



Kinetics and Mechanistic Investigation of Oxidation of Fluoroquinolone Antibacterial Agent, Norfloxacin, by Diperiodatargentate (III) in aqueous alkaline medium.

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Abstract: The kinetics and mechanism of oxidation of Norfloxacin (NF) by Diperiodatoargentate (III) (DPA) in alkaline medium at constant ionic strength of 0.10 mol dm^{-3} was studied spectrophotometrically. The reaction exhibits 1:1 DPA:NF stoichiometry and is first order in DPA but fractional order in both NF and alkali. The order was found to be negative fractional order with respect to periodate. The main reaction products were identified as hydroxylated NF and Ag(I). A mechanism involving free radicals was proposed. In a composite equilibrium step, norfloxacin binds to DPA to form a complex that subsequently decomposes to the products. The reaction was investigated at different temperatures and activation parameters with respect to the slow step of the proposed mechanism were calculated and discussed.

Keywords: Norfloxacin, Kinetics, Oxidation, Diperiodatoargentate (III), Reaction Mechanisms.

I. Introduction:

Diperiodatoargentate(III) (DPA) is a powerful oxidizing agent in alkaline medium with the reduction potential[1] 1.74 V. It is widely used as a volumetric reagent for the determination of various organic and inorganic species[2,3]. Jaya Prakash Rao et al.[4,5] has used DPA as an oxidizing agent for the kinetics of oxidation of various organic substrates. They normally found that, order with respect to both oxidant and substrate was unity and $[\text{OH}^-]$ was found to enhance the rate of reaction. It was also observed that they did not arrive the possible active species of DPA in alkali and on the other hand they proposed mechanisms by generalizing the DPA as $[\text{Ag}(\text{HL})\text{L}]^{(x+1)-}$. However, Kumar[6-8] et al. put an effort to give an evidence for the reactive form of DPA in the large scale of alkaline pH. In the present investigation, we have obtained the evidence for the reactive species for DPA in alkaline medium.

Norfloxacin, a fluoroquinolone, is a 1-ethyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3quinolinecarboxylic acid. Its empirical formula is $\text{C}_{16}\text{H}_{18}\text{FN}_3\text{O}_3$. Norfloxacin is a white to pale yellow crystalline powder with a molecular weight of 319.34 and a melting point of about 221°C . It is freely soluble in glacial acetic acid, and very slightly soluble in ethanol, methanol and water. Norfloxacin is a synthetic chemotherapeutic antibacterial agent[9,10] occasionally used to treat common as well as complicated urinary tract infections. It also inhibits DNA synthesis and is bactericidal[11-16]. Norfloxacin is a first generation synthetic fluoroquinolone (quinolone) developed by Kyorin Seiyaku K.K. It interacts with a number of other drugs, as well as a number of herbal and natural supplements. Such interactions increase the risk of anticoagulation and the formation of non-absorbable complexes, as well as increasing the risk of toxicity. As a result of their extensive usage, fluoroquinolones may enter the environment via wastewater effluent and biosolids from sewage treatment plants and via manure and litters from food-producing animal husbandry. The presence and accumulation of fluoroquinolone antibiotics in aquatic environments, albeit at low concentrations, may pose threats to the ecosystem and human health by inducing increase and spread of bacteria drug resistance due to long-term exposure. This necessitates development of the various advanced oxidation processes for the transformation of fluoroquinolones in water.

In view of potential pharmaceutical importance of norfloxacin and lack of literature on the oxidation of this drug by any oxidant except in two cases[17,18] and the complexity of the reaction, a detailed study of the reaction becomes important. The present investigation is aimed at checking the reactivity of norfloxacin toward Diperiodatoargentate (III) and arriving at a plausible mechanism.

II. Experiment

All chemicals used were of analytical reagent grade, and double distilled water was used throughout the work. The solution of norfloxacin (Sigma-Aldrich) was prepared by dissolving a known amount of the compound in 6.0 mL of 0.3 mol dm⁻³ NaOH and further diluted to 100 mL with double distilled water. The required concentration of norfloxacin was obtained from its stock solution. DPA was prepared by oxidizing Ag(I) in presence of KIO₄ as described elsewhere[19,20]. The complex was characterized from its UV spectrum, which exhibited three peaks at 210, 254, and 362 nm. These spectral features were identical to those reported earlier for DPA[19]. The magnetic moment study revealed that the complex is diamagnetic. The compound prepared was analysed[21] for silver and periodate by acidifying a solution of the material with HCl, recovering and weighing the AgCl for Ag, and titrating the iodine liberated when excess of KI was added to the filtrate for IO₄⁻. The stock solution of DPA was used for the required [DPA] solution in the reaction mixture. During the kinetics a constant concentration viz. 1.0x10⁻⁴ mol dm⁻³ of KIO₄ was used throughout the study unless otherwise stated. Thus, the possibility of oxidation of NF by periodate was tested and found that there was no significant interference due to KIO₄ under experimental condition. The total concentrations of periodate and OH⁻ was calculated by considering the amount present in the DPA solution and that additionally added.

Kinetics:

The kinetic measurements were performed on a Varian CARY 50 Bio UV-Vis Spectrophotometer under pseudo first order condition where [NF] > [DPA] at 25±0.1 °C, unless specified. The reaction was initiated by mixing previously thermostatted solution of the DPA to NF solution, which also contained required concentration of KNO₃, KOH, and KIO₄; and the progress of reaction was followed spectrophotometrically at 360nm by monitoring decrease in absorbance due to DPA (molar absorptivity index, 'ε' to be 13900±100 dm³ mol⁻¹ cm⁻¹). The application of Beer's law to DPA at 360 nm had been verified. The reaction was followed more than three half-lives. The first-order rate constants *k*_{obs} were evaluated from plots of log [DPA] versus time, and *k*_{obs} values were reproducible at 360 nm.

Kinetics runs were also carried out in N₂ atmosphere in order to understand the effect of dissolved oxygen on the rate of the reaction. No significant difference in the results was obtained under a N₂ atmosphere and in the presence of air. In view of the ubiquitous contamination of carbonate in the basic medium, the effect of carbonate was also studied. Added carbonate had no effect on the reaction rate. Fresh solutions were used during the experiments.

III. Results

The reaction orders were determined using the slopes of log *k*_{obs} versus log (concentration) plots by varying the concentration of norfloxacin, periodate and alkali while keeping other factors constant. With fixed concentrations of NF, 1.0x10⁻³ mol dm⁻³, IO₄⁻, 1.0x10⁻⁴ and alkali, 0.15 mol dm⁻³, at constant ionic strength, 0.10 mol dm⁻³, the DPA concentration was varied in the range of 5.0x 10⁻⁵ to 5.0x10⁻⁴ mol dm⁻³. All kinetic runs exhibited identical characteristics. The linearity of plots of log (absorbance) versus time, for different concentrations of DPA, indicates that the order in DPA is unity. This was also confirmed by the constant values of the pseudo first-order rate constants, *k*_{obs}, for different DPA concentrations (Table 1). The NF concentration was varied in the range of 2.0x10⁻⁴ to 5.0x10⁻³ mol dm⁻³ at constant alkali, periodate and DPA concentrations and constant ionic strength of 0.10 mol dm⁻³ at 25 °C. The *k*_{obs} values increased with increase in NF over the concentration range shown in (Fig. 3). The effect of alkali on the reaction was studied at constant concentrations of NF, periodate and DPA and a constant ionic strength of 0.10 mol dm⁻³ at 25 °C. The alkali concentration was varied in the range of 5.0x10⁻² to 5.0x10⁻¹ mol dm⁻³. The rate constant increased with increase in alkali concentration (Fig. 4), indicating a fractional-order dependence of the rate on alkali concentration. The periodate concentration was varied in the range of 5.0x10⁻⁵ to 5.0x10⁻⁴ mol dm⁻³. The rate constant decreased with increase in periodate concentration (Fig. 2), indicating a negative fractional-order dependence of the rate on periodate concentration. Initially added products did not have any significant effect on the rate of reaction. The order for different species is given in the following equation

$$\text{Rate} = k [\text{DPA}]^{1.0} [\text{NF}]^{0.30} [\text{OH}^-]^{0.1} [\text{IO}_4^-]^{-0.18} \quad (1)$$

A. Stoichiometry and Product Analysis

Different sets of reaction mixtures containing varying ratios of DPA to norfloxacin in presence of constant amount of OH⁻, KIO₄ and KNO₃, were kept for 3 h in closed vessel under nitrogen atmosphere. The remaining concentration of DPA was estimated spectrophotometrically at 360 nm. The results indicate that 1:1 stoichiometry for the reaction

as given in **Scheme 1**. The main reaction products were identified as Ag(I) and 1-ethyl-6-fluoro-2-hydroxy-4-oxo-7-piperazin-1-yl-1,4-hydro-quinoline-3-carboxylic acid identical to those obtained for the oxidation of NF with permanganate[18]. The oxidation product of norfloxacin, 1-ethyl-6-fluoro-2-hydroxy-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid, was isolated with the help of TLC and other separation techniques and characterized by LC-ESI-MS, FTIR, and ^1H NMR spectral studies. The presence of a product was confirmed with molecular ion of m/z 335 (yield 90%) which corresponds to 1-ethyl-6-fluoro-2-hydroxy-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid.

The IR spectroscopy shows a peak at 1731 cm^{-1} due to acidic C=O stretching; the peak due to ketonic C=O stretching will appear at 1644 cm^{-1} ; 3056 cm^{-1} is due to NH stretching of the piperzine moiety; and the broad peak at 3424 cm^{-1} is due to OH stretching. ^1H NMR (DMSO) shows singlet at 8.9 ppm due to acidic OH, and NH of piperzine moiety singlet appears in the region of 4.6 ppm and the singlet of phenolic OH at 6.6 ppm, which disappears on D_2O exchange and confirms the formation of product 1-ethyl-6-fluoro-2-hydroxy-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid.

B. Effects of ionic strength, dielectric constant and temperature

The effect of ionic strength was studied by varying the NaClO_4 concentration from 0.01 to 0.10 mol dm^{-3} at constant concentrations of DPA, NF, periodate and alkali. Increasing ionic strength had no effect on the rate constant. The effect of the dielectric constant (D) was studied by varying the t-butanol–water content (v/v) in the reaction mixture with all other conditions held constant. The rate of reaction increases with increasing t-butanol volume.

The kinetics was also studied at four different temperatures with varying concentrations of NF and alkali, keeping other conditions constant. The rate constants were found to increase with increase in temperature. The rate of the slow step was obtained from the slopes and intercepts of $1/k_{\text{obs}}$ versus $1/[\text{NF}]$ and $1/k_{\text{obs}}$ versus $1/[\text{OH}^-]$ plots at four different temperatures. The activation energy corresponding to these rate constant was evaluated from the Arrhenius plot of $\log k$ versus $1/T$ from which other activation parameters were also obtained (Table 2).

C. Test for free radicals

To test for the involvement of free radicals, acrylonitrile was added to the reaction mixture, which was then kept for 2 h under nitrogen. Addition of methanol, resulted in the precipitation of a polymer, suggesting the involvement of free radicals in the reaction. The blank experiment of reacting either DPA and NF alone with acrylonitrile did not induce polymerization under the same conditions.

IV. Discussion:

A literature survey[19] reveals that the water soluble DPA has a formula $[\text{Ag}(\text{IO}_6)_2]^{7-}$ with dsp^2 configuration of square planar structure, similar to diperiodatocopper(III) complex with two bidentate ligands, periodate to form a planar molecule. When the same molecule is used in alkaline medium, it is unlikely to be existed as $[\text{Ag}(\text{IO}_6)_2]^{7-}$ as periodate is known to be in various protonated forms[21,22] depending on pH of the solution as given in following multiple equilibria:



Periodic acid (H_5IO_6) exists in acid medium and also as H_4IO_6^- at pH 7. Thus, under the present alkaline conditions, the main species are expected to be $\text{H}_3\text{IO}_6^{2-}$ and $\text{H}_2\text{IO}_6^{3-}$. At higher concentrations, periodate also tends to dimerise[1]. However, formation of this species is negligible under the conditions employed for this kinetic study. On the contrary, the authors[4,5] in their recent studies have proposed the DPA as $[\text{Ag}(\text{HL})_2]^{x-}$ in which 'L' is a periodate with uncertain number of protons and 'HL' is a protonated periodate of uncertain number of protons. This can be ruled out by considering the alternative form[21,22] of IO_4^- at $\text{pH} > 7$ which is in the form $\text{H}_3\text{IO}_6^{2-}$ or $\text{H}_2\text{IO}_6^{3-}$. Hence, DPA could be as $[\text{Ag}(\text{H}_3\text{IO}_6)_2]^-$ or $[\text{Ag}(\text{H}_2\text{IO}_6)_2]^{3-}$ in alkaline medium. Therefore, under the present condition, DPA, may be depicted as $[\text{Ag}(\text{H}_3\text{IO}_6)_2]^-$.

The results suggest that in the prior equilibrium step 1, the $[\text{OH}^-]$, deprotonates the DPA to give a deprotonated DPA; in the second step, displacement of a ligand, periodate takes place to give free periodate which is evidenced by decrease in the rate with increase in $[\text{periodate}]$ (Table 1). It may be expected that lower Ag(III) periodate species such as monoperiodatoargentate(III) (MPA) will be more important in the reaction than the DPA. The inverse fractional order in $[\text{H}_3\text{IO}_6^{2-}]$ might also be due to this reason. In the pre-rate-determining stage, the MPA reacts with a molecule of NF to give a complex [C], which transfer one electron in slow step to give the free radical and Ag(II) species. The formation of intermediate Ag(II) species is evidenced by earlier work[6-8]. This free radical species combines with another Ag(II) species in a fast step to form hydroxylated norfloxacin compound. On the basis of square planar structure of DPA, the structure of the complex may be proposed as in Fig 1.

Spectroscopic evidence for the complex formation between oxidant and substrate was obtained from UV-Vis spectra of NF, DPA, $[\text{OH}^-]$ mol dm^{-3} and mixture of both. A bathochromic shift of about 4 nm from 332 to 336 nm in the spectra of DPA was observed.

The rate law for the Scheme 2 could be derived as

$$\text{Rate} = \frac{-d[\text{DPA}]}{dt} = \frac{kK_1K_2K_3[\text{DPA}][\text{NF}][\text{OH}^-]}{[\text{H}_3\text{IO}_6^{2-}] + K_1[\text{OH}^-][\text{H}_3\text{IO}_6^{2-}] + K_1K_2[\text{OH}^-] + K_1K_2K_3[\text{OH}^-][\text{NF}]} \quad (5)$$

$$k_{\text{obs}} = \frac{kK_1K_2K_3[\text{NF}][\text{OH}^-]}{[\text{H}_3\text{IO}_6^{2-}] + K_1[\text{OH}^-][\text{H}_3\text{IO}_6^{2-}] + K_1K_2[\text{OH}^-] + K_1K_2K_3[\text{OH}^-][\text{NF}]} \quad (6)$$

The rate law can be rearranged to the following form for verification.

$$\frac{1}{k_{\text{obs}}} = \frac{[\text{H}_3\text{IO}_6^{2-}]}{kK_1K_2K_3[\text{OH}^-][\text{NF}]} + \frac{[\text{H}_3\text{IO}_6^{2-}]}{kK_2K_3[\text{NF}]} + \frac{1}{kK_3[\text{NF}]} + \frac{1}{k} \quad (7)$$

The rate law may be thus verified by the linear plots of $1/k_{\text{obs}}$ versus $[\text{H}_3\text{IO}_6^{2-}]$, $1/k_{\text{obs}}$ versus $1/[\text{NF}]$ and $1/k_{\text{obs}}$ versus $1/[\text{OH}^-]$, as found in Fig. 2,3 and 4. The slopes and intercepts of such plots lead to the values of K_1 , K_2 , K_3 , and k as $(2.50 \pm 0.15) \text{ dm}^3 \text{ mol}^{-1}$, $(5.6 \pm 0.25) \times 10^{-4} \text{ mol dm}^{-3}$, $(3.8 \pm 1.22) \times 10^{-3} \text{ dm}^3 \text{ mol}^{-1}$, and $(7.4 \pm 0.8) \times 10^{-4} \text{ s}^{-1}$, respectively. Using these constants the rate constants were calculated and compared with experimental values (Table 1). The experimental rate constants were in good agreement with calculated values, which fortifies the proposed mechanism. The thermodynamic quantities for the first, second, and third equilibrium steps of Scheme 2 can be evaluated as follows. The $[\text{NF}]$, $[\text{OH}^-]$ and $[\text{H}_3\text{IO}_6^{2-}]$ as given in Table 1 were varied at four different temperatures. The values of K_1 , K_2 and K_3 are given in Table 3. A van't Hoff's plot was made for variation of K_1 with temperature (i.e., $\log K_1$ vs. $1/T$) and the values of enthalpy of reaction ΔH , entropy of reaction ΔS , and free energy of reaction ΔG_{298} , were calculated (Table 4). Similarly the thermodynamic quantities for the second and third equilibrium steps were also calculated (Table 4).

A comparison of the latter values with those obtained for the slow step of the reaction shows that these values mainly refer to the rate limiting step, supporting the fact that the reaction before the rate determining step is fairly slow and involves high activation energy [24,25]. The moderate values of ΔH and ΔS were both favorable for electron transfer processes. The value of ΔS that is within the expected range for radical reactions has been ascribed to the nature of electron pairing and unpairing processes and the loss of degrees of freedom formerly available to the reactants upon the formation of a rigid transition state [26]. The negative value of ΔS indicates that complex (C) is more ordered than the reactants [27,28].

The observed modest enthalpy of activation and a higher rate constant for the slow step indicates that the oxidation presumably occurs via an inner-sphere mechanism [29,30]. This conclusion is supported by earlier observations.

V. Conclusion:

Among various species of DPA in alkaline medium, $[\text{Ag}(\text{H}_2\text{IO}_6)(\text{H}_3\text{IO}_6)]^{2-}$ is considered as active species for the title reaction. It becomes apparent that in carrying out this reaction, the role of the reaction medium is crucial. The

overall mechanistic sequence described here is consistent with product studies, mechanistic studies and kinetic studies.

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APPENDIX

According to Scheme 2

The rate law for the Scheme 2 could be derived as

$$\text{Rate} = k[C] = \frac{kK_1K_2K_3[\text{DPA}][\text{NF}][\text{OH}]}{[\text{H}_3\text{IO}_6^{2-}]}$$

$$[\text{DAP}]_T = [\text{DPA}]_f + [\text{Ag}(\text{H}_3\text{IO}_6)(\text{H}_2\text{IO}_6)^{2-}] + [\text{Ag}(\text{H}_2\text{IO}_6)(\text{H}_2\text{O})_2] + [C] \quad (I)$$

$$= [\text{DPA}]_f \left[1 + k_1[\text{OH}^-] + \frac{K_1K_2[\text{OH}^-]}{[\text{H}_3\text{IO}_6^{2-}]} + \frac{K_1K_2K_3[\text{OH}^-][\text{NF}]}{[\text{H}_3\text{IO}_6^{2-}]} \right]$$

where T and f are refer to total and free concentrations

$$[\text{DPA}]_T = \frac{[\text{DPA}]_f [\text{H}_3\text{IO}_6^{2-}]}{[\text{H}_3\text{IO}_6^{2-}] + K_1[\text{OH}^-][\text{H}_3\text{IO}_6^{2-}] + K_1K_2[\text{OH}^-] + K_1K_2K_3[\text{OH}^-][\text{NF}]} \quad (\text{II})$$

$$[\text{OH}]_T = [\text{OH}^-]_f + [\text{Ag}(\text{H}_3\text{IO}_6)(\text{H}_2\text{IO}_6)^{2-}] + [\text{Ag}(\text{H}_2\text{IO}_6)(\text{H}_2\text{O})_2]$$

$$= \frac{[\text{OH}^-]_f + K_1[\text{DPA}][\text{OH}^-] + \frac{K_1K_2[\text{OH}^-][\text{DPA}]}{[\text{H}_3\text{IO}_6^{2-}]}}{1}$$

In view of the low concentration of [DPA] and $[\text{H}_2\text{IO}_6^{2-}]$ used:

$$[\text{OH}]_T = [\text{OH}]_f \quad (\text{III})$$

Similarly

$$[\text{AMP}]_T = [\text{AMP}]_f + [\text{C}] = [\text{AMP}]_f + \frac{K_1K_2K_3[\text{NF}][\text{DPA}][\text{OH}^-]}{[\text{H}_3\text{IO}_6^{2-}]}$$

In view of low concentration of [DPA], $[\text{OH}^-]$ and $[\text{H}_3\text{IO}_6^{2-}]$ used :

$$[\text{NF}]_T = [\text{NF}]_f \quad (\text{IV})$$

Substituting the Eqn (II-IV) in Eqn (I) and omitting the subscripts T and f, we get

$$\text{Rate} = \frac{-d[\text{DPA}]}{dt} = \frac{kK_1K_2K_3[\text{DPA}][\text{NF}][\text{OH}^-]}{[\text{H}_3\text{IO}_6^{2-}] + K_1[\text{OH}^-][\text{H}_3\text{IO}_6^{2-}] + K_1K_2[\text{OH}^-] + K_1K_2K_3[\text{OH}^-][\text{NF}]} \quad (\text{V})$$

Table 1. Effect of [DPA], [NF], $[\text{OH}^-]$ and $[\text{IO}_4^-]$ on the oxidation of Norfloxacin by Diperiodatoargentate(III) in aq.alkaline medium at Temp 25 °C; I=0.25 mol dm⁻³

[DPA] x 10 ⁴ (mol dm ⁻³)	[NF] x10 ³ (mol dm ⁻³)	[OH ⁻] (mol dm ⁻³)	[IO ₄ ⁻] x10 ⁴ (mol dm ⁻³)	k x10 ⁴ (s ⁻¹)	
				Found	Calculated
0.5					
0.8	1.0	0.15	1.0	5.10	5.15
1.0	1.0	0.15	1.0	5.18	5.15
2.0	1.0	0.15	1.0	5.21	5.15
5.0	1.0	0.15	1.0	5.12	5.15
1.0	1.0	0.15	1.0	5.20	5.15
1.0	0.2	0.15	1.0	2.96	2.35
1.0	0.5	0.15	1.0	4.01	3.95
1.0	1.0	0.15	1.0	5.18	5.15
1.0	2.0	0.15	1.0	6.18	6.08
1.0	5.0	0.15	1.0	6.75	6.81
1.0	1.0	0.05	1.0	4.60	4.39
1.0	1.0	0.08	1.0	4.86	4.79
1.0	1.0	0.15	1.0	5.12	5.15
1.0	1.0	0.2	1.0	5.31	5.27
1.0	1.0	0.5	1.0	5.78	5.49
1.0	1.0	0.15	0.5	5.55	5.48
1.0	1.0	0.15	0.8	5.25	5.28
1.0	1.0	0.15	1.0	5.15	5.15
1.0	1.0	0.15	3.0	4.04	4.18
1.0	1.0	0.15	5.0	3.50	3.48

Table 2: Thermodynamic activation parameters for the oxidation of Norfloxacin by Diperiodatoargentate(III) in aqueous alkaline medium with respect to the slow step of scheme 1

Temperature (K)	$k \times 10^4$ s^{-1}	Parameters	Values
298	7.4 $\pm$ 0.8	Ea (kJ mol ⁻¹)	28.72 $\pm$ 1.2
303	9.1 $\pm$ 0.6	$\square$ H (kJ mol ⁻¹)	26.24 $\pm$ 1.0
308	10.8 $\pm$ 1.0	$\square$ S [#] (J K ⁻¹ mol ⁻¹)	-115 $\pm$ 1.5
313	13.2 $\pm$ 0.8	$\square$ G ₂₉₈ [#] (kJ mol ⁻¹)	36.9 $\pm$ 1.8

*. [DPA] = 1.0 x 10⁻⁴ [NF] = 1.0 x 10⁻³ [OH⁻] = 0.15 [IO₄⁻] = 1.0 x 10⁻⁴

Table 3: Effect of temperature to calculate K₁, K₂ and K₃ for the oxidation of Norfloxacin by Diperiodatoargentate(III) in aq.alkaline medium *

Temperature (K)	K ₁ dm ³ mol ⁻¹	K ₂ x 10 ⁴ mol dm ⁻³	K ₃ x 10 ⁻³ dm ³ mol ⁻¹
298	2.50 $\pm$ 0.15	5.6 $\pm$ 0.25	3.8 $\pm$ 1.22
303	3.64 $\pm$ 0.11	4.6 $\pm$ 0.18	5.0 $\pm$ 1.4
308	4.90 $\pm$ 0.12	3.8 $\pm$ 0.20	6.4 $\pm$ 1.8
313	6.61 $\pm$ 0.25	3.0 $\pm$ 0.11	8.1 $\pm$ 1.5

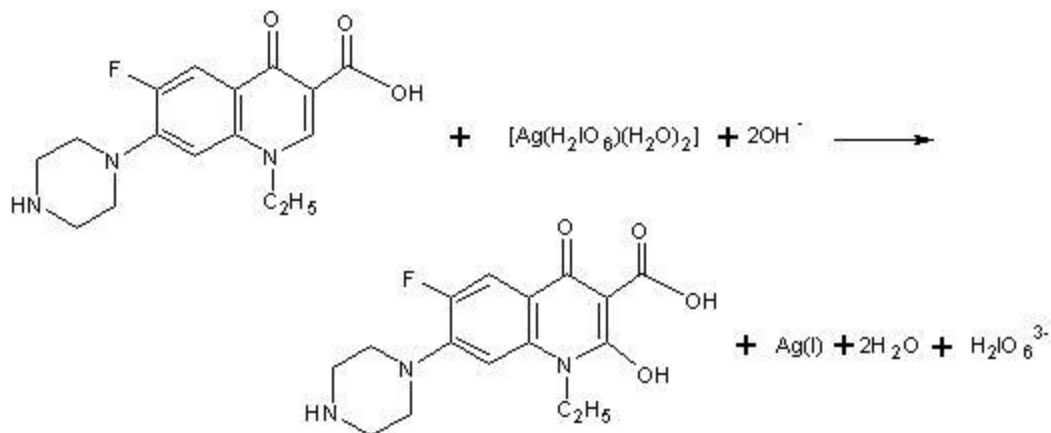
*. [DPA] = 1.0 x 10⁻⁴ [NF] = 1.0 x 10⁻³ [OH⁻] = 0.15 [IO₄⁻] = 1.0 x 10⁻⁴

Table 4: Thermodynamic quantities using K₁, K₂ and K₃

Thermodynamic quantities	Values from		
	K ₁	K ₂	K ₃
$\square$ H (kJ mol ⁻¹)	45.4 $\pm$ 1.8	-33.11 $\pm$ 0.8	35.82 $\pm$ 1.14
$\square$ S [#] (J K ⁻¹ mol ⁻¹)	108 $\pm$ 2.12	-75 $\pm$ 1.75	-44 $\pm$ 1.6
$\square$ G ₂₉₈ [#] (kJ mol ⁻¹)	13.2 $\pm$ 1.8	-10.76 $\pm$ 1.45	48.93 $\pm$ 1.80

*. [DPA] = 1.0 x 10⁻⁴ [NF] = 1.0 x 10⁻³ [OH⁻] = 0.15 [IO₄⁻] = 1.0 x 10⁻⁴

Scheme 1: Formation of hydroxylated Norfloxacin and Ag(I)



Scheme 2: Proposed mechanism for the oxidation of Norfloxacin by Diperiodatoargentate(III) in aq. Alkaline medium

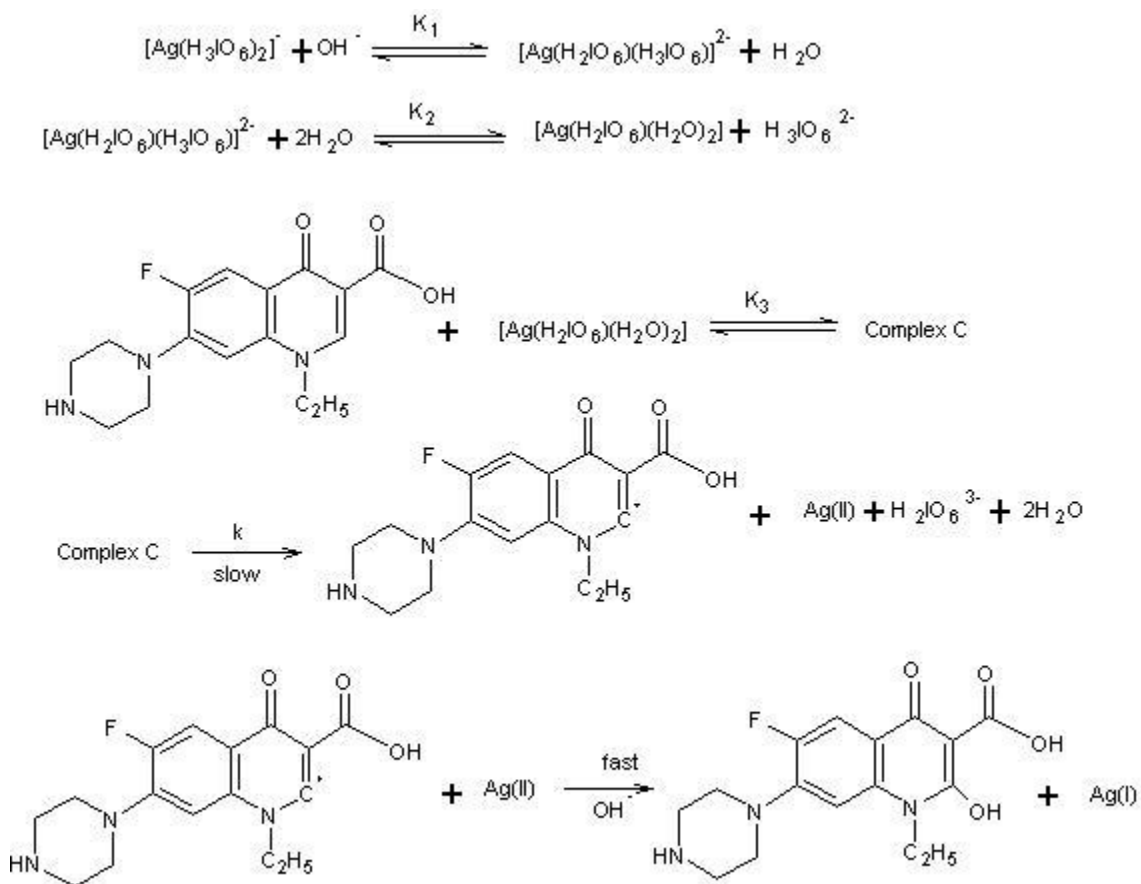


Fig 1: Structure of Complex C

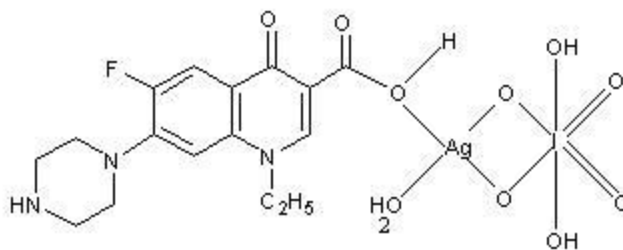


Fig 2: Plots of $1/k_{\text{obs}}$ Vs $[\text{H}_3\text{IO}_6^{2-}]$ at four different temperatures (Conditions as in Table 1)

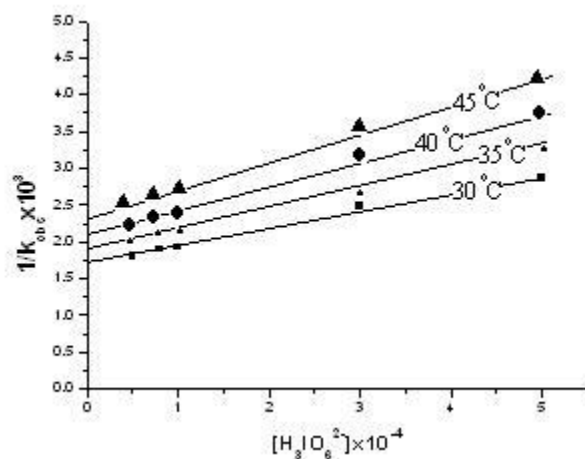


Fig 3: Plots of $1/k_{\text{obs}}$ Vs $1/[\text{NF}]$ at four different temperatures (Conditions as in Table 1)

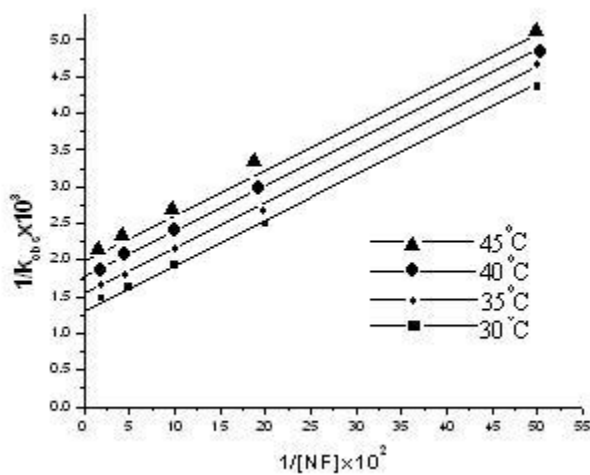


Fig 4: Plots of $1/k_{\text{obs}}$ Vs $1/[\text{OH}^-]$ at four different temperatures (Conditions as in Table 1)

