Asian Journal of Chemistry Vol. 19, No. 6 (2007), 4602-4608

Oxidative Hydrolysis of Some Alkyl Substituted 1-Methyl-2,6-diphenyl Piperidin-4-one Oximes by Pyridinium Fluorochromate: A Kinetic and Mechanistic Approach

K. THARINI* and T.S. JANI BAI†
School of Chemical & Biotechnology, SASTRA Deemed University
Thirumalaisamudram-613 402, India
E-mail: tharini71@yahoo.co.in

The rates of oxidation of a few alkyl substituted 1-methyl-2,6-diphenyl piperidin-4-one oximes (X = -H, -Me, -Et, -iPr, -3,3-diMe, -3,5-diMe) by pyridinium fluorochromate (PFC) was followed in aqueous acetic acid medium. The influence of substrates, oxidant, H^+ ions, ionic strength and dielectric constant on the reaction rates at various temperatures was studied. The stoichiometry is 1:1 and the product of oxidation is the corresponding ketone. Activation energies and related thermodynamic parameters have been calculated and the plausible mechanism for oxidation reaction is discussed.

Key Words: Kinetics, Oxidation, Heterocyclic ketoximes.

INTRODUCTION

A variety of compounds containing chromium(VI) have proved to be versatile reagents capable of oxidizing almost every oxidizable functional group[1]. A number of new chromium(VI) containing compounds with heterocyclic bases, like pyridinium chlorochromate (PCC)[2], pyridinium bromochromate (PBC)[3], quinolinium fluorochromate (QFC)[4], quinolinium bromochromate (QBC)[5] and imidazolium fluorochromate (IFC)[6] have been developed to improve the selectivity of oxidation of organic compounds. Among these oxidants, fluorochromates have been reported to be very stable and more reactive than other halochromates[7].

Pyridinium fluorochromate, a mild oxidizing agent gives higher yields in short reaction times. Amount of oxidant required is less compared to other similar agents (pyridinium chlorochromate) and the oxidation can be carried out in variety of solvents.

Despite of wide spectrum of kinetics and mechanism of pyridinium fluorochromate (PFC) oxidation of organic compounds available in the

---

†Department of Chemistry, Seethalakshmi Ramaswami College, Trichirapalli-620 002, India.

literature[8-11], studies on oxidation of alkyl substituted 1-methyl-2,6-diphenyl piperidin-4-one oximes by PFC have not been attempted. Hence in the present paper, the oxidation of alkyl substituted 1-methyl-2,6-diphenyl piperidin-4-one oximes by PFC is reported.

EXPERIMENTAL

Pyridinium fluorochromate (PFC), a complex of chromium trioxide, pyridine and hydrofluoric acid was prepared in the laboratory by the method cited in the literature[7] and 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[12]. The oximes were recystallized 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[13]. 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 278-308 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 spectrophotometrically 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 %.

Test for free radical intermediates: 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.

Stoichiometry and product analysis: 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 7.0-13.0×10^{-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 semicarbazones and oximes by PFC[14,15] and in chromic acid oxidations[16].

TABLE - 1
RATE DATA FOR THE OXIDATION OF 1-METHYL 2,6-DIPHENYL PIPERIDIN-4-ONE OXIMES BY PFC AT 293 K

[PFC] × 10^4 (mol dm^{-3})	[1-Me-3-EtPPO] × 10^2 (mol dm^{-3})	[H_2SO_4] × 10^3 (mol dm^{-3})	μ (mol dm^{-3})	AcOH·H_2O % (v/v)	$k_1 \times 10^4$ (s^{-1})
7.0	1.00	2.00	0.021	60:40	5.29
9.0	1.00	2.00	0.021	60:40	4.18
11.0	1.00	2.00	0.021	60:40	3.30
13.0	1.00	2.00	0.021	60:40	2.88
9.0	0.50	2.00	0.021	60:40	2.07
9.0	0.75	2.00	0.021	60:40	3.15
9.0	1.10	2.00	0.021	60:40	4.72
9.0	1.00	1.00	0.021	60:40	3.61
9.0	1.00	3.00	0.021	60:40	4.41
9.0	1.00	4.00	0.021	60:40	4.80
9.0	1.00	2.00	0.018	60:40	3.61
9.0	1.00	2.00	0.024	60:40	4.72
9.0	1.00	2.00	0.027	60:40	4.91
9.0	1.00	2.00	0.021	40:60	8.17
9.0	1.00	2.00	0.021	50:40	5.37
9.0	1.00	2.00	0.021	70:30	3.18
9.0	1.00	2.00	0.021	80:20	2.80

*at 288 K; 2.23; at 298 K; 6.22; at 303 K;11.51.

Order with respect to oximes: The reactions were investigated at varying concentration of the oxime in the range 0.50-1.10 × 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 [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.

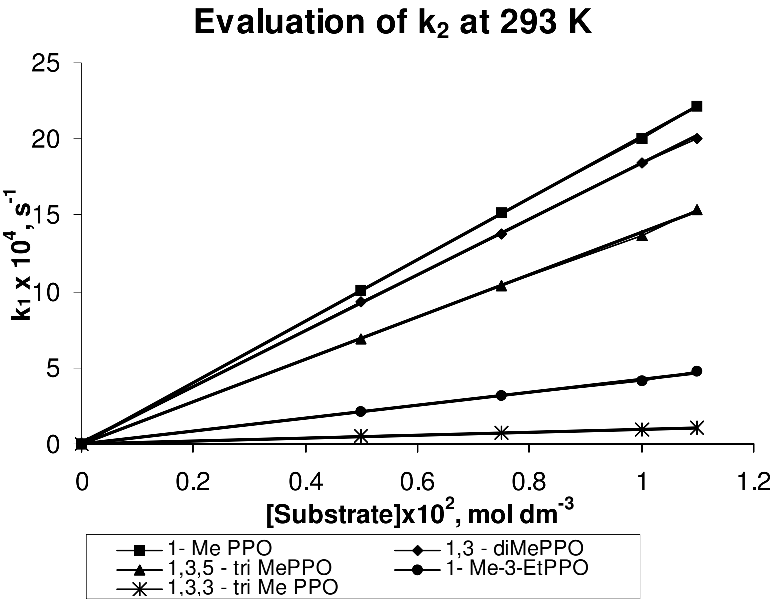


Fig. 1

Effect of [H$^+$]: The acidity of the medium was varied from 1.0-4.0 × 10^{-3} mol dm^{-3} to check 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[17].

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[18].

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 OXIMES OF 3-ALKYL SUBSTITUTED 1- METHYL 2,6-DIPHENYL PIPERIDINE -4-ONE

Substrates	$K_2 \times 10^2$ (dm^3 mol^{-1} s^{-1})							E_a (KJ mol^{-1})	$\Delta H^{\#}_{293K}$ (KJ mol^{-1})	$\Delta S^{\#}_{293K}$ (JK^{-1} mol^{-1})	$\Delta G^{\#}_{293K}$ (KJ mol^{-1})
	278K	283K	288K	293K	298K	303K	308K				
1-Me PPO	14.60	16.60	20.40	22.50	-	-	-	24.18	23.00	-234.00	86.84
1,3-diMe PPO	4.18	8.36	12.60	18.46	-	-	-	60.47	58.03	-113.00	87.06
1,3,5-triMe PPO	-	9.71	11.50	13.70	16.90	-	-	21.89	19.45	-244.00	87.77
1-Me-3-EtPPO	-	-	2.22	4.18	6.20	11.50	-	74.20	71.76	-64. 58	90.68
1,3,3-TRIME PPO	-	-	-	0.99	1.49	1.96	2.49	52.65	50.22	-144.00	94.18

Mechanism: In the light of all the experimental results obtained in the present investigation and the evidences from the other investigations involving the oxidative hydrolysis of oximes[19,20] a polar mechanism may be proposed for the reaction involving PFC and piperidin-4-one oxime.

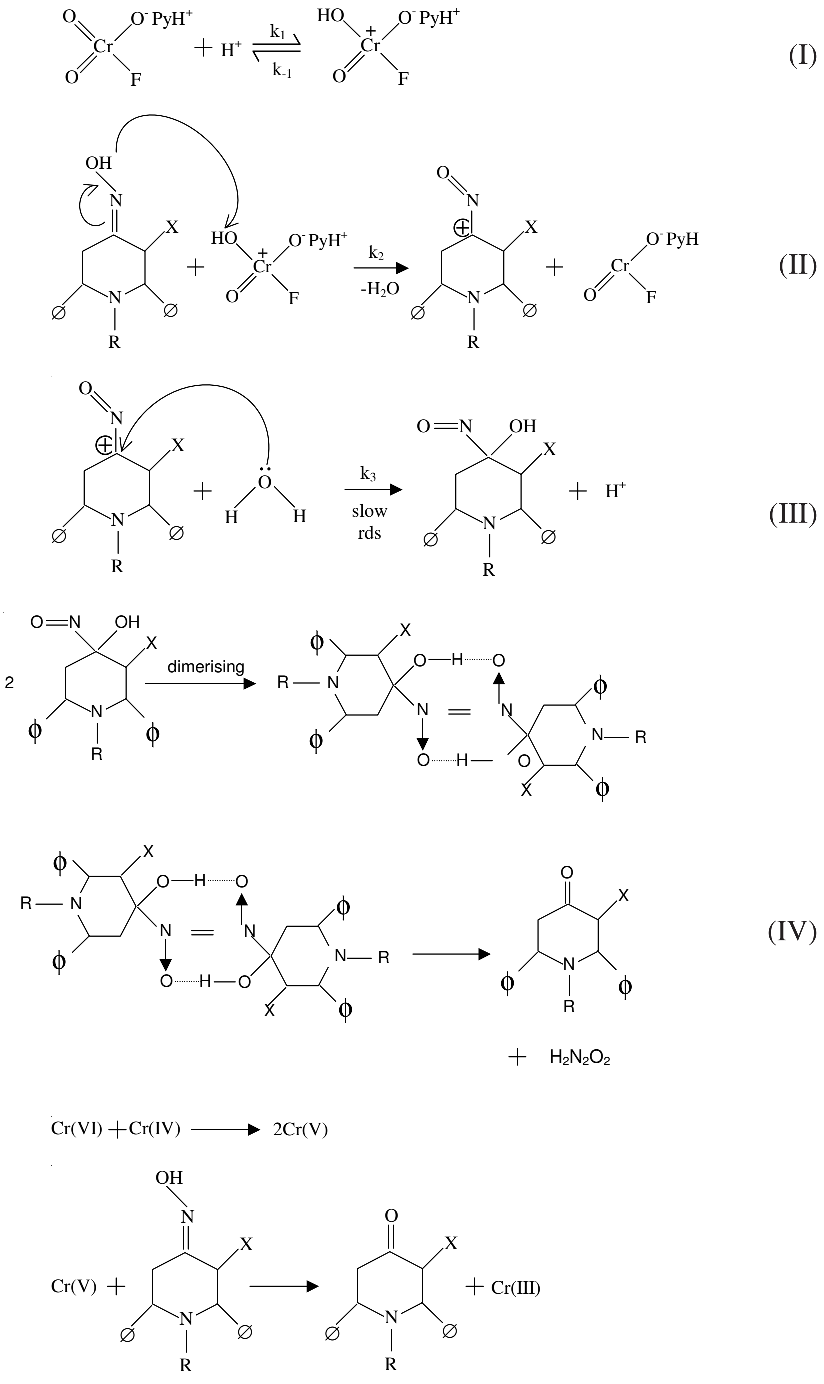
The mechanism involves a slow formation of a positively charged PFC ester between the substrate and the protonated PFC by the removal of water molecule as reported in the chromic acid oxidation of alcohols[21], oxidation of aldehydes by PFC[22], acids by PCC[23], oximes by PCC[19] and alicyclic oximes by PFC[24]. 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, which is presented in **Scheme-I**.

Structure and reactivity: The rate constants of all oximes were determined in 60 % (v/v) acetic acid.

From the magnitude of the rate constants, it is observed that the reactivity decreases as the size of the alkyl substituent increases. For example, 1,3-dimethyl-2,6-diphenyl piperidin-4-one oxime reacts slower than 1-methyl-2,6-diphenyl piperidin-4-one oxime. This indicates that there should be more steric crowding in the transition state than in the ground state. This trend can be attributed to the change of the central atom from a trigonal to a tetragonal state. It is evidnt that the increase in the steric crowding is proportional to the bulkiness of the substituent in the third position. That is why the reactivity decreases in the order

1-Me PPO > 1,3-diMe PPO > 1,3,5-triMe PPO >
1-Me-3-EtPPO > 1,3,3-triMe PPO

The inductive effect of the substituents increases in the same order which may decelerate the reaction by reducing the (+ve) charge of the central carbon atom. Thus the reactivity trend can be accounted by both steric[25-30] crowding and inductive effect. This fact provides substantial supportive evidence for the proposed mechanism.



X = -H, -Me, -Et, -3,3-diMe, -3,5-diMe; R = -Me

Scheme-I

REFERENCES

1. K.B. Wiberg, Oxidations in Organic Chemistry, Academic Press, New York (1965).
2. E.J. Corey and D.L. Boger, *Tetrahedron Lett.*, **28**, 2461 (1978).
3. N. Narayanan and T.R. Balasubramanium, *J. Chem. Res (S)*, 336 (1991).
4. A. Pandurangan and V. Murugesan, *Oxidn. Commun.*, **20**, 93 (1997).
5. A. Pandurangan, V. Murugesan and M. Palanisamy, *J. Indian Chem. Soc.*, **72**, 479 (1995).
6. A. Pandurangan, G.A. Raj Kumar, B. Arabindoo and V. Murugesan, *Indian J. Chem.*, **38B**, 99 (1999).
7. M.N. Bhattacharjee, M.K. Chaudhuri, H.S. Dasgupta, N. Roy and D.T. Khathing, *Synthesis*, 588 (1982).
8. L. Friedman, D.L. Fishel and H. Schecter, *J. Org. Chem.*, **30**, 1453 (1965).
9. W. Watanabe and F.H. Westheimer, *J. Chem. Phys.*, **17**, 61 (1949).
10. K.K. Sengupta, S. Dey, S.S. Gupta, M. Adhikari and A. Banerjee, *Tetrahedron*, **46**, 2431 (1990).
11. P.S. Radhakrishnamurthi and B.K. Panda, *Indian J. Chem.*, **21A**, 128 (1982).
12. V. Baliah, K. Pandiyarajan and M.A. Lakshmanan, *Indian J. Chem.*, **16B**, 72 (1978).
13. K.J.P. Ortan and A.E. Brad Field, *J. Indian Chem. Soc.*, **4**, 983 (1927).
14. T.S.J. Bai and R. Subbalakshmi, *J. Indian Council Chem.*, **21**, 39 (2004).
15. T.S.J. Bai, R. Subbalakshmi and V. Usha, *Asian J. Chem.*, **17**, 1240 (2005).
16. K.B. Wiberg, Oxidation in organic chemistry, Part A, Academic Press, New York, p. 65 (1965).
17. E.S. Amis, Solvent Effects on Reaction Rates and Mechanism, Academic Press, New York, p. 40 (1967).
18. K.J. Laidler, Chemcial Kinetics, Tata Mc-Graw Hill Publ., New Delhi, p. 228 (1965).
29. R. Gurumurthy, G. Mangalam, M. Koshy, S. Rajam and K. Sathiyanarayanan, *Indian J. Heterocycl. Chem.*, **2**, 82 (1992).
20. V. Sundari and R. Chitradevi, *Curr. Sci. (India)*, **55**, 850 (1986).
21. K.K. Sengupta, T. Samanta and S.N. Basu, *Tetrahedron*, **42**, 681 (1986).
22. A. Aggarwal, K. Chowdhury and K.K. Banerji, *J. Chem. Res. Synop.*, **3**, 86 (1990).
23. K.K. Banerji, *Indian J. Chem.*, **17A**, 300 (1979).
24. T.S.J. Bai, R. Subbalakshmi and V. Usha, *Asian J. Chem.*, **17**, 1240 (2005).
25. P.M. Kumar, L. Kotai and K.K. Banerji, *Indian J. Chem.*, **42A**, 72 (2003).
26. I. Dave, V. Sharma and K.K. Banerji, *Indian J. Chem.*, **41A**, 493 (2002).
27. K. Karunakaran, R. Gurumurthy and K.P. Elango, *J. Indian Chem. Soc.*, **75**, 297 (1998).
28. V. Baliah and J. Chandrasekaran, *Indian J. Chem.*, **15B**, 826 (1977).
29. V. Baliah and J. Chandrasekaran, *Indian J. Chem.*, **15B**, 1035 (1977).
30. V. Baliah, J. Chandrasekaran and K. Natarajan, *Indian J. Chem.*, **15B**, 829 (1977).

(*Received*: 4 July 2006; *Accepted*: 21 April 2007) AJC-5597