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Ruthenium (III) catalyzed Oxidation of Cefixime by Hexacyanoferrate (III) in Alkaline medium: A Kinetic and mechanistic approach

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ABSTRACT

Kinetics of ruthenium (III) catalyzed oxidation of cefixime by Hexacyanoferrate (III) has been studied spectrophotometrically. The reaction is found to be first order with respect to concentration of hexacyanoferrate and catalyst Ruthenium. It was found to be fractional order dependence on substrate concentration and alkali. The reaction product of the study was found by LC-MS method. A suitable mechanism involving complexation between CEF and $[Ru(H_2O)_5 OH]^{2+}$ *was proposed. The stoichiometry of the reaction was found to be 2:1 which explains that for one mole of cefixime required two moles of hexacyanoferrate (III) ion. The activation parameters like* E_a *and* $\Delta S^{\#}$ *were calculated & the values observed as 38kJ* mol^{-1} *and -203kJ* mol^{-1} *respectively.*

Keywords: Kinetics, Mechanism, Oxidation, Cefixime, Hexacyanoferrate (HCF).

INTRODUCTION

Cefixime, Fig 1, a synthetic fluoroquinolone antibiotic [1] and is chemically 7-{[2-(2-amino-1,3-thiazol-4-yl)-2 (carboxymethoxyimino)acetyl]amino}-3-ethenyl-8-oxo-5thia-1- azabicyclo oct-2-ene-2-arboxylic acid. It is used for urinary tract infection, bronchitis, pneumonia, prostatitis, syphilis and infections of reproductive organs.[2] Literature survey revealed the analysis of Cefixime along with other drugs using various spectrum studies UV [3-4], HPLC [5-9], flow injection analysis [10] and HPTLC [11].

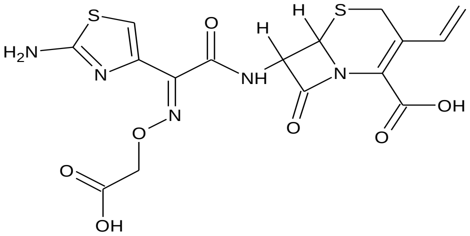


Fig 1. Chemical Structure of Cefixime (Molecular weight 453.45)

Kinetic experiments on oxidation of a number of substances, both organic [12-17] and inorganic [18-23], by hexacyanoferrate (III) in alkaline medium have been done by many researchers. One of the important iron(III) cyanide complex is the hexacyanoferrate(III) anion, $[Fe(CN)_6]^{3-}$, a mild oxidant with the Fe^{3+} center bound in octahedral geometry to six cyanide ligands.

Hexacyanoferrate (III) is a poor oxidant when compared with potassium permanganate, but a selective outer sphere reactant, applicable to the most easily oxidisable substrates and couple one of the most extensively investigated outer-sphere redox reactions. Studies involving hexacyanoferrate (III) as an oxidant in acid media are limited [24-26] by the fact that reduction potential of the couple is small ($[Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-}$: 0.356V) [27]. However, hexacyanoferrate (III) is very sensitive to the solvent and acidity. Hexacyanoferrate (III) forms different species in alkaline media [28]. The mechanism may be quite interesting due to the formation of different intermediates of hexacyanoferrate (III) [23].

Hence, in the present study, we have investigated the kinetics and mechanism of oxidation of Cefixime by hexacyanoferrate (III) in aqueous alkaline medium in order to understand the behavior of the active species of hexacyanoferrate(III) and to propose a suitable mechanism based on experimental results.

Kinetics study using spectrophotometer have got high demand in chemical and pharmaceutical analysis because of many specific advantages of the method, if quote few selectivity due to the measurements based on the absorbance with time of reaction, easily experimental with the common chemicals available in the laboratories, applicable, sensitive with less cost of processing. There have been only few investigations in the oxidation of cefixime (CEF) using oxidants like potassium permanganate [29], electrocatalytic oxidation behavior of cefixime antibiotic at bimetallic Pt-W nanoparticle-decorated multi-walled carbon nanotubes [30], modified carbon paste electrode with zeolite containing cobalt [31]. The literature study revealed no kinetic study on oxidation of Cefixime using hexacyanoferrate. The objective of the study of the system was to develop a sensitive method by using spectrophotometer for the kinetic colorimetric oxidation of cefixime using hexacyanoferrate alkaline medium. The uncatalyzed reaction was fairly slow but with micro amounts of Ru the reaction happened to 85% within 30min. Catalyst has been widely used in synthetic organic chemistry in the past few decades. Transition and platinum group metal ions and their complexes have been used in micro quantities as catalyst under homogeneous conditions [32]. Ruthenium (III) acts as an economical catalyst in many redox reactions involving different complexities due to the formation of different intermediate complexes[33-34], free radicals[35] and multiple oxidation states of ruthenium[36].

A microscopic amount of ruthenium (III) ($4x10^{-6}$mol dm^{3-1}) is sufficient to catalyze the reaction between cefixime and hexacyanoferrate (III) in the alkaline medium. Further we describe the results of the title reaction in order to understand the active species of oxidant, reductant and catalyst and to arrive at a plausible mechanism. A literature study on oxidation of Cefixime, by HCF (III) in alkaline medium catalyzed by Ru (III) was scanty. The work was done to have a deep understanding on the oxidation reaction of the cefixime in presence of catalyst.

MATERIALS AND METHODS

Double beam UV-Visible Spectrophotometer with a pair of matched quartz cells were used to measure absorbance of the system under study.

Chemicals used were all analytical grade. Cefixime was provided by Thorab pharma and Research laboratory. A standard solution of cefixime was prepared dissolving pure cefixime (1mg/ml) in doubly distilled water and making up to the mark using same distilled water to 50ml which was marked as stock solution. For the working solution 5ml of the stock solution was diluted to 50ml with distilled water.

Hexacyanoferrate (III) was preferred after recrystallization. Hexacyanoferrate (II) solution was prepared by dissolving a known amount of $K_4[Fe(CN)_6]$ in water, (s. d. fine-chem) in water and standardized by Iodometric titration[37] .The maximum absorbance range chosen was 420nm as it noted only in the period no turbidity/precipitate was formed. The AR grade chemicals were used for sodium hydroxide, ruthenium, HCF (III) and $NaClO_4$. NaOH has been standardized using potassium hydrogen phthalate (KHP, $KC_8H_4O_4H$) using phenolphthalein as the indicator. And all the solutions were prepared using doubly distilled water and each run was carried out using fresh solutions.

About 0.5g of ruthenium (III) chloride is continuously treated with 0.20mol $dm^{-3\ -1}$ till all the chloride is completely expelled and finally diluted to 500 mL. The solution is standardized by the method suggested by Beamish and Valnoon [38]. Solution of desired concentration is prepared from this stock by suitable dilution.

Kinetic studies: The required quantity of HCF(III) $4x10^{-4}$mol $dm^{3\ -1}$ was mixed with the solution of cefixime $2x10^{-2}$mol $dm^{3\ -1}$, sodium hydroxide$1x10^{-1}$mol $dm^{3\ -1}$, ruthenium(III)$4x10^{-6}$mol $dm^{3\ -1}$ and sodium perchlorate$5x10^{-1}$mol dm^{3-1} kept at constant temperature 25°C. Pseudo-first order conditions were maintained with cefixime in excess. The reaction progress was followed by measuring the absorbance HCF (III) at 420nm using the UV-Visible spectrophotometer [39]. At 420nm, all other materials concerned have no absorbance. Application of beer's law under the reaction conditions had been verified between HCF(III) concentration $1.0x10^{-4}$ and 1.0 x 10^{-3} mol $dm^{-3\ -1}$ and ε was found to be 1486 ±25dm^{-3} $mol^{-1}cm^{-1}$ (Fig:2)

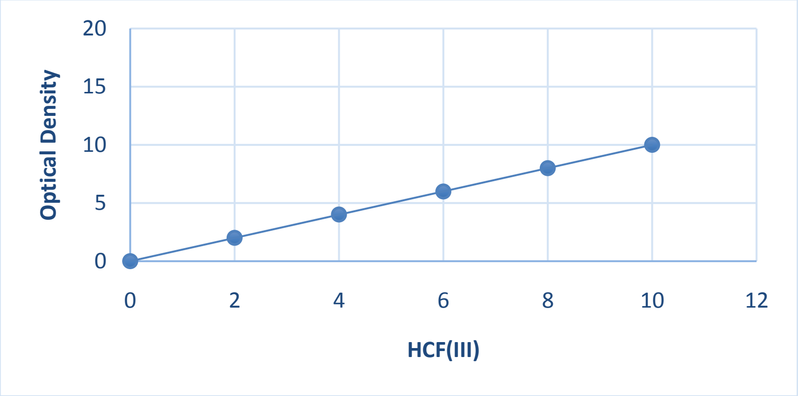
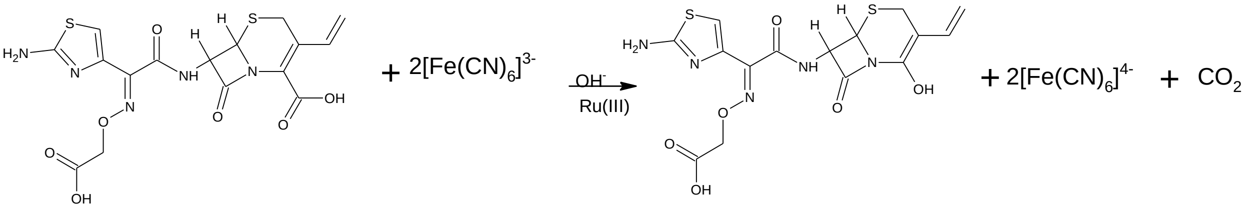


Fig. 2 Verification of Beer's law for hexacyanoferrate (III) at 420nm in 0.4mol/dm^{-3} NaOH

RESULTS AND DISCUSSION

Stoichiometry and product analysis: Accurate amount of cefixime were allowed to react completely with a known excess of HCF (III) in alkaline medium that is 0.4mol $dm^{3\ -1}$ NaOH at room temperature, sodium perchlorate (0.5mol $dm^{3\ -1}$) to maintain ionic strength, also $4x10^{-6}$mol $dm^{3\ -1}$ of ruthenium as catalyst. The mixture was kept for 24h. The stoichiometry was studied by estimating the amount of HCF(III) ions left over after definite interval of time by titrating with ceric (IV) sulphate using ferroin as the indicator[40].The result showed that one mole of cefixime consumed two moles of hexacyanoferrate(III), thus following reaction is deduced:



Further the product was extracted into ether and the isolated compound was analyzed by LC-MS method. Fig:3 LC-MS analysis of CEF oxidation reaction indicated the formation of product with a molecular ion of m/z (M^+H^+ peak) at 303MHz. Literature survey supports the predicted product [40]. The liberation of CO_2 was identified by the limewater test.

Reaction Order: Kinetic measurement study were done at different concentration of the one reactant keeping the concentration of other reactants constant [41]. The reaction orders were determined from the slopes of log of initial rates k_{obs} Vs log (concentration) plot, by varying the concentrations of the oxidant, reductant, alkali or catalyst, while keeping the concentrations of the other reacting species constant[42]

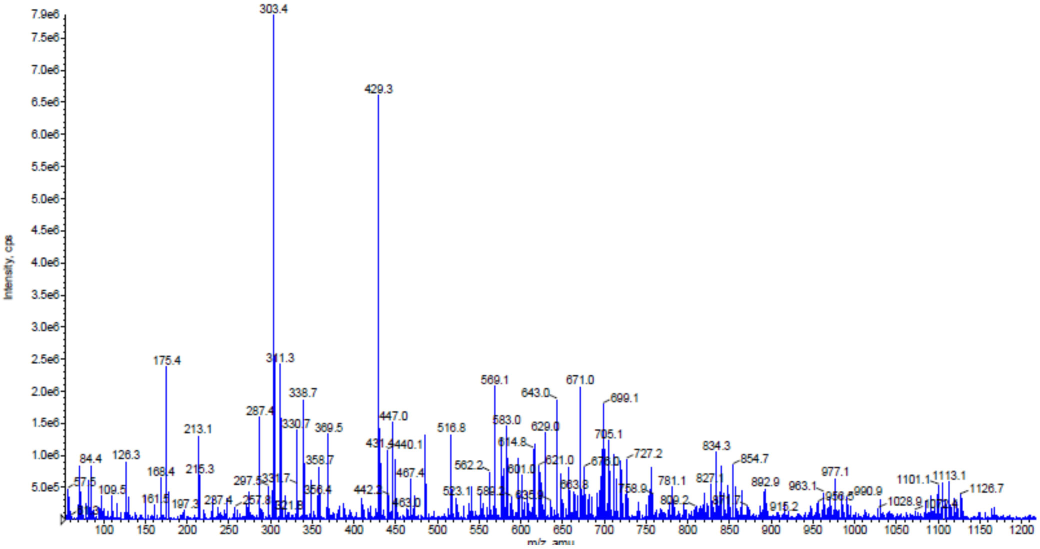


Fig. 3 LC-MS Spectrum of the oxidation product is {[(*E*)-{1-(2-amino-1,3-thiazol-4-yl)-2-[(3-ethenyl-2-hydroxy-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-en-7-yl)amino]-2-oxoethylidene}amino]oxy}acetic acid

Effect of [Substrate]: The [cefixime] was varied in the range of $0.5x10^{-2}$-5.0 $x10^{-2}$ mol dm^{-3}at 25°C, by keeping all other reactant, HCF (III)$4x10^{-4}$mol dm^{3-1}, Ru(III)$4x10^{-6}$mol dm^{3-1}, NaOH$4x10^{-1}$moldm$^{3\ -1}$ and Sodiumperchlorate$5x10^{-1}$moldm$^{3\ -1}$concentrations constant. The rate constant values was found to increase with increase in [CEF] and the order with respect to [CEF] as given in table 1 was found to be fractional.

Table 1: Effect of [CEF], [HCF(III)], [Ru(III)], [OH^-] and [$NaClO_4$] on the pseudo – first order rate constant in the oxidation study of CEF using HCF(III) in the presence of Ru(III) catalyst

[CEF] 10^2 mol/dm^3	[HCF(III)] 10^4 mol/dm^3	[Ru(III)] 10^6 mol/dm^3	[OH^-]10^1 mol/dm^3	[NaClO4]10^1mol/dm^3	$k_{obs}x10^4sec^{-1}$ Experimental	$k_{obs}x10^4sec^{-1}$ Calculated	$k_{obs}x10^4sec^{-1}$ Experimental
					For Catalyzed		For Uncatalysed
2.0	1.0	4.0	4.0	5.0	5.0	4.8	-
2.0	2.0	4.0	4.0	5.0	5.3	4.8	-
2.0	4.0	4.0	4.0	5.0	5.1	4.8	-
2.0	4.0	-	4.0	5.0	-	-	2.9
2.0	8.0	4.0	4.0	5.0	2.4	4.8	-
2.0	10.0	4.0	4.0	5.0	4.9	4.8	-
0.5	4.0	4.0	4.0	5.0	4.8	4.7	-
1.0	4.0	4.0	4.0	5.0	4.9	5.0	-
2.0	4.0	4.0	4.0	5.0	5.1	5.0	-

2.0	4.0	-	4.0	5.0	-	-	2.9
3.0	4.0	4.0	4.0	5.0	5.1	5.2	-
5.0	4.0	4.0	4.0	5.0	5.2	5.2	-
2.0	4.0	2.0	4.0	5.0	4.9	4.9	-
2.0	4.0	3.0	4.0	5.0	3.7	4.9	-
2.0	4.0	4.0	4.0	5.0	5.1	5.0	-
2.0	4.0	-	4.0	5.0			2.9
2.0	4.0	5.0	4.0	5.0	5.2	5.2	-
2.0	4.0	6.0	4.0	5.0	5.3	5.3	-
2.0	4.0	4.0	1.0	5.0	3.1	4.8	-
2.0	4.0	4.0	3.0	5.0	4.8	4.8	-
2.0	4.0	4.0	4.0	5.0	5.1	4.8	-
2.0	4.0	-	4.0	5.0	-	-	2.9
2.0	4.0	4.0	6.0	5.0	9.8	4.8	-
2.0	4.0	4.0	8.0	5.0	10.5	4.8	-
2.0	4.0	4.0	4.0	6.0	5.5	4.8	-
2.0	4.0	4.0	4.0	7.0	6.1	4.8	-
2.0	4.0	4.0	4.0	5.0	6.6	4.8	-
2.0	4.0	-	4.0	5.0	-	-	2.9
2.0	4.0	4.0	4.0	10.0	6.5	4.8	-
2.0	4.0	4.0	4.0	12.0	6.3	4.8	-

The plots of [Ru(III)]/kobsVs. 1/[CEF] (Fig. 4) were found to be linear with positive intercepts on the rate axis which indicates that the reaction obeys Michaelis-Menten behavior. But no spectrophotometric evidence was obtained for formation of complex between ruthenium (III) and cefixime. Since there is no change in the λ_{max} (except some hyperchromicity) for the mixture of CEF and ruthenium (III) compared with that of CEF or ruthenium (III) itself. This helps to predict the involvement of weak interactions. However, Michaelis-Menten plot supports the complex formation through kinetic studies. The plot of [Ru (III)]/k_{obs} vs. 1/[CEF] is linear with an intercept supporting the Ru(III)–CEF complex.

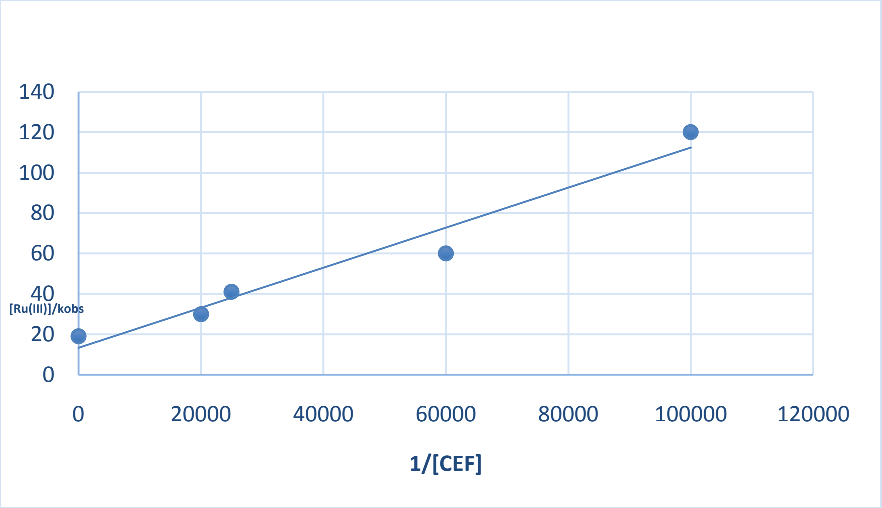


Fig. 4 Plot [Ru(III)]/kobsvs 1/[CEF]. Reaction

Effect of [HCF(III)]: Oxidant effect was studied by varying concentration of hexacyanoferrate(III) in the reaction medium from $2.0x10^{-4}$–$12.0x10^{-4}$mol $dm^{3\ -1}$at constant cefixime($2x10^{-2}$mol $dm^{3\ -1}$), NaOH($4x10^{-1}$mol $dm^{3\ -1}$), and ruthenium(III)($4x10^{-6}$mol $dm^{3\ -1}$)concentrations and ionic strength($5x10^{-1}$mol $dm^{3\ -1}$). By plotting graph of initial rates with concentration of HCF, straight line is obtained which is linear upto 80% completion of the reaction. Hence the reaction is first order with respect to oxidant, HCF (III). Deviation from first order may be observed due to interference of one of the product K_4[Fe $(CN)_6$].

Effect of Catalyst: The catalyst, [ruthenium (III)] was varied in the range $2.0x10^{-6}$-$6.5x10^{-6}$mol dm^{3-1} keeping the concentration of all other reactants constant. When the pseudo first order rate constants obtained from the absorbance versus time plots were plotted against [ruthenium(III)] a straight line passing through origin is obtained indicating the order with respect to [ruthenium(III)] to be unity. The uncatalyzed reaction, under the given conditions was very slow Table 1.

Effect of alkali: Alkali effect on the rate of the reaction was studied at constant concentrations of cefixime($2x10^{-2}$mol $dm^{3\ -1}$)and HCF(III)($4x10^{-4}$mol $dm^{3\ -1}$)and at a constant ionic strength of 0.5mol $dm^{3\ -1}$.The rate constants obtained were found to increase with the increase in [alkali] as given in the Table 1. When a plot log k_{obs}Vs. log [OH^-] was plotted, a straight line with a slope of 0.73 is obtained indicating fraction order dependence on [alkali].

Effect of ionic strength: At constant concentrations of reactants and with other conditions constant, the concentrations of sodium perchlorate was varied from 0.5-1.2mol $dm^{3\ -1}$. The rate constant for pseudo first order reaction indicates that the reaction rate is not dependent of ionic strength of the medium (Table 1)

Polymerisation study (Test for free radicals): The involvement of free radicals was examined as follows: Acrylonitrile (free radical scavenger) was added in known quantity to the reaction mixture and was kept in an inert atmosphere for five hours at room temperature. After that it was diluted with methanol, a precipitate was resulted, confirming the presence of intervention of free radical.

Effect of temperature: The rate constants were experimented at for four different temperatures with the concentration of cefixime ($2x10^{-2}$mol $dm^{3\ -1}$), hexacyanoferrate (III)($4x10^{-4}$mol $dm^{3\ -1}$), NaOH($4x10^{-1}$mol $dm^{3\ -1}$), and ruthenium(III)($4x10^{-6}$mol $dm^{3\ -1}$)concentrations and ionic strength($5x10^{-1}$mol $dm^{3\ -1}$)and were used to calculate the activation parameters. The energy of activation was calculated from the slope of the plot of log k vs 1/T and the value is 38± 2 $kJmol^{-1}$. The enthalpy of activation, $\Delta H^{\neq}$ and entropy of activation, $\Delta S^{\neq}$, were obtained by Eyring equation [43-45].

The Table 2 shows the k_{obs} (s^{-1}) values at different temperatures. The activation parameters calculated are shown in Table 3

Table. 2 Effect of temperature on the oxidation of CEF using HCF(III) un presence of Ru catalyst

Temperature(^{O}C)	$k_{obs}(s^{-1})$
25	$5.1x10^{-4}$
30	$5.8x10^{-4}$
35	$6.5x10^{-4}$
40	$6.8x10^{-4}$

Table. 3 Activation parameters for oxidation of CEF using HCF(III) in presence of Ru catalyst with respect to slow step of scheme 1

Parameters	Values
E_a	38kJ/mol
$\Delta H^{\#}$	40kJ/mol
$\Delta G^{\#}$	55kJ/mol
$\Delta S^{\#}$	-203J/K/mol

The present study of antibiotic cefixime with hexacyanoferrate (III) exhibits 1:2 stoichiometry in the presence of ruthenium (III) catalyst and the orders were found to be fractional order dependence on substrate and alkali concentration and first order with respect to catalyst and oxidant hexacyanoferrate. Considering the very low concentration of ruthenium(III) used, there is no kinetic evidence for the formation of ruthenium(V). The use of $RuCl_3$ as a homogeneous catalyst in both acidic and alkaline media is of much interest in the recent kinetic study. In dilute HCl solution the salt yields complex ions [46] such as $[Ru(H_2O)_6]^{3+}$, $[Ru(H_2O)_5Cl]^{2+}$, $[Ru(H_2O)_4Cl_2]^{+}$,$[RuCl_6]_3$, $[RuCl_4]$ and $[Ru(H_2O)_2Cl_4]$. The various chloride complexes of ruthenium(III) are possible [46] on refluxing in presence of high acid concentration. As only very low acid was used up for Ru preparation, the existence of such complexes seems to be negligible due to the insignificant effect of chloride ions on the reaction rate. The electronic spectrum for the ruthenium (III) solution used is similar to that reported [47] for the $[Ru(H_2O)_6]^{3+}$spectrum. Hence $[Ru(H_2O)_6]^{3+}$ has been considered to be the active species of ruthenium (III) under our experimental conditions. In alkaline media, ruthenium(III) is known to exist as its hydroxylated species($[Ru(OH)_x(H_2O)_{6}$ $)_{x}]^{(3)x}$), where x < 6).[48-50]

$$[Ru(H_2O)_6]^{3+} + OH^- \longleftrightarrow [Ru(H_2O)_5OH]^{2+} + H_2O$$

We understood that alkali concentration has direct influence on rate of the reaction. The active form of the ruthenium (III) is $[Ru(H_2O)_5OH]^{2+}$. Based on the above perceptions the following mechanisms are drawn. The reaction rate can be written as

$$\text{Rate} = -d[Fe(CN)6]^{3-} / dt = k\,[CEF]\,[OH^-]\,[Ru(III)] \text{ ----------------(1)}$$

Scheme-1

$[Ru(H_2O)_6]^{3+} + OH^- \xrightarrow{K1} [Ru(H_2O)_5OH]^{2+} + H_2O$ -----------------(2)

$[Ru(H_2O)_5OH]^{2+}$ + Cefixime $\rightleftharpoons$ Intermediate complex -----------(3)

Intermediate complex $+2[Fe(CN)_6]^{3-} \xrightarrow{k,\ slow}$ Product + $[Ru(H_2O)_5H]^{2+}$ $+2[Fe(CN)_6]^{4-}$------(4)

$[Ru(H_2O)_5H]^{2+} + 2OH^- + 2[Fe(CN)_6]^{3-} \xrightarrow{fast} [Ru(H_2O)_5OH]^{2+} + 2[Fe(CN)_6]^{4-} + H_2O$ ----(5)

The reactive aqua complex of ruthenium $[Ru(H_2O)_5OH]^{2+}$is formed in first step which in turn reacts with cefixime to give an intermediate complex. The intermediate complex slowly disproportionate to give a final product and the hydride species of ruthenium (III). In last step, the ruthenium (III) hydride species re-oxidized to its original reactive species $[Ru(H_2O)_5OH]^{2+}$.

Equation (4) is rate determining step which can be given by,

$-d[Fe(CN)_6]^{3-}/ dt = k$ [Intermediate complex] ---------------------(6)

Substituting equation (2) and (3), equation (6) becomes

$-d[Fe(CN)_6]^{3-}/ dt = kK1K2\,[CEF]\,[OH^-]\,[Ru(III)]$ -----------------(7)

By considering equation (2) and (3), the total, $[Ru(III)]_T$ can be written as

$[Ru(III)]_T = [Ru(III)]_f + [Ru(H_2O)_5OH]^{2+}$ + [Intermediate complex]

The rate law reduces to

$-d[Fe(CN)_6]^{3-}/ dt = kK1K2[CEF]\ [OH^-]\,[Ru(III)]\,T / 1+ K1[OH^-]+ K1K2\,[CEF]\,[OH^-]$

$-d[Fe(CN)_6]^{3-}/ dt = kK1K2\,[CEF]\,[OH^-]\,[Ru(III)]\,T / 1+ K1[OH^-]\,(1+ K2\,[CEF])$-------- (8)

At lower concentration of cefixime, the inequality 1>>K2[CEF], Equation (8) becomes

$-d[Fe(CN)_6]^{3-}/ dt = kK1K2\,[CEF]\,[OH^-]\,[Ru(III)]\,T / 1+ K1[OH^-]$------------------------ (9)

Equation (8) shows first order kinetics at lower concentration of cefixime. Further at lower concentration of alkali, $1>>K1[OH^-]$, equation (9) becomes

$-d[Fe(CN)_6]^{3-} / dt = kK1K2\,[CEF]\,[OH^-]\,[Ru(III)]_T$---(10)

Equation (10) holds good first order kinetic with hydroxyl ion at lower concentration and at higher concentration $K1[OH^-] >> 1$, equation (10) becomes

$-d[Fe(CN)_6]^{3-} / dt = kK1K2\,[CEF]\,[Ru(III)]_T$---(11)

Equation (11) holds good zero order kinetics with respect to $[OH^-]$ at higher concentration, equation (8) at constant $[Ru(III)]_T$ becomes,

$-d[Fe(CN)_6]^{3-} / dt = kK1K2\,[CEF]\,[OH^-] / 1+ K1[OH^-]+ K1K2\,[CEF]\,[OH^-]$---------------------- (12)

Verification of rate law

Equation (12) in reciprocal form can be written as,

$1/Rate = 1 / [CEF] (1 / kK1K2 [OH^-] + 1 / kK2) + 1/k$-- (13)

The plot of 1/ k_{obs} versus 1 / [CEF] and 1/ k_{obs} versus 1 / $[OH^-]$ were found to be linear and from the slope and positive intercepts k, K1, K2 were calculated and values are found to be 0.02, 135.11 and 156.93 respectively(**Fig. 5 and Fig. 6**). The thermodynamics parameters like the energy of activation E_a and entropy of activation $\Delta S^\#$ were computed for the rate determining step using linear least squares method and is recorded as 39kJ mol^{-1} and -203.8 kJ mol^{-1} respectively

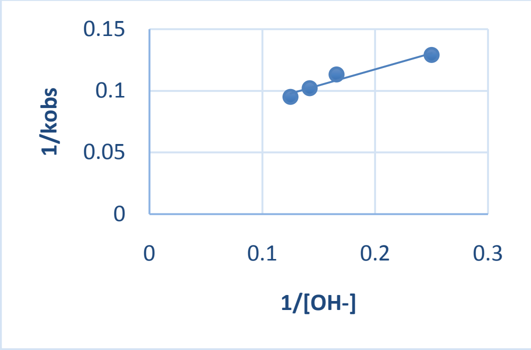


Fig. 5 Plot of 1/kobsvs 1/$[OH^-]$

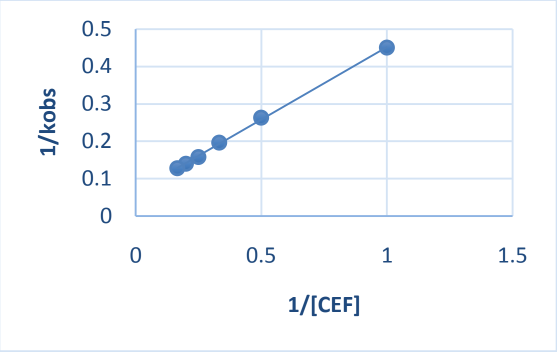


Fig. 6 Plot of 1/kobsvs 1/[CEF]

APPLICATIONS

The studied reaction between hexacyanoferrate (III) and cefixime undergoes with measurable velocity in the presence of micro amounts of ruthenium as catalyst compared to the uncatalyzed reaction in alkaline medium.

CONCLUSIONS

The titled reaction between hexacyanoferrate (III) and cefixime undergoes with measurable velocity in the presence of micro amounts of ruthenium as catalyst compared to the uncatalyzed reaction in alkaline medium. The product predicted is {[(*E*)-{1-(2-amino-1, 3-thiazol-4-yl)-2-[(3-ethenyl-2-hydroxy-8-oxo-5-thia-1-azabicyclo [4.2.0]oct-2-en-7-yl)amino]-2-oxoethylidene}amino]oxy}acetic acid. The reaction is first order with respect to concentration of hexacyanoferrate and catalyst ruthenium; also fractional order dependence on substrate concentration and alkali. The active form of ruthenium (III), $[Ru (H_2O)_5 OH]^{2+}$ with the substrate form the intermediate which oxidized to form the product under slow step. The large negative value of entropy change predicted that the formation of complex between catalyst and the substrate as discussed in the scheme. Rate constant with respect to slow step and equilibrium constant involved in the mechanism are calculated. The activation parameters with respect to the slow step and thermodynamic quantities are evaluated and discussed. The k (expl) and the k(cal) from rate equation are in good agreement as shown in Table 1.

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