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KINETICS OF REACTIONS OF O-(2,4-DINITROPHENYL) BENZALDOXIMES WITH METHYLAMINE, CYCLOHEXYLAMINE AND PIPERDINE. REACTIVITY AT DIFFERENT ELECTROPHILIC SITES

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Abstract - Kinetics of reaction of E-O-(2,4-dinitrophenyl) benzaldoximes [X-C_6H_4-CH = N-O-$C_6H_3(NO_2)_2$ (2:4) ; where X = H, p-Me, p-Cl, p-NO_2] have been studied with $MeNH_2$, cyclohexylamine (CHA) and piperdine (PiP) in 1:1 (v/v) ethanol-water at 35±0.1°C under pseudo first order conditions. The reactions are overall second order, first order with respect to each reactant. Hammett plots are linear with a ρ value of +0.73 for $MeNH_2$, +0.61 for CHA and +1.25 for PiP. $MeNH_2$ and CHA predominantly give the corresponding N-(2,4-dinitrophenyl)amine with attack at the aromatic carbon in sharp contrast to earlier observation with OH^-. With piperdine both elimination and substitution products are obtained, the former product predominanting when strong electron-withdrawing substituents are present in the phenyl ring of the oxime.

Site of base attack on O-substituted aldoximes, particularly O-acyl ones has either been the methine hydrogen or the carbonyl carbon depending on the configuration. The Z-isomer on treatment with a base predominantly give the nitrile while the E-isomer reverts to the starting oxime[1-7]. Pyrolytic elimination which follows a different mechanism has been mostly successful with the E-isomer. O-(2,4-Dinitrophenyl) benzaldoximes (I) have a number of electrophilic sites of varied hardness and reaction with a strong base results in the abstraction of the benzylic hydrogen, the other reaction sites hardly get any cognisane. However, a moderate base like an amine is likely to be less discriminatory and show broad reactivity. To explore this possibility we have studied the kinetics of interaction of amines ($MeNH_2$, cyclohexylamine, piperidine) with E-O(2,4-dinitrophenyl) benzaldoxime [X-C_6H_4-CH=N-O-C_6H_3 $(NO_2)_2$ (2:4), where X=H(Ia), p-Me(Ib), p-Cl(Ic) and p-NO_2(Id)] results of which are presented and discussed in this paper.

RESULTS AND DISCUSSION

The kinetics of the reactions of O-(2,4-dinitrophenyl)benzaldoximes with $MeNH_2$ and cyclohexylamine (CHA) were followed at 365 nm corresponding to the λ_{max} of the principal product N-(2,4-dinitrophenyl) methylamine and N-(2,4-dinitrophenyl) cyclohexylamine respectively. The reaction with piperidine (Pip) was however, followed at 370 nm being the λ_{max} of the principal product N-(2,4-dinitrophenyl) piperidine. The reactions were carried out in 1:1 ethanol-water (v/v) at 35±0.1°C under pseudo first order conditions.

All the reactions followed overall second order kinetics, first order with respect to each reactant (Table 1).

As expected, a plot of pseudo first order rate constant (k_o) vs [Amine] was linear passing through the origin. The effect of ionic strength on rate was insignificant. However, the rate increased with increase in the polarity of the medium. Laidler-Erying and Amis plots were linear. All the reactions followed Arrheniuss relationship. Activation parameters for reactions covering all the substrates have been computed. Relevant data for methylamine reaction are given in Table 2. In all the cases high and negative values of entropy of activation suggesting clearly the congested nature of the transition state have been obtained. The observance of a clear isosbestic point in each case rules out the possibility of existence of any stable intermediate in these reactions.

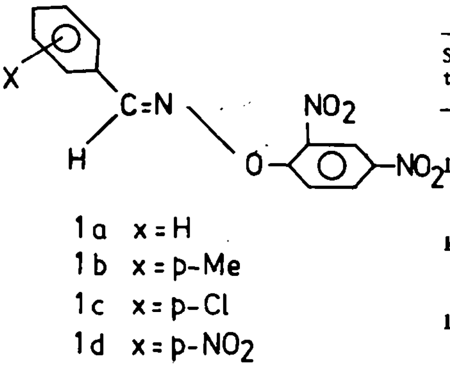


Table 1. Rate constants for the reaction of (I) with amines. [Substrate] = 4.0×10^{-5} mol dm^{-3} ; [Amine]=5×10^{-2} mol dm^{-3} ; μ = 0.2, $k_r = k_o$/[amine]

Substrate	Amine	$10^4 k_o$ s^{-1}	$10^3 k_r$ $dm^3\ mol^{-1} s^{-1}$	pH
Ia	$MeNH_2$	8.9	17.8	10.7
	CHA	1.0	2.0	10.8
	Pip	2.3	4.6	11.2
Ib	$MeNH_2$	7.3	14.6	10.7
	CHA	0.9	1.8	10.7
	Pip	1.8	3.6	11.2
Ic	$MeNH_2$	14.0	28.0	10.7
	CHA	1.4	2.8	10.8
	Pip	3.7	7.4	11.2
Id	$MeNH_2$	35.6	71.2	10.7
	CHA	2.9	5.8	10.8
	Pip	21.1	42.0	11.2

Table 2. Activation parameters for the reactions of (I) with $MeNH_2$ in 1:1 (v/v) ethanol-water

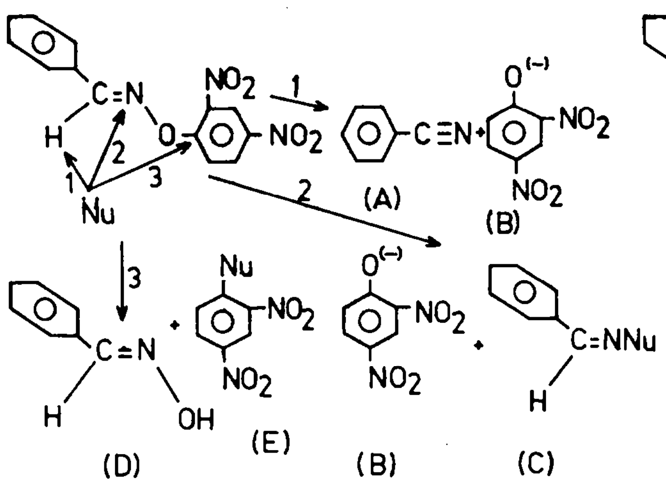
Substrate	E_a k J mol^{-1}	$10^6 A_1$ mol^{-1}s^{-1}dm^3	$\Delta G^{\neq}$ k J mol^{-1}	$-\Delta S^{\neq}$ J mol^{-1}K^{-1}	$\Delta H^{\neq}$ k J mol^{-1}
Ia	50.1	8.2 (± 0.7)	86.0 (± 0.9)	123.0 (±0.8)	48.5 (±0.07)
Ib	52.2	10.0 (± 0.4)	87.7 (± 1.0)	119.6 (±0.6)	49.6 (±0.06)
Ic	50.1	8.4 (± 0.3)	84.5 (± 0.8)	121.0 (±0.4)	47.6 [±0.04)
Id	44.2	1.9 (± 0.1)	83.3 (±1.0)	133.0 (±0.5)	41.6 (±0.1)

0-(2,4-Dinitrophenyl) benzaldoxime and its other nuclear substituted derivatives have three electrophilic sites, viz., the benzylic hydrogen, the oxime nitrogen and the nitro activated aromatic carbon attached to the oxime oxygen. Base atttack at the benzylic hydrogen results in the cleavage of C-H and N-O bonds[7], the formation benzonitrile A and 2,4-dinitrophenoxide ion B as shown in Scheme I (Path 1). When the site of attack is the oxime nitrogen, cleavage of the N-O bond occurs with the formation of B and the corresponding N-substituted derivative[9] C. Attack on the aromatic carbon results in the formation of the starting oxime D and the nucleophile substituted 2,4-dinitrophenylbenzene E.

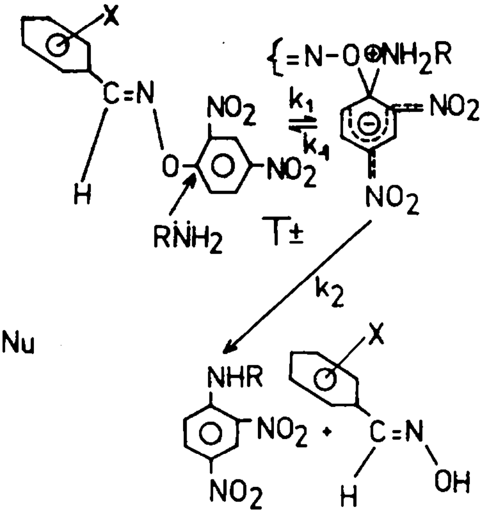
The products obtained for the reactions of various 0-(2,4-dinitrophenyl) benzaldoximes with cyclohexylamine and methylamine were N-(2,4-dinitrophenyl) cyclohexylamine and 0-(2,4-dinitrophenyl) methylamine respectively in quantitative yield on the basis of spectral data and tlc studies. Absence of 2,4-dinitrophenoxide ion suggests that routes 1 and 2 (scheme 1) do not make any significant contribution when methylamine and cyclohexylamine are used as bases.

The coloured products identified in the reactions of various 0-(2,4-dinitrophenyl) benzaldoximes with piperidine were N-(2,4-dinitrophenyl) piperidine and 2,4-dinitrophenoxide ion. The formation of the latter product is an indication that route 1 or 2 or both (scheme 1) needs consideration. A quantitative analysis of products showed that for 0-(2,4-dinitrophenyl)-p-nitrobenzaldoxime, the major product was 2,4-dinitrophenoxide ion (81%). However, in the case of 0-(2,4-dinitrophenyl) benzaldoxime, only 30% formation of 2,4-dinitrophenoxide ion occurred. The presence of an electron-withdrawing group in the phenyl ring of oxime increases the acidity of the benzylic hydrogen and facilitates its abstraction by the base. Further, the progressive occurrence of a peak at 225 nm corresponding to benzonitrile during reaction suggests that 2,4-dinitrophenoxide ion is formed via route 1 (scheme 1) rather than route 2.

It may be pointed out here that the various electrophilic sites present in 0-(2,4-dinitrophenyl) benzaldoxime differ in reactivity on the consideration of their hard-soft nature. In the light of Parr and Pearson hardness scale[10] and taking into consideration the factors[11] influencing hardness, the various electrophilic sites may be arranged as follows on the basis of their hardness :



SCHEME 1



SCHEME 2

benzylic hydrogen > oxime nitrogen > nitro activated aromatic carbon. The decreasing order of hardness of the attacking base may be computed as : OH^- > piperidine > methylamine > cyclohexylamine. Abstraction of the benzylic hydrogen from E-0-arylbenzaldoxime involves cis elimination and takes place in the presence of a strong and a hard base like the hydroxide ion. Methylamine and cyclohexylamine being comparatively weaker bases, nucleophilically attack at the relatively soft nitroactivated aromatic carbon and reactions occur via route 3 (scheme 1). Piperidine being on the border line show fascination for some or all the three sites depending on nature of the substituent in the phenyl ring of the oxime.

Hammett LFER is applicable for these reactions. Hammett ρ values for reactions with methylamine and cyclohexylamine are + 0.75 and + 0.61 respectively. The importance of the electron-withdrawing group in stabilizing the transition state is indicated. The weak susceptibility of the reaction to the substituent may be due to its remoteness from the reaction site. In the case of piperidine, ρ value was found to be + 1.25, the relatively higher sensitivity observed in this case may be due to the proximity of the reaction site to the substituent and supports the view that formation of phenoxide ion takes place by an attack at the benzylic hydrogen (scheme 2).

When methylamine and cyclohexylamine are used, the formation of a zwitter ionic transition state with attack at the nitroactivated aromatic carbon may be envisaged (scheme 2). The same mechanism is followed in the case of piperidine when electron-donating groups are present in the phenyl ring of benzaldoxime. But when electron withdrawing groups are present in the phenyl ring of the oxime, abstraction of the benzylic hydrogen with simultaneous breakage of C-H and N-O bonds and formation of benzonitrile and 2,4-dinitrophenoxide ion take place (scheme 2).

EXPERIMENTAL

Preparation of O-(2,4-dinitrophenyl) benzaldoxime

E Benzaldoxime was prepared as per Vogel's procedure[12]. This was treated with 2,4-dinitrochlorobenzene as per method described elsewhere[13] to obtaine 1(a), m.p. 145°(lit.[13] 145°C) ; 1(b) m.p. 169° (lit.[13] 168°C) ; 1(c) m.p. 205° (lit.[13] 210°C) ; 1(d) 216° (lit.[13] 216°C).

Kinetic measurements were made in a Unicam SP 500 spectrophotometer fitted with thermostatted cell holders. Rate constants were calculated with the help of a DEC 2050 computer. All the pH measurements were made in a Global digital D pH 500 pH meter. Electronic spectral measurements were carried out in a Beckman DU6 spectrometer.

Product analysis

This was carried out with the help of comparative tlc studies of the actual product and authentic sample. A typical example is given below : 20 ml of 8.0×10^{-5}M alcoholic solution of O-(2,4-dinitrophenyl) benzaldoxime and 20 ml of 0.1 M aqueous solution of methylamine were mixed at 35 ± 0.1°C. After the completion of reaction (2 hr), this was concentrated in vacuo and subjected to tlc studies using authentic samples of N-(2,4-dinitrophenyl) methylamine and 2,4-dinitrophenoxide ion. The chromatogram was developed in 1:1 acetone-petroleum ether. The reaction mixture showed a single coloured spot of R_f value 0.95 identical with that of N-(2,4-dinitrophenyl) methylamine. No 2,4-dinitrophenoxide ion could be detected. The other product was benzaldoxime as confirmed by comparison with authentic sample. These products estimated from their known molar extinction coefficients and measured absorbance were quantitative.

The products obtained from 1(a) to 1(d) with methylamine and cyclohexylamine were N-(2,4-dinitrophenyl) methylamine and N-(2,4-dinitrophenyl) cyclohexylamine in addition to the parent oxime in each case. But in the case of piperidine, the tlc of the reaction mixture developed as above showed two coloured spots of R_f values 0.55 and 0.95 identical with those of 2,4-dinitrophenoxide ion and N-(2,4-dinitrophenyl) piperidine respectively. For further information regarding nucleophilic attack, quantitative estimation of 2,4-dinitrophenoxide ion, formed in the reaction of 0-(2,4-dinitrophenyl) benzaldoxime and 0-(2,4-dinitrophenyl)-p-nitrobenzaldoxime with piperidine was carried out. The 2,4-dinitrophenoxide ion shows an intense peak at 360 nm in the alkaline pH. On acidification, however, this peak shifts to the UV region. N-(2,4-dinitrophenyl) piperidine also absorbs in the 360-370 nm region. But his peak remains uneffected on acidification. This information was made use of for the estimation of 2,4-dinitrophenoxide ion in the presence of N-(2,4-dinitrophenyl) piperidine. After acidification the absorbance due to N-(2,4-dinitrophenyl) piperidine at 360 nm was recorded and estimated from its known value of molar extenction coefficient. The relevant data are given in Table 3.

Table 3. Percentage yield for the reaction of piperdine with 1a and 1b

Substrate	Absorbance of the reaction mixture at 360 nm pH 12-13	pH 1-2	% N-(2,4-dinitrophenyl) piperidine	% 2,4-dinitrophenoxide ion
1a	0.62	0.47	70	30
1b	0.56	0.15	19	81

For reaction of 0-(2,4-dinitrophenyl) benzaldoxime with hydroxide ion, a progressive increase in absorbance at 225 nm corresponding to that of benzonitrite was recorded. The peak appearing at 360 nm completely disappeared on acidification. The products were identified to be benzonitrile and 2,4-dinitrophenoxide ion.

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