Oxidative Deoximation of 3-Alkyl Substituted 2,6-Diphenyl Piperidin-4-one Oximes by Pyridinium Fluorochromate: A Kinetic Study

K. Tharini*, T.S. Jani Bai† and M. Lakshmi‡

School of Chemical & Biotechnology, SASTRA Deemed University, Thanjavur-613 412, India
E-mail: tharini71@yahoo.co.in

The oxidation of oximes of 2,6-diphenyl piperidin-4-one and various alkyl substituted 2,6-diphenyl piperidin-4-one by pyridinium fluorochromate (PFC) has been studied. The reaction follows first order each in [PFC] and [oxime]. The reactivity sequence observed is 3-H > 3-Me > 3-Et > 3,3-dime > 3-*i*pr which has been rationalized on the basis of steric crowding by the substituents.

Key Words: Piperidone oximes, Kinetics, Oxidation, Pyridinium fluorochromate, Mechanism.

INTRODUCTION

Many valuable natural products with carbonyl groups are crystallized out only in the form of their oximes and semicarbazones from their biological sources[1]. Oximes have been converted to the corresponding aldehydes or ketones by treatment with reagents like thallium(III)[2], manganese(III)[3], cetyltrimethyl ammonium permangnanate (CTAP)[4], tetrammine copper(II) permanganate (TACP)[5], phenyl iodoso diacetate (PIA)[6] and peroxomono sulphate (PMS)[7]. However, extensive work in this conversion has not been carried out with chromium containing oxidants. Hence in the present investigation kinetics of the oxidation of heterocyclic oximes by pyridinium fluorochromate (PFC) has been chosen.

EXPERIMENTAL

Pyridinium fluorochromate (PFC), a complex of chromium trioxide, pyridine and hydrofluoric acid was prepared in the laboratory by the reported method[8]. Its purity was checked by iodometric method. A stock solution of PFC of strength 5.0×10^{-3} mol dm^{-3} was prepared in conductivity water. The piperidin-4-one oximes were prepared by the standard procedures[9].

---

†Seethalakshmi Ramaswami College, Trichirapalli -620 002, India.
‡Selvam College of Engineering and Technology, Namakkal-637 003, India.

The oximes were recrystallized from ethanol. The purity of the sample was confirmed by comparing the respective physical constants with literature values which show good concordance. Acetic acid used for kinetic runs was thrice distilled by adopting the usual procedures[10]. All other chemicals used were of analytical grade.

Rate measurements were carried out in 60 % (v/v) aqueous acetic acid medium in the temperature range 283-308 K in the presence of sulphuric acid of strength 2.0×10^{-3} mol dm^{-3}. The reactions were carried out under pseudo-first order conditions keeping the [substrate] in considerable excess over that of [PFC]. The progress of the reaction was followed spectrophoto-metrically at 355 nm up to 80 % completion of the reaction. The pseudo-first order rate constants were evaluated and found to be reproducible within ± 3 %.

The possibility of free radical formation is ruled out since there was no polymer formation when freshly distilled acrylonitrile monomer was added to the reaction mixture. This suggests a non-radical reaction pathway.

A known excess of PFC was allowed to react with a known concentration of substrate in 60 % (v/v) aqueous acetic acid medium. Estimation of the unreacted PFC from the reaction mixture after the completion of the reaction showed that the stoichiometry of the reaction is 1:1. The reaction mixture was also analyzed for the products by qualitative tests. The product was detected to be the corresponding ketone which was further confirmed by TLC experiments.

RESULTS AND DISCUSSION

Order with respect to oxidant: The dependence of rates of reaction on oxidant concentration was studied by varying [PFC] in the range 5.0-13.0×10^{-4} mol dm^{-3}. From the linear plots of log [PFC] against time (min) the order with respect to oxidant is determined to be unity. However, the pseudo first order rate constants were found to decrease with increase in concentration of gross PFC (Table-1). Similar observations have been reported earlier in the oxidation studies involving aromatic oximes and semicarba-zones by PFC[11,12] and in chromic acid oxidations[13].

Order with respect to substrate: The reactions were investigated at varying concentration of the oxime in the range 0.50-1.50×10^{-3} mol dm^{-3} and fixed concentrations of the other reactants. The plots of log [PFC] against time (min) at different initial concentrations of oximes were linear and the values of k_{obs} (s^{-1}) evaluated from the slopes were found to be dependent on the initial concentration of the substrates. The plot of log k_{obs} *vs.* log [substrate] was linear with unit slope showing a first order dependence on [oxime]. The value k_{obs} (s^{-1}) plotted against [substrate] gave straight lines passing through the origin proving a first order dependence on the

TABLE-1
RATE DATA FOR THE OXIDATION OF [3-ET PPO] BY PFC AT 293 K

[PFC] $\times 10^4$ (mol dm^{-3})	[Substrate] $\times$ 10^2 (mol dm^{-3})	[H$_2$SO$_4$] $\times$ 10^3(mol dm^{-3})	μ (mol dm^{-3})	AcOH:H$_2$O %(v/v)	k$_1 \times 10^4$ (s^{-1})
5.0	1.00	2.00	0.021	60:40	9.60
7.0	1.00	2.00	0.021	60:40	6.91
9.0	1.00	2.00	0.021	60:40	5.41
11.0	1.00	2.00	0.021	60:40	4.68
13.0	1.00	2.00	0.021	60:40	4.03
9.0	0.50	2.00	0.021	60:40	2.80
9.0	0.75	2.00	0.021	60:40	4.29
9.0	1.25	2.00	0.021	60:40	6.83
9.0	1.50	2.00	0.021	60:40	8.06
9.0	1.00	1.00	0.021	60:40	4.72
9.0	1.00	3.00	0.021	60:40	5.68
9.0	1.00	4.00	0.021	60:40	6.14
9.0	1.00	2.00	0.018	60:40	4.80
9.0	1.00	2.00	0.024	60:40	5.83
9.0	1.00	2.00	0.027	60:40	6.41
9.0	1.00	2.00	0.021	40:60	8.94
9.0	1.00	2.00	0.021	50:50	6.87
9.0	1.00	2.00	0.021	70:30	4.34
9.0	1.00	2.00	0.021	80:20	3.10

*at 288 K, 3.38; at 298 K, 7.68; at 303 K, 9.60.

[oxime] as well as the absence of self decomposition of PFC (Fig. 1). From the slopes of the above plots the second order rate constants k$_2$ dm^3 mol^{-1} s^{-1} were evaluated.
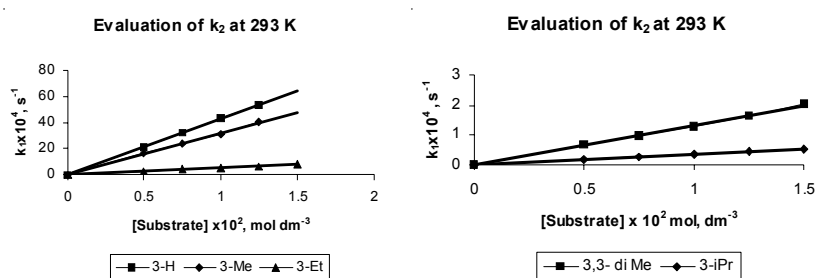

Fig. 1.

Effect of [H$^+$]: The acidity of the medium was varied from 1.0-4.0 $\times$ 10^{-3} mol dm^{-3} to learn the effect of acid on the reaction rate at constant [PFC], [oxime] and ionic strength (0.021 mol dm^{-3}). The oxidation reactions

were found to be acid catalyzed. The plots of log k_{obs} *vs.* log [H$^+$] were linear and the slopes indicate fractional order with respect to [H$^+$].

Influence of ionic strength: The rate studies were made at different ionic strengths of the medium, varied by the addition of sodium sulphate maintaining constant [H$^+$]. The influence of ionic strength on the rates of oxidation was negligible indicating the participation of an ion and a dipole in the rate determining step[14].

Dependence on solvent polarity: The effect of dielectric constant on the reaction rate was examined by varying the percentage of acetic acid in the range 40-80 % (v/v). The rate constants were found to decrease on lowering the dielectric constant of the medium. This may be due to polar mechanism[15].
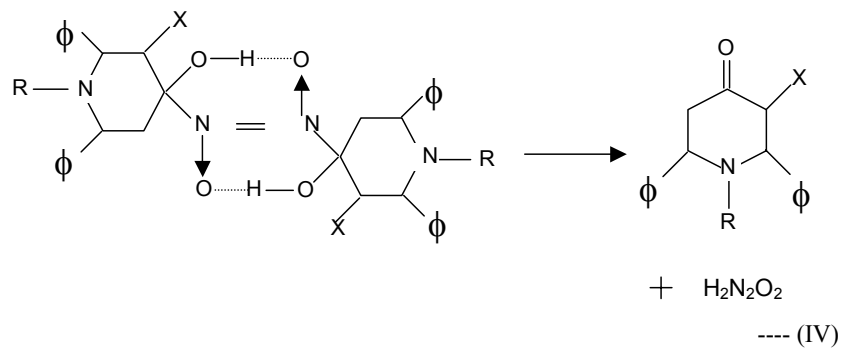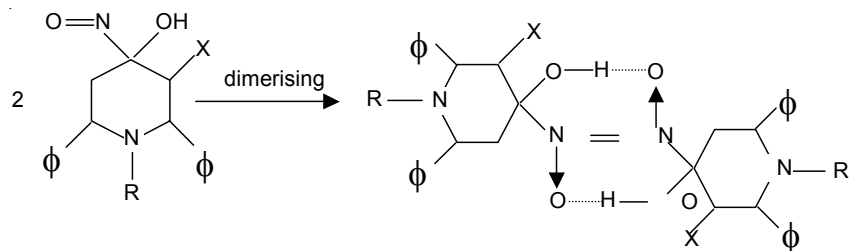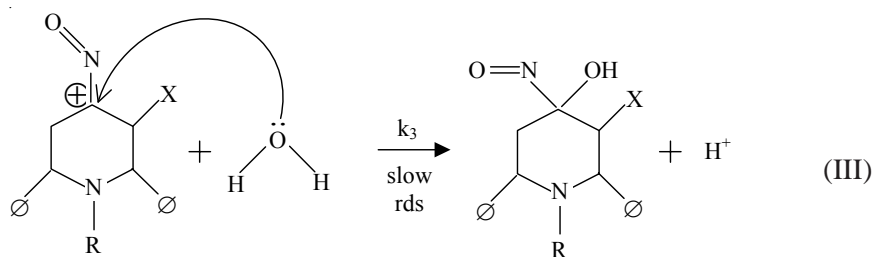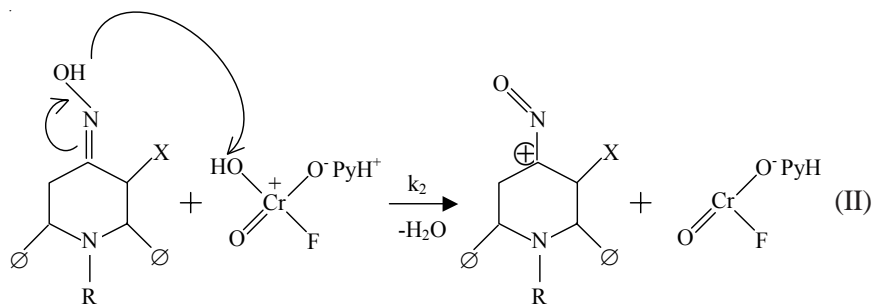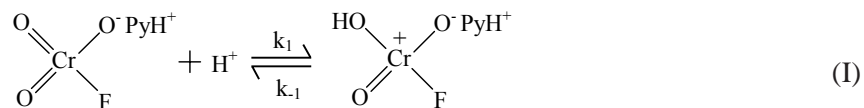
Rate and activation parameters: From the observed kinetic data, the second order rate constants for the oximes were found to increase with increase in temperature. The plots of log k_2 *vs.* 1/T were linear indicating that the Arrhenius law is being obeyed. The thermodynamics parameters E_a (KJ mol^{-1}), $\Delta G^{\#}$ (KJ mol^{-1}), $\Delta H^{\#}$ (KJ mol^{-1}) and $\Delta S^{\#}$ (JK^{-1} mol^{-1}) have been computed and tabulated (Table-2).
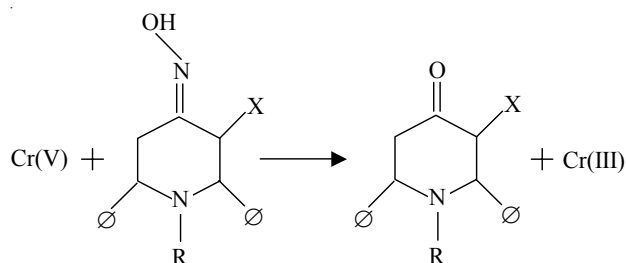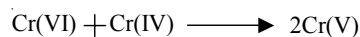
TABLE-2
RATE AND ACTIVATION PARAMETERS FOR 3-ALKYL SUBSTITUTED
2,6-DIPHENYL PIPERIDINE-4-ONE OXIME SYSTEM

Substrates	$K_2 \times 10^2$ (dm^3 mol^{-1} s^{-1})						E_a (KJ mol^{-1})	$\Delta H^{\#}$ (KJ mol^{-1})	$\Delta S^{\#}$ (KJ mol^{-1})	$\Delta G^{\#}$ (KJ mol^{-1})
	283 K	288 K	293 K	298 K	303 K	308 K				
PPO	11.20	24.20	42.90	89.90	-	-	91.90	89.47	15.17	85.02
3-me PPO	11.40	21.30	31.70	45.20	-	-	73.33	70.90	-50.68	85.75
3-et PPO	-	3.38	5.41	7.60	9.59	-	55.91	53.47	-124.81	90.04
3,3-dimePPO	-	-	1.30	2.65	4.00	5.37	85.01	82.58	-37.37	93.50
3-*i*pr PPO	-	-	0.35	0.70	1.05	1.45	82.91	80.47	-55.46	96.72

Mechanism: In the light of the experimental results obtained in the present investigation and the evidences from the other investigations involving the oxidative hydrolysis of oximes[16,17], a polar mechanism may be proposed for the reaction involving PFC and piperidin-4-one oxime.

The mechanism involves a slow formation of a positively charged PFC ester between the substrate and the protonated PFC by the removal of water molecule as reported in the chromic acid oxidation of alcohols[18], oxidation of aldehydes by PFC[19], acids by PCC[20], oximes by PCC[15] and alicyclic oximes by PFC[12]. Hence in the light of these arguments a polar mechanism has been proposed for the oxidation of piperidin-4-one oximes by PFC, ruling out the radical mechanism involving the formation of iminoxy radicals[2], which is presented in **Scheme-I**.

$$\text{(I)}$$

$$\text{(II)}$$

$$\text{(III)}$$

$$+ \quad H_2N_2O_2$$

$$\text{---- (IV)}$$

$$Cr(VI) + Cr(IV) \longrightarrow 2Cr(V)$$

X = -H, -Me, -Et, -*i*Pr, -3,3-diMe

Scheme-I

REFERENCES

1. P.S. Kalsi, Chemistry of Natural Products, Kalyani, New Delhi, p. 262 (1983).
2. A. Meenakshi, P. Maruthamuthu, K.V. Seshadri and M. Santappa, *Indian J. Chem.*, **11**, 608 (1973).
3. V. Venkat Rao, B. Sethuram and T. Navneeth Rao, *Indian J. Chem.*, **19A**, 1128 (1980).
4. R. Sankhla, S. Kothari, L. Kotai and K.K. Banerji, *J. Chem. Res.*, 127 (2001).
5. P.K. Mishra, L. Kotai and K.K. Banerji, *Indian J. Chem.*, **42A**, 72 (2003).
6. N. Bhavani and K. Lily, *Oxidn. Commun.*, **20**, 87 (1997).
7. T.S. Jani Bai, Ph.D. Thesis, Bharathidasan University (1988).
8. M.N. Bhattacharjee, M.K. Chaudhuri, H.S. Dasgupta, N. Roy and D.T. Khathing, *Synthesis*, 588 (1982).
9. V. Baliah, K. Pandiyarajan and M.A. Lakshmanan, *Indian J. Chem.*, **16B**, 72 (1978).
10. K.J.P. Ortan and A.E. Brad field, *J. Chem. Soc.*, 983 (1927).
11. T.S. Jani Bai and R. Subbalakshmi, *J. Indian Coun. Chem.*, **21**, 39 (2004).
12. T.S. Jani Bai, R. Subbalakshmi and V. Usha, *Asian J. Chem.*, **17**, 1240 (2005).
13. K.B. Wiberg, Oxidations in Organic Chemistry, Academic Press, New York (1965).
14. E.S. Amis, Solvent Effects on Reaction Rates and Mechanism, Academic Press, New York (1967).
15. K.J. Laidler, Chemcial Kinetics, Tata McGraw Hill Publication, New Delhi, p. 228 (1965).
16. R. Gurumurthy, G. Mangalam, M. Koshy, S. Rajam and K. Sathiyanarayanan, *Indian J. Heterocycl. Chem.*, **2**, 82 (1992).
17. V. Sundari and R. Chitradevi, *Curr. Sci.*, **55**, 850 (1986).
18. K.K. Sengupta, T. Samanta and S.N. Basu, *Tetrahedron*, **42**, 681 (1986).
19. A.A. Aggarwal, K. Chowdhury and K.K. Banerji, *J. Chem. Res. (S)*, **3**, 86 (1990).
20. K.K. Banerji, *Indian J. Chem.*, **17A**, 300 (1979).