_o + k_1[HO^-] \qquad (1)$$

Table 1. Summary of observed rate constants for the hydroxide-catalysed hydrolysis of (*E*)- and (*Z*)-esters (**6**) and (**4**)

	Rate constants (k_1, M^{-1} s^{-1})^a		
X	R = Me	R = CH_2Cl	R = $CHCl_2$
H	3.1	400	1 140
Cl	5.5	660	
NO_2	16.7	700	

^{a} At 25 °C in water over pH range 9—11 [μ = 1.0 (KCl)].



Scheme 2.

Reaction of (E)- *and* (Z)-*Hydroximoyl Chlorides*.—When the (*Z*)-*O*-acetyl- or *O*-chloroacetyl-esters (**4**) were introduced into a basic solution, initial ester hydrolysis was rapid and a slow subsequent reaction, identified as the hydrolysis of the nitrile oxide (**13**), was observed. The nitrile oxide (**13**) was shown previously[9] to react at a measurable rate with the benzohydroxamic acid (**12**) under these conditions. The nitrile oxide was confirmed as an intermediate by direct generation from the hydroximoyl chloride (**3**) [the rates of reaction of (**13**) formed from (**3**) or (**9**) were identical in the pH range 4—12] and by trapping of (**13**) formed from (**9**) at pH 10 with the secondary amine morpholine which gave the amidoxime (**14**) [R_2 = $(CH_2)_2O(CH_2)_2$] as a product. It was not possible, using any of the (*Z*)-esters as substrates, to detect the loss of Cl^- from the (*Z*)-hydroximoyl chloride as this reaction (see Figure 5) was faster than ester hydrolysis at all pHs > 3.

The reaction of the (*E*)-hydroximoyl chloride was followed by introducing the (*E*)-chloroacetyl chloride (**6c**) into aqueous solution at pH > 10. Under these conditions, repetitive scans of the u.v. region show that a reaction with $t_{\frac{1}{2}}$ *ca.* 100 s is observed (see Figure 6). This was shown to be dehydrohalogenation of the (*E*)-hydroximoyl chloride (**16**), since (a) the same rate of reaction was observed independent of the (*E*)-ester (acetyl, chloroacetyl, dichloroacetyl) used as substrate; and (b) the rate of reaction observed was distinctly different (see below) from that which would be observed from the reaction of other species (*e.g.*, the nitrile oxide would react at a rate proportional to [HO^-] over the pH range 10—13; see Figures 5 and 6).

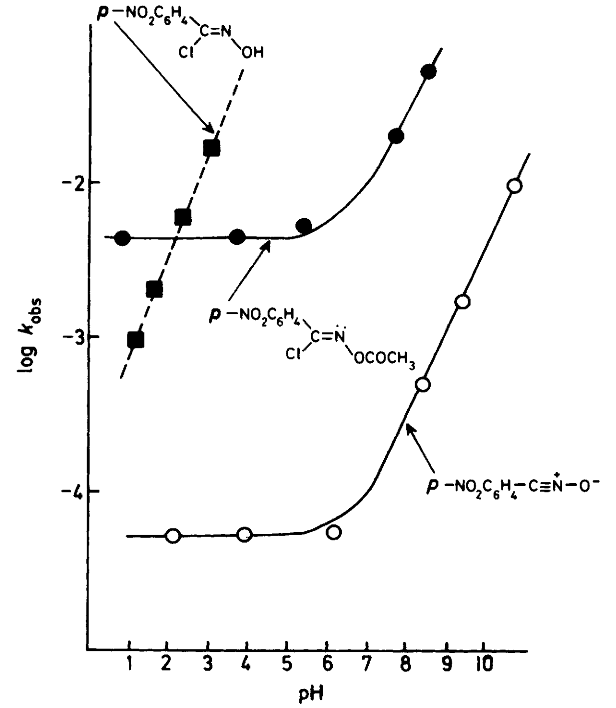


Figure 5. Plot of the log of the observed rate constants against pH for the reaction of the ester (**4h**), the nitrile oxide (**13**) (Ar = p-$NO_2C_6H_4$) and the (*Z*)-hydroximoyl chloride (**3h**)

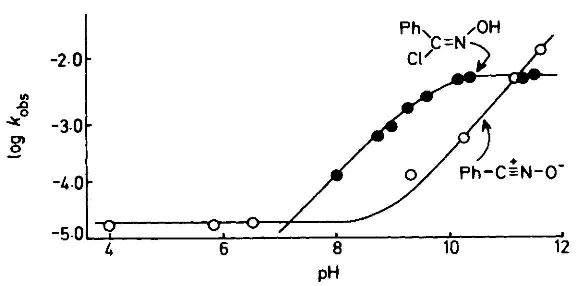
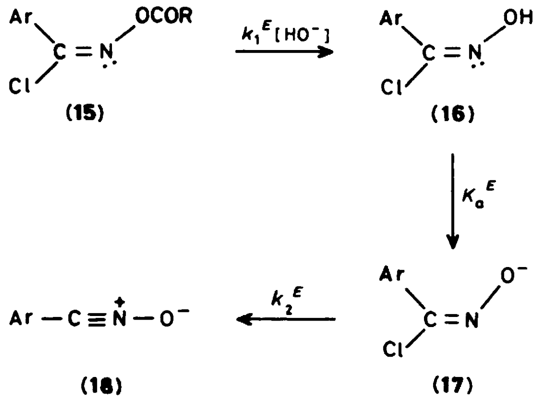


Figure 6. Plot of the log of the observed rate constants for the hydrolysis of the (*E*)-chloride (**16**) [derived from the (*E*)-esters (**6b**) or (**6c**) *in situ*] and of hydrolysis of benzonitrile oxide in water at 25 °C

It can be seen (Figure 6) that the reaction rate is proportional to $[HO^-]$ at pH < 10, but then becomes pH independent in the range 10—14. At pH *ca.* 11, it was difficult to measure the rate of reaction of (**16**) since reaction of the nitrile oxide (**18**) subsequently formed was similar in this pH range. This problem was overcome by running the reaction in the presence of an excess of the secondary amine morpholine. The added amine was shown not to affect the rate of dehydrohalogenation of (**16**), but rapidly trapped the nitrile oxide (**18**) to give the stable (under basic conditions) (*E*)-amidoxime (**14**).

Addition of morpholine (*ca.* 0.3M free amine) also had the advantage of catalysing ester hydrolysis so that the less reactive acetyl esters could be used as precursors of the (*E*)-hydroximoyl chlorides even at pH < 10. In effect, therefore, the addition of the amine catalysed both ester hydrolysis and subsequent reaction of the nitrile oxide, while leaving the rate of reaction of the (*E*)-hydroximoyl chloride (in effect the reaction of interest) unaffected.



Scheme 3.

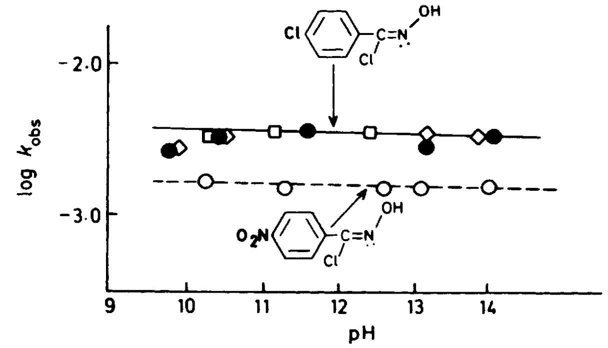


Figure 7. pH-Independent rates of hydrolysis of the (*E*)-chlorides (**16**) (Ar = p-ClC_6H_4 and p-$NO_2C_6H_4$) in water at 25 °C; the data were derived with (**6g**) as substrate (● in the absence and ◇ in the presence of added morpholine) while for points ☐ the acetyl ester (**6f**) was used to generate the substrate

$$k_{obs.} = k_2^E \cdot \frac{K_a^E}{a_H{}^+ + K_a{}^E} \qquad (2)$$

Figure 6 shows a plot of the log of the observed rates of dehydrohalogenation of the (*E*)-chloride (**16**) as a function of pH. These results imply that the substrate has an apparent pK_a of 9.6 and that only the anion (**17**) is reactive. Although the pK_a calculated from the kinetic data [the line in Figure 6 was drawn using equation (2) with $k_2^E = 6.6 \times 10^{-3}$ and $pK_a^E = 9.6$] cannot be measured directly using spectrophotometric techniques since both the (*E*)- and (*Z*)-chlorides are too reactive, the value calculated is not unreasonable. Thus Armand,[10] using the pK_a of 11.0 for the (*E*)-benzaldoxime as base, estimated a pK_a of 9.2 for benzohydroximoyl chloride (**10**) (9.6 from the present work).

Rates of dehydrohalogenation of the other (*E*)-chlorides (**16**) studied are summarised in Figure 7; these were obtained in the absence and presence of added morpholine and using different esters (**15**) as substrates.

Assuming similar pK_as for the (*E*)- and (*Z*)-chlorides, we can then estimate the rate of loss of Cl^- from the (*Z*)-anions (**11**) to be 4×10^5 s^{-1} for Ar = Ph, 8×10^4 s^{-1} for Ar = p-ClC_6H_4, and 3.5×10^4 s^{-1} for Ar = p-$NO_2C_6H_4$. The rate ratio for loss for Cl^- from the (*Z*)- and (*E*)-anions k_2^Z/k_2^E is therefore very large in each case (*ca.* 2—6 × 10^7). This is shown in Figure 8, which compares the reactivity of *Z*- and *E*-chlorides, as well as that of benzonitrile oxide.

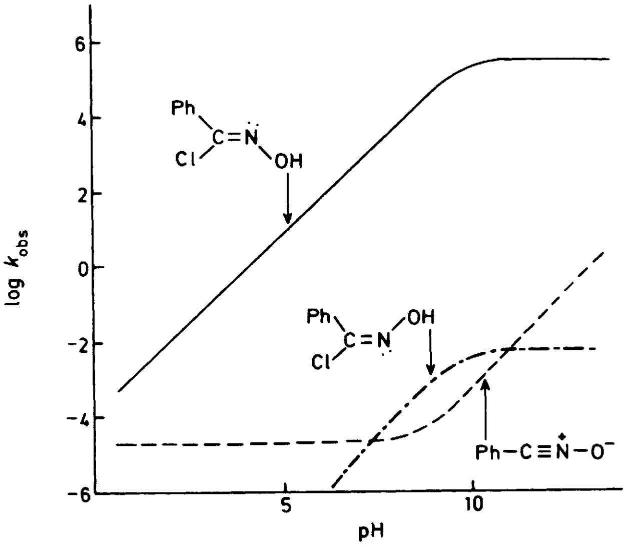
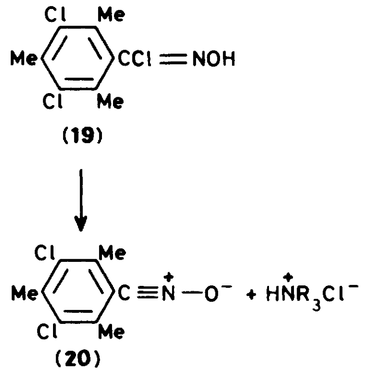


Figure 8. Plot showing the relative reactivities of the (*Z*)-chloride (**10**; Ar = Ph) by extrapolation, and of the (*E*) chloride (**16**; Ar = Ph) at 25 °C in water. The pH-profile for the hydrolysis of benzonitrile oxide (formed from either) is also included

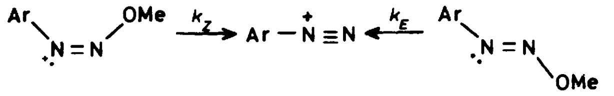


(**19**)

(**20**)

Previously, Beltrame and Dondoni[11] have reported on the dehydrohalogenation of 3,5-dichloro-2,4,6-trimethylbenzohydroximoyl chloride (**19**) in acetonitrile, catalysed by tertiary amines. Although the configuration of the chloride used was unknown (it was most likely *Z*-, as are all the more stable imidoyl halide isomers examined to date), it was stated that the reactivity should be independent of configuration of the substrate. Based on the present work and on the ionization of *O*-methylbenzohydroximoyl chlorides reported by Johnson,[8,12] this is clearly incorrect. A concerted reaction, involving partial O–H bond cleavage in the transition state, was also proposed for the reaction of (**19**) in acetonitrile, based on a small primary isotope effect (k_H/k_D *ca.* 2.0); this isotope effect was however obtained at a very low level of deuterium incorporation (*ca.* 18%) and is therefore unlikely to be reliable. In water, as shown above by the absence of buffer catalysis, dehydrohalogenation is a stepwise (rather than a concerted) reaction involving pre-equilibrium formation of the anions (**11**) and (**17**).

Previously it was estimated on the basis of ionisation of *O*-methylbenzohydroximoyl chlorides that nitrilium formation from (**7**) (X = Cl) occurred 470-fold faster than from the (*E*)-isomer (**8**) (X = Cl). Since it was also demonstrated that the free energy difference between the two substrates was small (3 kcal mol^{-1}) through equilibration studies, it was calculated that the free energy difference in the two transition states for nitrilium ion formation is *ca.* 8 kcal mol^{-1}. These energy and rate differences are clearly smaller than in the present study but there are two possible reasons for this: (a) the work carried out by Johnson and co-workers[12] was at 120—150 °C where prior (*E*) to (*Z*) isomerisation of the chloride [(**8**) → (**7**)] may be occurring (the experimental data presented do not rule this out); or (b) the much more stable nitrile oxide (Ar–C≡N$^+$–O$^-$) formed in the present study may imply an earlier transition state than those reactions in which the unstable Ar–C≡N$^+$–OMe ion is an intermediate. Although we have not been able to measure the relative ground-state energies of our (*E*)- and (*Z*)-hydroximoyl chlorides, the difference is unlikely to be very large, as shown by analogous oximes and MNDO calculations on isomeric imidoyl chlorides.[13]



(**21**) (**22**) (**23**)

Broxton[14] has also found evidence for stereoelectronic control in the reactions leading to the arenediazonium ions (**22**). The (*Z*)-arylazo methyl ether (**21**) loses methoxide ion *ca.* 10^5-times faster than the *anti*-arylazo methyl ether (**23**). Preferential elimination occurs from the isomer in which the leaving group and the lone pair on the adjacent nitrogen are antiperiplanar.

The high stereospecificity of these reactions was previously predicted in theoretical calculations of the energy pathway for the reaction of fulminic acid (HC≡N$^+$–O$^-$) and acetonitrile oxide (MeC≡N$^+$–O$^-$) with water as a nucleophile.[15] Formation of the *cis* product is clearly favoured; in fact there is no 'valley' on the reaction surface corresponding to the formation of the *trans* product.

We can conclude, therefore, that when a single lone pair (on nitrogen) is involved, and the transition state occurs early on the reaction co-ordinate, then there is a marked preference for addition to give an antiperiplanar arrangement of nucleophile and lone pair in the kinetic product and for antiperiplanar rather than synperiplanar elimination. The question with regard to oxygen is rather more difficult to answer because of the instability of simple oxocarbocations and the probable domination of ring strain effects in model systems.

Experimental

Substrates.—Benzohydroximoyl Chloride (**3a**). α-Benzaldoxime (prepared by the method of Vogel[16] and twice distilled) was dissolved in commercial-grade chloroform at 0 °C. Dry chlorine gas was passed through the solution for 30 min. The solution was initially a deep blue-green colour; nitrogen gas was then bubbled through to remove excess of chlorine. Evaporation of the solvent left a light yellow oil (70%) which solidified, m.p. 51—53 °C (hexane) (lit.,[16] 49—51 °C). The *p*-chloro- and *p*-nitro-benzohydroximoyl chlorides (**3h**) and (**3f**) were synthesised similarly using dichloromethane containing 1.5% ethanol in place of chloroform as solvent, and had m.p. 87—89 °C ($CHCl_3$–pentane) (lit.,[17] 82—86 °C) and 125—127 °C ($CHCl_3$–pentane) (lit.,[17] m.p. 123—124 °C).

Esters of Hydroximoyl Chlorides.—Three general methods were used for the synthesis of acetyl and benzoyl esters; the method used is detailed in Table 2.

Method A. The appropriate hydroximoyl chloride (0.02 mol) and the acid chloride (0.04 mol) were dissolved in benzene (50 ml). Dry pyridine (15 ml) was added dropwise to the cooled (10 °C) mixture. The mixture was stirred at room temperature

Table 2. Preparative data and properties of *O*-acetyl benzohydroximoyl chlorides

Compd.	Method of preparation	M.p./°C	^{1}H N.m.r./δ, p.p.m.	I.r. principal absorptions/cm^{-1}	Molecular formula	C	H	N	Cl
(4a)	A	43—44 (hexane)	2.3 (s, 3 H) 7.5 (m, 3 H) 8.0 (m, 2 H)	1 770, 1 590 (KBr)	$C_9H_8ClNO_2$	53.5 (54.8)	3.8 (4.1)	6.8 (7.1)	17.7 (17.8)
(6a)	2 h irradiation of **(4a)**	56—60	2.12 (s, 3 H) 7.5 (m, 5 H)			53.9	4.1	6.7	17.8
(4b)	B	57—58 (hexane)	4.32 (s, 2 H) 7.45 (m, 3 H) 7.9 (m, 2 H)	1 790, 1 580 (KBr)	$C_9H_7Cl_2NO_2$	47.15 (46.55)	3.2 (3.0)	6.2 (6.0)	31.0 (30.6)
(6b)	14 h irradiation of **(4b)**		4.18 (s, 2 H) 7.6 (m, 5 H)	1 765, 1 580 (KBr)		46.1	3.45	5.75	
(4c)	B	61—63	6.25 (s, 1 H) 7.6 (m, 3 H) 8.1 (m, 2 H)	1 781, 1 580 (KBr)	$C_9H_6Cl_3NO_2$	40.2 (40.7)	2.3 (2.3)	4.6 (5.2)	
(4d)	A	104—106 (hexane)	7.76 (m, 6 H) 8.25 (m, 4 H)	1 770, 1 600	$C_{14}H_{10}ClNO_2$	64.1 (64.8)	4.3 (3.9)	4.9 (5.4)	
(4e)	C	40—41		1 815, 1 600 (Thin film)					
(4f)	A	78—79	2.28 (s, 3 H) 7.4 (d, 2 H)		$C_9H_7Cl_2NO_2$	46.25 (46.5)	3.05 (3.0)	6.2 (6.0)	
(6f)	3.5 h irradiation of **(4f)**	65—70	2.15 (s, 3 H) 7.5 (d, 2 H) 7.6 (d, 2 H)			46.3	3.1	5.8	
(4g)	B	Oil	4.37 (s, 2 H) 7.5 (d, 2 H) 8.0 (d, 2 H)	1 795, 1 600 (Thin film)	$C_9H_6Cl_3NO_2$	40.3 (40.75)	2.5 (2.3)	4.8 (5.2)	
(6g)	7 h irradiation of **(4f)**	Oil	4.16 (s, 2 H) 7.56 (d, 2 H) 7.62 (d, 2 H)			40.3	2.6	5.0	
(4h)	A	89—91 (hexane)	2.25 (s, 2 H) 8.27 (d, 2 H) 8.32 (d, 2 H)	1 775, 1 575 (KBr)	$C_9H_7ClN_2O_4$	44.0 (44.6)	3.2 (2.9)	11.6 (11.6)	
(6h)	3.5 h u.v. irradiation of **(4h)**	108—110	2.15 (s, 3 H) 7.85 (d, 2 H) 8.4 (d, 2 H)	1 780, 1 590 (Thin film)		44.0	2.7	11.0	
(4i)	B	88—91	4.4 (s, 2 H) 8.3 (d, 2 H) 8.4 (d, 2 H)	1 790, 1 570 (KBr)	$C_9H_6Cl_2N_2O_4$	38.5 (39.1)	2.0 (2.2)	10.0 (10.1)	24.9 (25.3)
(4j)	A	Oil			$C_{14}H_9ClN_2O_4$	54.7 (55.3)	3.1 (3.0)	9.1 (9.2)	11.5 (11.5)

for 1 h and ether added. The ether was washed with water, dried (Na_2SO_4), and evaporated to give the *O*-acetyl derivative (in *ca.* 90% yield).

Method B. The hydroximoyl chloride (0.02 mol) was stirred at room temperature with an excess (20 ml) of the substituted acetyl chloride for 2 h. The excess of acetylating agent was evaporated off under reduced pressure and the resulting product recrystallised from hexane.

Method C. Benzohydroximoyl chloride (**3a**) was refluxed with excess of trifluoroacetic anhydride for 3 h; the ester was isolated by removing the trifluoroacetic acid and excess of anhydride under reduced pressure.

Isomerisation of (Z)-O-*Acetylbenzohydroximoyl Chlorides.*— The (*Z*)-chloride (**3**) (0.03 mol) was dissolved in 1:1 pentane–benzene (30 ml). The solution was irradiated in a water-cooled quartz reaction vessel using a 450-watt medium-pressure u.v. lamp. The irradiation times varied from 3 to 20 h (see Table 2). The course of the reaction was followed using n.m.r.; long reaction times led to decomposition. In general a 60:40 mixture of (*Z*)- and (*E*)-chlorides resulted and the pure (*E*)-esters were separated using preparative t.l.c. (on silica gel using 75:25 pentane–ether as eluant). The R_F value of the (*E*)-ester (**6**) was lower than that of the (*Z*)-ester (**4**) in each case.

Kinetic Method.—The course of reactions was followed using a Cary Model 210 or Beckmann Model 25 u.v. spectrophotometer. Initial repetitive scans of the u.v. region established suitable wavelengths at which reactions could be followed. Reaction was initiated by injecting 10—15 µl of the substrates (10^{-2}M) in dry dioxane into a cell containing aqueous solutions buffered at the appropriate pH at 25 °C. Good first-order plots were obtained using experimental infinity values (the kinetic methods have been described in more detail previously[18]).

In the reactions measured at varying chloride ion concentrations, sodium perchlorate was added to maintain the ionic strength constant (at $\mu = 1.0$).

References

1 P. Deslongchamps, 'Stereoelectronic Effects in Organic Chemistry,' Pergamon Press, Oxford, 1983.
2 M. L. Sinnott, *Biochem. J.*, 1984, **224**, 817; M. L. Sinnott and L. Hosie, *ibid.* J., 1985, **226**, 437.
3 S. Chandrasekhar, A. J. Kirby, and R. J. Martin, *J. Chem. Soc., Perkin Trans. 2*, 1983, 1916; A. J. Kirby and R. J. Martin, *ibid.*, pp. 1627, 1633; A. J. Briggs, C. M. Evans, R. Glenn, and A. J. Kirby, *ibid.*, p. 1637.
4 See for example, R. Daudel, G. Leroy, D. Peeters, and M. Sana, 'Quantum Chemistry,' Wiley, New York, 1983, p. 142.
5 Preliminary communication: A. F. Hegarty and M. Mullane, *J. Chem. Soc., Chem. Commun.*, 1984, 229.
6 J. P. Declercq, G. Germain, and M. Van Meersche, *Acta Crystallogr. Sect. B*, 1975, **31**, 2894.
7 O. Exner, G. Barbaro, and A. Dondoni, *J. Chem. Soc., Perkin Trans. 2*, 1980, 1051.
8 J. E. Johnson, E. A. Nalley, Y. K. Kunz, and J. R. Springfield, *J. Org. Chem.*, 1976, **41**, 252.
9 K. J. Dignam, A. F. Hegarty, and P. L. Quain, *J. Org. Chem.*, 1978, **43**, 388.
10 J. Armand, *Bull. Soc. Chim. Fr.*, 1966, 883.
11 D. Beltrame, A. Dondoni, G. Barbaro, G. Gelli, A. Loi, and S. Steffe, *J. Chem. Soc., Perkin Trans. 2*, 1978, 607.
12 J. E. Johnson and S. C. Cornell, *J. Org. Chem.*, 1980, **45**, 4144.
13 R. Keese, personal communication.
14 T. J. Broxton, *Aust. J. Chem.*, 1979, **32**, 1031; 1978, **31**, 1519.
15 M. T. Nguyen, M. Sana, G. Leroy, K. J. Dignam, and A. F. Hegarty, *J. Am. Chem. Soc.*, 1980, **102**, 573.
16 'Vogel's Textbook of Practical Organic Chemistry,' 4th Edn., Longmans, London, 1978, p. 758.
17 H. Rheinboldt, *Justus Liebigs Ann. Chem., 1926*, **451**, 161.
18 K. J. Dignam, A. F. Hegarty, and P. L. Quain, *J. Chem. Soc., Perkin Trans. 2*, 1977, 1457.

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