CHAPTER – I

INTRODUCTION

1.1 A Comprehensive Review on the Chemistry of Schiff Bases
1.2 KMnO₄ as a Versatile Oxidant in Aqueous Acidic and Basic Solutions
1.3 A Perusal of Reaction Kinetics and Mechanism in Micellar Media
1.4 Scope of the Work

Bibliography
INTRODUCTION

1.1 A COMPREHENSIVE REVIEW ON THE CHEMISTRY OF SCHIFF BASES

Schiff bases are formed due to the condensation of aldehydes or ketones with amines.

\[
\begin{align*}
R'\cdot\text{C}=\text{O} & \quad + \quad R''\text{NH}_2 \quad \rightarrow \quad R'\text{CR}(\text{OH})\text{NHR}'' \quad \rightarrow \quad R'\cdot\text{CR}=\text{NHR}'' \\
\end{align*}
\]

(R = H for aldehydes and R = alkyl for ketones)

Aldehydes except formaldehyde react with ammonia in ethereal solution and give a precipitate of aldehyde-ammonia [1,2] or acetalaldimine. Acetalaldimine thus formed may yield trimer in subsequent steps.

\[
\text{CH}_3\cdot\text{CHO} \quad + \quad \text{NH}_3 \quad \rightarrow \quad \text{CH}_3\cdot\text{CH(OH)}\cdot\text{NH}_2
\]

\[
\begin{align*}
\text{CH}_3\cdot\text{CH(OH)}\text{NH}_2 \quad \rightarrow \quad \text{MeCH}=\text{NH} \quad \rightarrow \quad \text{MeCH} \quad \text{NH} \\
\text{Me} \quad \text{NH-CH} \\
\text{Me} \quad \text{NH-CH} \\
\end{align*}
\]

Structure of the trimer thus obtained is established from X-ray analysis that the trihydrate of trimethylhexahydrothiazine.
Aldehydes and ketones which possess α-hydrogen atom form enamines with cyclic secondary amines. Enamines are α,β-unsaturated amines. Enamines are generally prepared by the reaction between a carbonyl compound which contains at least one (α)(H) atom and a secondary amine. The general equation is given as

$$\text{CH}-\text{C}=\text{O} + \text{H-N} \rightarrow \text{C}=\text{C}-\text{N}$$

Enamines prepared from ketones are more stable than those from aldehydes and both types derived from cyclic secondary amines are more stable than those from acyclic secondary amines, the most common of which are pyrrolidine, piperidine and morpholine, eg., cyclohexanone and pyrrolidine form N-cyclohexenopyrrolidine.
Primary amines are also known to form enamines, which in turn tautomerise to imines.

\[
\begin{align*}
\text{enamine} & \\
CH-C=O + H_2N-R & \rightarrow \frac{\text{C=C-NH}}{R} = \frac{\text{CH-C=N-R}}{\text{imine}}
\end{align*}
\]

Further, it is well established that in presence of 1° amines, the tautomeric equilibrium completely shifts to right such that enamine cannot be isolated. Enamines could be represented as resonance hybrids of two canonical structures.

\[
\begin{align*}
\text{C=C-N} & \leftrightarrow \frac{\text{C-N}}{C-C=N}
\end{align*}
\]

From the above structures it appears that the ‘β’ carbon atom is susceptible to electrophilic attack. Due to the above reason enamines are very much used as intermediates in organic synthesis.

Formation of Schiff bases in vivo is well established. For instance formation of Schiff base due to the interaction of carbohydrates and peptides or proteins play vital role in the biological systems. Earlier it was also reported that de-amination or de-carboxylation reaction of amino acid can be accomplished by migration of electron from a bond to form (>C=N-) Schiff base derivatives [3]. This Schiff base linkage is usually broken and remade during the functioning of enzymes in catalysis.
Schiff bases are known to act as good donors to form metal complexes. One of the best known Schiff base ligand is bis[salicylaldehyde]ethylene diamine. It is an acidic tetra dentate ligand.

Complexes of un-ionised or partly ionised Schiff bases are also reported in literature earlier [1]. Schiff bases are a class of ligands which could also form bimetallic complexes with two metal atoms, such as (Mn$^{II}$-Mn$^{II}$) or (Mn$^{II}$-Mn$^{III}$) [4]. Macrocyclic amine ligands are known to form Schiff base complexes, controlled by metal ions (template synthesis). These complexes are also made independently [5,6].

Spectroscopic studies like electron spin resonance (esr), infrared (ir) and conductivity studies performed by Gaber et al, revealed that the interaction of 3-amino-1,2,4-triazole Schiff bases with Chloro-p-benzoquinone [7] could afford charge transfer (CT) complexes.

The Schiff bases formed due to the reaction of amines with ketones are called ketimines. Certain Ketimines are hydrolysed to form pyridoxamine phosphate and keto acid. Mechanism of this reaction was explained by Esmond Snell and Alexander Braunstein [8-10].
1.2 POTASSIUM PERMANGANATE AS A VERSATILE OXIDANT IN AQUEOUS ACIDIC AND BASIC SOLUTIONS

Oxidation and reduction reactions (or redox reaction where electron transfer takes place) are prime important to both chemists and biochemists. By studying these reactions a large number of physiological process occurring in situ and analytical process occurring in the experimental conditions can be understood with their mechanistic pathway. In all the biological process electron transport chain reactions (more complicated) occur leading to the exergonic process. Study of oxidation and reduction reactions with mechanism gives a better scope for understanding the nature of life. Living organisms are all chemically reacting system involving oxidation and reduction [11]. Simple ionic reaction of direct electron
transfer generally do not occur in complicated organic reactions. The simple electron transfer reactions are those in which neither the coordination number, nor the co-ordinated ligands of reaction partners are changed in the overall (net) reaction. Electron exchange reactions are those where only a single element is involved in an electron transfer reaction.

\[ \text{Fe}^{2+} + \text{Fe}^{3+} \rightleftharpoons \text{Fe}^{3+} + \text{Fe}^{2+} \]

Based on the number of electrons transferred in the redox reactions electron transfer reactions are classified as one equivalent or two equivalent reactions. The one equivalent oxidations generally have redox potentials in the range 1.0 - 2.0 volts. Two equivalent oxidants exhibit faster reaction rates than one equivalent oxidant (which have similar redox potentials) [12-14]. This is because two equivalent oxidants (i) do not form high energy free radicals as intermediates and (ii) the free energy change occurs in these reactions is twice to that of one equivalent systems on the whole. Over the past two decades, electron transfer redox reactions, have received quite some attention and considerable contribution is made [15-17]. In homogenous gas phase redox reactions direct electron transfer mechanism was proposed, but in liquid phase system it is complicated. The electron transfer reactions are explained by electron tunneling theory [16] according to which an electron can leak through a potential energy barrier to distances considerably greater than that would correspond to actual collision of the reactants. Over the years a variety of transition metal ions, heavy metal ions and metal complexes have been used as one or two equivalent oxidants in synthetic organic chemistry. By choosing appropriate oxidant the
reactivity of substrate can be controlled. Hyper valent transition metal ions such as Mn(VII) and Cr(VI), V(V) are widely employed as one or two equivalent oxidants in synthetic organic chemistry in the past few decades [12-15]. Permanganate ion is a versatile reagent in aqueous solution which behaves peculiarly as one or two electron oxidant depending on the pH conditions. In permanganate reactions electron transfer occur as

\[
\text{MnO}_2^- + \text{MnO}^-_4 \rightarrow \text{MnO}^-_4 + \text{MnO}^2^-_4 \quad \text{(One electron transfer)}
\]

In this reaction electron transfer results in no net chemical change and such reactions are often termed as electron exchange reactions. In these reactions electron transfer occurs between two different oxidation states of the atom.

In neutral or slightly alkaline solutions or in dark the reaction is slow. This reaction is accelerated by light. In basic solutions it acts as a powerful oxidising agent \((E^0 = +1.23 \text{ V})\).

\[
\text{MnO}^-_4 + 2\text{H}_2\text{O} + 3e^- \rightarrow \text{MnO}_2 + 4(\text{OH}^-)
\]

(Solid)

In presence of strong base and excess of \text{MnO}^-_4 gives manganate ion \((\text{Mn}^{+6})\).

\[
\text{MnO}^-_4 + e^- \rightarrow \text{MnO}_4^{2-} \quad (E^0 = +0.56 \text{ V})
\]

In presence of acidic medium permanganate is reduced to \text{Mn}^{2+} by an excess of reducing agent \((E^0 = +1.51 \text{ V})\)
\[
\text{MnO}_4^- + 8H^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4H_2O
\]

\[
\text{MnO}_4^- \text{ oxidises Mn}^{2+} \quad (E^0 = + 0.46 \text{ V})
\]

\[
2\text{MnO}_4^- + 3\text{Mn}^{2+} + 2H_2O \rightarrow 5\text{MnO}_2 + 4H^+
\]

MnO₂ solid is obtained if MnO₄⁻ is taken in excess.

Heptavalent Mn(VII) in strong acid medium initially forms Mn(IV) and finally it gives rise to Mn(II). All the species formed in the conversion of Mn(VII) to Mn(II) act as oxidants, but the main species involved for the oxidation depends on the medium and pH of the reaction mixture. Permanganate is used as an agent conveniently over a wide range of temperatures from below 0°C to 100°C. The temperature fixation is dependent on the nature of the substrate taken, for example, alkenes and alcohols, can be oxidized at very low temperatures and aromatic compounds with alkyl side chain requires above 100°C [18,19].

Potassium permanganate is one of the important oxidizing agent in the laboratory. Tompkins observed that the rate of permanganate oxidation of benzaldehyde is of second order and rate dependent on factors like concentration, temperature and pH [20]. Wiberg and Stewart gave similar type of results and studied eight aromatic aldehydes between a pH range of 5 and 13 [21] with KMnO₄ as an oxidising agent only, effects of mixed solvents were studied by other workers [22-24]. Permanganate oxidation of benzaldehyde and its derivatives has been studied in water/acetic acid mixture and Arrhenious parameters were evaluated. In this report it is
stated that rate constants are found to increase with increasing ACOH concentration. Mechanism of oxidation was explained with participation of water molecule in the slow step.

Phase transfer catalysis (PTC) is one of the most attractive new techniques in organic synthesis [25-28]. Herriott and Picker reported the oxidation of several organic substrates by KMnO$_4$ under PTC using tricapryl methyl ammonium chloride with very good yields. Weber and Shepherd [29] reported the controlled oxidation of olefins to the corresponding cis-glycols in moderate yields by potassium permanganate in dichloroethane using benzyl triethyl ammonium chloride as catalyst.

To solubilise potassium permanganate in benzene dicyclohexyl-18-crown-6 is added. With this Sam and Simmons [30] oxidized a number of organic substrates in good to excellent yield. Various quaternary ammonium salts are used as catalysts for potassium permanganate oxidation of benzaldehydes substituted benzaldehydes in different solvents [31]. Oxidation of various amino acids were studied extensively by potassium permanganate, in various solvents. It was reported that DL alanine oxidation with KMnO$_4$ in acid catalysed reactions have a reactive species of (MnO$_4$)$^-$ [32].

The permanganate oxidation of aromatic aldehydes in HClO$_4$ medium were studied and it is reported that ester formation mechanism is operating and it is confirmed by thermodynamic values and activation parameters [33].
Oxidation of amines by the permanganate ion is discussed thoroughly [34,13]. Amines when oxidized by MnO₄⁻ changed to higher oxidation states. This is accomplished in two ways. Either the electron is lost from a nitrogen atom or a carbon atom adjacent to nitrogen. It was earlier reported that in primary, secondary and tertiary amines rapid oxidation occurred in t-butyl alcohol solution at 25°C when there is a hydrogen atom to carbon and in turn attached to nitrogen. Complex mixture of products obtained as imines, enamines, Schiff bases and cleavage products [34-37]. It was reported earlier that neutral permanganate in aqueous t-butyl alcohol at 60° to 80°C oxidizes amines to aldehydes and ketones in good to excellent yield.

\[
\text{KMnO}_4 \rightarrow \text{R-CH}_2\text{-NH}_2 \rightarrow [\text{R-CH=N-H}] \rightarrow \text{R-CH=O}
\]

The mechanism of oxidation of primary amines with KMnO₄ in neutral medium was discussed as (hydrogen atom or hydride ion abstraction, electron transfer) by other workers [33,36-38]. Methyl amine oxidation with KMnO₄ was explained through hydrogen atom abstraction. Benzyl amine is oxidized by alkaline permanganate solution to benzaldehyde, benzamide and benzoic acid [39]. But use of neutral permanganate solutions results in a complex series of reactions that involves the coupling of imine intermediates with themselves and with unreacted starting material to give amides and hydrazines [36,37].
The oxidative dimerisation of N-phenyl-2-naphthylamine by neutral permanganate solution also yields a series of products, this is due to carbon-nitrogen and carbon-carbon coupling of the amino free radicals [40,41].

Oxidation of phthalimido-ethoxy acetaldehyde by potassium permanganate has been reported to afford corresponding acids in quantitative yields in presence of strong acidic solution.
For the oxidation of alkenes aq. KMnO₄ is used as a successful oxidizing agent over decades. The reagent was originally used for the conversion of alkenes into diols (Wagner dihydroxylation reactions) [42].

\[
\begin{align*}
\text{R} & \quad \text{R} \\
\text{C}=\text{C} & \quad \xrightarrow{\text{MnO}_4^-} \quad \text{OH} & \quad \text{OH} \\
\text{R} & \quad \text{R}
\end{align*}
\]

Hydrolysis of alkenes in presence of alkaline medium gives diols, glycols with 50% yield. The yield is increased in phase transfer catalysis in acidic medium cleavage products (with in C-C) predominates. In the initial step of oxidation of alkenes cyclic manganese esters are formed [12,43-45]. In the proposed mechanism formation of cis two hydroxyl groups are added [46] and oxygen atoms are transformed directly from (MnO₄)^-. Manganese (V) esters intermediate species with a short life have been detected recently by stopped flow techniques [47-49].
The oxidation of symmetrically disubstituted alkenes with KMnO₄ in cold acetic anhydride yields α-diketones. This was found and reported by Sharpless & Coworkers [50].

Phase transfer catalysed cis-hydroxylation of alkenes, Weber and Shepherd [51] found out that alkenes like cyclohexene, cis cyclo octane and trans cyclo octane can be oxidized stereospecifically to vicinal cis diols by cold dilute alkaline KMnO₄ in the presence of a catalytic quantity of benzyl triethyl ammonium chloride as the phase transfer agent in water/dichloromethane as the solvent.

Ogino and Mochizuki [52] reported that in homogeneous non-aqueous, one phase system, i.e., KMnO₄ solubilised in dichloromethane in the presence of equimolar amount of benzyl triethyl ammonium chloride readily oxidized alkenes under anhydrous conditions. Either 1,2-diols or aldehydes are obtained in good yields.
Permanganate ion oxidizes alkenes into carboxylic acid or a mixture of carboxylic acids and ketones [53] in presence or absence of phase transfer catalyst.

Oxidation of Alkynes

Kahn and Newman [54] reported that alkynes on oxidation with KMnO₄, under controlled pH give diones. For instance stearolic acid is converted to 9,10-diketostearic acid.
Lee and Chang [55,56] reported that oxidation of non-terminal alkynes by MnO$_4^-$ is possible in three different pathways.

(1) In aqueous solution cleavage of the (-C≡C-) triple bond occurs and results in the formation of carboxylic acids.

(2) In anhydrous dichloromethane solution, reactions assisted by phase transfer leads to the formation of diketones in good yields.

(3) In aqueous solution in phase transfer catalysed assisted reactions yield α-diketones and also cleavage products.

\[
\begin{align*}
\text{KMnO}_4 & \quad \text{C}_6\text{H}_5\text{-C≡C-H} \quad \rightarrow \quad \text{C}_6\text{H}_5\text{CO}_2\text{H} \\
\text{C}_7\text{H}_{15}\text{-C≡C-C}_7\text{H}_{15} & \quad \text{KMnO}_4/\text{CH}_2\text{Cl}_2 \quad \text{H}_2\text{O-Adogen} \quad \rightarrow \quad \text{C}_7\text{H}_{15}\text{-C-C-C}_7\text{H}_{15} \\
& \quad \text{72%}
\end{align*}
\]

Simmandi and Jaky [57], were of the view that the mechanism of oxidation of alkynes proceeds through the formation of intermediate manganese (V) ester which undergoes an internal electron transfer and
releases Mn(III) as the dione forms. In non aqueous solvents, dione enolises and gets oxidized and gives cleavage products. In aqueous solutions the oxidation of diketone results in symmetrical cleavage of the carbon carbon bond between the two carbonyl groups is initiated by a nucleophilic attack of the oxidant on a carbonyl carbon atom followed by cyclisation and oxidative decomposition.

Oxidation of alkanes, arenes and alkyl side chains

Permanganate oxidizes side chains of arenes and produces corresponding acids. On the basis of kinetic observations free radical mechanism operating in the side chain oxidation was proposed in neutral and basic conditions [58-60]. In higher acidic conditions permanganic acid (HMnO₄) and permanganyl cation (MnO₃⁺) [61] were proposed as the reactive species and electrophilic attack on aromatic nucleus occurs. Trifluoro acetic acid is used as a solvent it has a unique property by inertness to oxidative degradation and provides adequate solubilities for the reactants.

Permanganate oxidation of alkanes in acidic medium occurred through the participation of MnO₃⁺ and alkane in the rate determining step in which alkane decomposes homolytically to yield alkyl radical. The radical thus formed is finally converted to carboxylic acids in fast steps.
Oxidation of arenes gives degradation products and proceeds by a mechanism where in the rate determining step electrophilic attack by permanganyl ion (MnO$_{4}^{+}$) takes place at the activated positions of the ring and yields degradation products. It is believed that phenols are given as intermediates. Oxidation of alkyl and aryl side chains with potassium permanganate yields respective acids.
Oxidation of alcohols by permanganate ion was reported earlier [43,44,34,36]. In acidic or basic or neutral media alcohols oxidize with $\text{KMnO}_4$ leads to the corresponding products, but it cannot be used in the non-aqueous solvents [36], $\text{KMnO}_4$ is used for the oxidation of hydroxy compounds such as lactic and mandelic acids. Aqueous acetic acid can also be used as a solvent.

Two phase solvent systems as ether/water dichloroethane/water, are also used for the permanganate oxidation of alcohols. The oxidation of benzhydrols with alkaline $\text{KMnO}_4$ was studied and a mechanism is provided by Stewart [12,62].

\[ \text{R}^1 \text{CH-OH} \rightleftharpoons \overset{+\text{OH}^-}{\text{CH-O}^-} \overset{\text{MnO}_4^- \text{ (slow)}}{-\text{H}_2\text{O}} \overset{\text{HMnO}_4}{\rightarrow} \text{R}^1 \text{C}=\text{O} \]

Oxidation of alcohols, aldehydes, ketones and carboxylic acids

Oxidation of aliphatic [63], aromatic [64], aldehydes with potassium permanganate in acidic or alkaline solutions gives corresponding acids. In neutral medium the rate of reaction is slow [65]. Piperonal in aqueous permanganate at 70-80°C gives piperonylic acid with 90% yield.
In the mechanism of oxidation of aldehydes it was reported that cleavage of carbon-hydrogen bond takes place in the rate determining step [66,67], kinetic studies of oxidation of aliphatic aldehydes [68], benzaldehyde [69,70] and p-nitro benzaldehydes were reported earlier.

Oxidation of ketones by potassium permanganate occurs in presence of alkaline or highly acidic conditions. The intermediates formed are considered as enols. In case of cyclic ketone permanganate oxidations occurs through carbon-carbon bond cleavage and dicarboxylic acids are obtained cyclohexanone on oxidation with potassium permanganate gives adipic acid with 55% yield [71]. Aromatic methyl ketones [72] and heteroaromatic methyl ketones [73] on oxidation with potassium permanganate are converted to α-keto acid.

(a) \[H_3C\begin{array}{c} \text{O} \\ \text{C} \text{H}_3 \end{array} \text{C} \text{H}_3 \xrightarrow{\text{MnO}_4^-/\text{OH}^-/\text{H}_2\text{O}} \begin{array}{c} \text{O} \\ \text{C} \text{H}_3 \\ \text{C} \text{O} \text{H} \end{array} \] 70%

(b) \[\begin{array}{c} \text{N} \\ \text{C} \text{H}_3 \\ \text{N} \\ \text{C}_6 \text{H}_5 \end{array} \text{C} \text{H}_3 \xrightarrow{\text{MnO}_4^-/\text{OH}^-/\text{H}_2\text{O}} \begin{array}{c} \text{N} \\ \text{C} \text{H}_3 \\ \text{N} \\ \text{C}_6 \text{H}_5 \end{array} \text{C} \text{O} \text{H} \] 80%

In alkaline medium permanganate selectively oxidizes carboxylic acids containing tertiary carbon in α-position to α-hydroxy carboxylic acids [74-76]. However, such conversion could not be achieved with a tertiary carbon at β-position.
The kinetics and mechanism of permanganate ion oxidation of 2,2-dimethyl propanal (pivalaldehyde) and other aliphatic aldehydes over the pH range 2.8-6.86 have been investigated [77]. The catalytic ability of [2(n-dodecyl methyl butyl siloxy)-ethyl] trimethyl ammonium nitrate under micellar emulsion conditions has been assessed with the use of potassium permanganate oxidation of piperonal to piperonylic acid 50-60°C (45% yield conversions) [78]. The kinetics and mechanism of the oxidation of aliphatic aldehydes by acid permanganate (permanganate in aqueous per chloric acid) was reported [79].

Extensive study of kinetics of oxidation of various acids, formic acid [80], acetic acid [81], oxalic acid were done. Permanganate was also used in studying the kinetics and mechanism of oxidation of trans cinnamic acid [82], maleic and fumaric acid [83] and cis-2-substituted-1-cyclopropane carboxylic acid [84] and in the oxidative decarboxylation of DL-aspartic acid [85].
Permanganate oxidation of organic sulphur compounds

Organic sulphur compounds when treated with potassium permanganate yields sulphoxide compounds.

In addition to potassium permanganate other salts of permanganate are also used as oxidants. For instance, Barium permanganate is used for the oxidation of primary aromatic amines to azo compounds [86]. The reagent has also been used for oxidative dimerisation of alkyl or aryl thiols which yields disulphides, Bis, [2,2’-bipyridyl] copper(II) permanganate is also used as an oxidant for the dimerisation of thiols to sulphides [87]. This mild oxidizing agent can also be used for the oxidation of benzyl alcohols, aromatic amines and oximes [88].

Another novel oxidizing reagent derived using permanganate is Lemieux-Von-Rudloff reagent. It could be obtained insitu when periodate is used in combination with potassium permanganate. It is used for the opening of a ring of 5α-cholestan-3-one to give the di-acid in 75% yield [89].
1.3 A PERUSAL OF REACTION KINETICS AND MECHANISM IN MICELLAR MEDIA

For a number of transformation reactions like organic, inorganic or bio-organic, micelles or micro emulsions form a very attractive reaction media. Muller and Burkhan defined that micelles are aggregates of colloidal size surfactant molecules of relatively low molecular weights [90]. Micelles are included under the category of “Association Colloids” which have a size in the range of $10^9\text{A}$, which is more than that of normal solute particles [91].

Surfactant monomers dynamically associate to form large molecular aggregates and are called as micelles. The small range of concentration in which these molecular aggregates are formed, is called as critical micelle concentration (CMC). This specific concentration above which the monomer concentration remains constant and if surfactant is added more, it increases the total no. of micelles. The examples of anionic, cationic and non-ionic micelles are

\[
\begin{align*}
\text{(SDS)} & \quad \text{OSO}_3^+ \text{Na}^+ \quad (\text{C}_{12}\text{H}_{25}\text{OSO}_3^\text{Na}) \\
\text{(CTAB)} & \quad \text{N(CH}_3\text{)_3 X}^- \quad (\text{C}_{16}\text{H}_{33}\text{NMe}_3\text{Br}) \\
\text{(Tri - X)} & \quad \text{(Tri - X)} \\
\end{align*}
\]
The cationic surfactants are found to exhibit bactericidal activity and effectively used as pharmaceuticals especially in cleansing wounds on the skin. These are also useful as emulsifying agents in the formation of cream and lotions. Micelles are also used as preservatives [92]. Anionic surfactants most frequently used are alkali or alkaline earth metal salts of mono and poly basic carboxylic acids (fatty acids) and of sulphuric, sulphonic and phosphoric acids containing a saturated or unsaturated hydrocarbon substituents. Anionic surfactant sodium dodecyl sulphate is also used pharmaceutically as a pre-operative skin cleanser, having bacteriostatic action and also in medicated shampoos. The lower chain compounds around \( C_{12} \) have better wetting property while the higher members (\( C_{16} \) to \( C_{20} \)) have detergent properties. These compounds generally retain their property over a wide pH range.

The non-ionic surfactants have better considerations in the reaction media than ionic surfactants. The properties of non-ionic surfactants are not effected by pH. In non-ionic surfactants the hydrophilic and hydrophobic portions are balanced. The non-ionic surfactants are poly oxy ethylene or poly oxy propylene derivatives of alcohols, alkyl phenols, fatty acid esters, alkyl amines, amides, poly alcohols, carbohydrates and esters, etc. Examples of non-ionic micelle is Triton-X 100. The Tx-100 is spherical.

The surfactant monomers are in rapid dynamic equilibrium with the micelles.
Micelles are responsible for the alteration in the rate of reactions, but the individual surfactant molecules (monomeric species) do not alter the rate. Choice of the micelle is important. If the appropriate micelle is added to the reaction the rate of the reaction increases from 5 to 1000 fold compared to that of the same reaction in absence of the micelle. Increase in the concentration leads to aggregation which is energetically favourable. These stable aggregates are not completely poly dispersed, size and shape of micelles is determined by packing factors and by hydrophobic forces. To discuss about the structure of micelles in aqueous solutions, the modern concept says that initially the spherical formation of a micelle consists of liquid hydrocarbon core covered with a layer of polar ionogenic groups. Then a further growth in the concentration, the system gets transformed into a lamellar mesomorphic phase.

In aqueous solution the formation and breaking of micelles to monomers is very fast. Though the micelles have well organized structures, the reaction of monomers in the formation of micelles is very fast and found that half life is in the range of milliseconds [93].

Surfactants forming micelles in aqueous solutions have a general formula of RX- in which 'R' is the hydrophobic moiety consisting of alkyl chain with 8 to 18 carbons in it. 'X' is the hydrophilic group of cationic, anionic or non ionic groups.
Typical cationic surfactants have quaternary ammonium or phosphonium groups, anionic surfactants have sulphate, sulphonate or carboxylate group and non-ionic surfactants have generally a poly oxy ethylene groups. Due to the formation of micelle the properties of solutions change abruptly, like surface tension, conductivity, viscosity, etc. Micelle formation is entropy driven $\Delta G$, energy for micelle formation is $\Delta G = 2470 - 18.9T$ J.mol$^{-1}$ [94].

Not only ionic and non ionic micelles but also micelles with zwitterions moiety are known [95,96]. Naturally occurring phosphotides and lipids form there amphiphiles, surfactants are present as colloidal aggregates rather than monomers above the Kraft temperature. The dissolution of monomers in a solvent is explained by the hydrophilic and hydrophobic portions present in a surfactant.

Solubility of non-polar organic molecules in water is very low but simple polar molecules or ions are highly soluble in water but they are not associated. Amphipathetic molecules possess polar and non polar characters. Surfactants are amphipathetic molecules having hydrophilic and hydrophobic properties. In presence of surfactants compounds are incorporated into micellar aggregates and association constant for complexation is $41$ M$^1$ [97]. The organic reactions in aqueous media are catalysed by micelles. This phenomenon for the catalysed reaction by surfactant micelles is attributed to the following reasons. (a) The polarity of micelle is less than water. Medium effect may be favourable in the dielectric constant of CTAB (= 36). (b) The transition states are stabilized.
by electrostatic interactions of the head group of opposite charge. (c) The electrostatic effects may cause the lowering of pKa values of ionic reagents. (d) The concentration of reactants may be higher in micelles than in the bulk solutions. Thus the rates of bimolecular reactions are increased [93].

There are some similarities in the catalytic effect of micelles and to that of enzymes. The enzyme binds to the substrate tightly and it organizes for the reaction further. Enzyme binds in a way that reaction transition state is particularly favoured. This requires a highly structure catalyst of well defined orientation [98]. In the structure of micelles formed from simple surfactants as sodium dodecyl sulphate is spherical consists of 50 - 100 surfactant molecules per micelle. The hydrophilic groups occupy the surface of the micelle and are exposed to the solvent, while hydrophobic portion occupies the interior portion. This interior portion shows the properties of liquid hydrocarbon [91a]. Certain organic substrates have association with hydrocarbon like portion of the micellar phase. Immediately adjacent to the hydrocarbon core of the micelle there is a highly charged layer in which the counter ions are tightly bound to the micelle itself. This layer is "stern layer". Beyond the stern layer the remainder of counter ions exist relatively unorganized with respect to micellar surface. According to Boltzman distribution law the concentrations of counter ions decreases as one recedes from the surface. The charge on the micellar surface is neutralized (up to 60 - 70%) by counter ions in the stern layer.
The hydrophobic properties of the micelle is pronounced when the concentration of counter ions is increased. It indicates that micellar surface charge is completely neutralized. The hydration of the charged groups within the stern layer is similar to that of the charged groups alone [99]. Thickness of stern layer is equal to that of ionic head of micelle. The potential difference between the bulk and micellar phase is in the range of 50 – 100 mv. Surface of micelle is rough due to this and the molecules adsorbed on the surface will have hydrophobic interactions. The reactions of micelles occur by two factors: (1) electrostatic interactions between the micellar phase and (2) hydrophobic interactions between the micellar phase and reactants, transition states and products.

The hydrophilic unit of one monomer will be in close vicinity of another monomer hydrophilic unit. Similarly the hydrophobic unit of one monomer will be in close proximity of another hydrophobic unit of adjacent monomer. Critical micelle concentration is defined as the narrow range of surfactant concentration at which the micelles first become detectable by change in physical properties, electrical conductivity, emf, pH, specific heat, viscosity and optical and spectroscopic properties. It was reported in earlier papers that addition of alcohol decreases the value of CMC, aggregation number and dielectric constant of the medium [100a] and a fraction of the head groups are also neutralized by the addition of alcohol [100b]. At CMC of SDS the micelles are aggregated with a diameter of ~50Å and it has 80 SDS monomer units in it. Below the Kraft temperature (Tk) increasing the concentration of SDS leads to precipitation of solid SDS. The Tk for SDS is 20°C. All the physical properties of the micelles are dependent on
pressure, temperature and composition of the system [101-110]. The aggregation number is defined as the number of monomers which determines the size and geometry of the micelle. The aggregation number is in the range of 10 to 100 in aqueous solutions. Aggregation number is determined by light scattering, diffusion, viscosity and sedimentation velocity and nmr spectroscopic techniques. Aggregation numbers were found to be more for non-ionic surfactants.

Aggregation of surfactant changes with a change in the polarity of solvent. In presence of a non polar solvent, the polar groups are concentrated in the interior of the aggregate while their hydrophobic moieties extend into, and are surrounded by the bulk apolar solvent [111]. The species formed due to the aggregation of surfactant monomers, in a non polar solvent is quite often termed as reversed or inverted micelle. Significantly considerable amount of water can be solubilised by reversed micelles. This surfactant – solubilised water is often referred to as a water pool.

Reversed micellar solutions are homogeneous and optically transparent. The most important difference between aqueous and reversed micelles is that substrates do not penetrate appreciably into the former, but, if polar, they are localized in the hydrophilic cavities of reversed micelles. Interactions between the substrate and the polar head groups of the surfactant, between the substrate and the solubilised water, and between the solubilised water and the surfactants can be quite strong and specific, substantial rate
enhancements or retardations are expected. The reversed micellar effects are studied initially in hydrocarbon and chlorocarbon media [112].

The most interesting feature of the micellar reaction is its resemblance as the micellar catalysis to that of enzyme catalysis. The following few points are considered for the similarity of the two.

(1) X-ray crystallographic studies revealed structural similarities, between micelles and globular proteins.

(2) The solubilisation energy of non-polar compounds is almost identical for aqueous micelles and globular proteins.

(3) Protein denaturing agents such as urea and grandinum salts etc., were also found to disrupt micelles.

(4) In many micellar catalysed reactions Michaelis-Menton kinetics is obeyed which shows the resemblance with enzyme catalysis.

(5) The effect of inhibitions on micellar catalysed reactions was also found to be by and large similar to enzymatic reactions.

Rate enhancement or inhibition of chemical reactions in presence of micellar (i.e., solubilisation) is mainly dependent on electrostatic and hydrophobic interaction. These effects were found to follow Hartley indicator rules [113].
(i) The chemical reactions involving cationic species are accelerated in anionic and non ionic micellar media and inhibited in cationic micellar media due to electrostatic interactions. The inverse is true for the reactions involving anionic species.

(ii) Additives containing counter ions enhance the reaction rates in micellar media.

(iii) Reactions involving non ionic, hydrocarbons and molecular species are catalysed in non ionic micellar media due to hydrophobic interaction.

The oxidation of alcohols in presence of SDS micelle by chromic acid has been studied extensively [114]. A number of different catalytic or inhibitory effects of SDS in chemical reactions like acid catalysed hydrolysis [115], base catalysed hydrolysis [116], replacement reactions [117], halogenation reactions [118], dimerisation of cation radicals [119], oxidation of olefins and ferrocenes [120] and electron transfer reactions between transition metal complexes [121] were studied extensively. Alcohol oxidation in aqueous phase was also recently studied by Perez Benito. The kinetic results were conveniently explained using pseudo phase ion exchange kinetic model [122] considering that micellar counter ion and H\(^+\) ions compete for the ionic head groups of the micellar surface. Ghosh and co workers studied the mixed surfactant system [123] in order to know the synergetic and incompatibility effects that operate between hydroxamic acids and surfactants in solution.
The use of surfactants in redox reactions involving aquated electrons has been studied [124]. In the above case it was reported that rate enhanced mixed micellar systems in a variety of chemical reactions not only the rate effects were studied but also the catalytic studies and extended to enzymatic reactions in reversed micelles [125,126]. On a perusal of the experimental data, different types of mechanisms such as Michaelis-Menton kinetics, Ping-Pong bi-bi mechanism. Random order mechanism and Theorell-chance mechanism were observed to be operative.

1.4 SCOPE OF THE WORK

There has been an upsurge in the chemistry of Schiff bases since several decades because of their immense importance in biological defence mechanisms. The Schiff bases are formed in situ in a wide a variety of cell reactions due to the condensation of aldehydes, ketones, carbohydrates with amines or amino acids.

It was reported earlier that the formation and hydrolysis of Schiff base of pyridoxal-5'-phosphate and n-dodecyl amine, the formation constants are higher [127]. The hydrophobic substituents present in amino acids, protected the imine bond being hydrolysed. From the kinetic data and pKa values it was concluded that Schiff base of pyridoxal-5'-phosphate and dodecyl amine in aqueous medium is an accurately descriptive model for enzyme system in hydrophobic environments. Kinetics and oxidations of glutamine, serine and alanine in presence and absence of aliphatic aldehydes by peroxomonomosulphate was reported by Ramachandran et al., who proposed
that Schiff base is formed in situ as a reactive intermediate [128]. The Schiff base on oxidation yield amides (imines to amides) [129].

Permanganate (MnO$_4^-$) is a classical oxidant whose versatality can be accounted for the fact that it is susceptible to undergo reduction into lower oxidation states, i.e., from Mn(VII) to Mn(V), Mn(IV), Mn(III) or Mn(II) depending on the pH of the medium and nature of the solvent. In view of this even after a century it is receiving increased attention by biochemists and analytical chemists.

The permanganate oxidation of the components of large biological molecules such as nucleic acids and proteins has also received considerable attention. Kinetic studies of the permanganate oxidation of thymine [130], uracil [131] and several amino acids have already been undertaken. The occurrence of auto-catalysis in permanganate reactions appears to be extensive [132-134], in particular the permanganate oxidation of amines [135-137] deserves special mention among the auto-catalytic reactions due to the close relation that can be established between amines and amino acids.

Permanganate is also effectively used as a reagent in the histo-chemical oxidation of muco-substances [138], complex carbohydrates [139] and hematoxylin [140]. It is also used in the stereo selective synthesis of organic compounds, such as, cis diols.
Permanganate was used as analytical reagent in the estimation of bio-organic compounds like cinnamocyanogenic, pyruvic and L-ascorbic acids, D-mannose, thio-urea chlorinated pesticide residues in food.

Surfactants are macromolecules which form cluster like aggregates in a small concentration range. These aggregates are known as micelles. Micellar chemistry is receiving the attention of biologists and chemists since more than three decades because of a close parallelism with enzymes.

In view of the foregoing striking factors the author has taken up the present work entitled “Redox Reactions in Well Organised Micellar Media – A Kinetic View”.

The proposed kinetic study has been taken up in four stages in aqueous acid/buffer micellar media:

(i) Oxidation of aromatic amines, amino acids and peptides such as glycyl glycine.

(ii) Oxidation of aromatic aldehydes such as salicylaldehyde, p-anisaldehyde, p-tolualdehyde, glucose and fructose.

(iii) Oxidation of Schiff bases derived from aldehydes, amines, amino acids/peptides and carbohydrates.

(iv) Oxidation of mixed organic substrates with a combination of (a) amines + aldehydes and (b) (amino acids/peptides) + carbohydrates.
Steps (iii) and (iv) were proposed to compare and contrast the kinetic features to gain an insight whether mixed organic substrates form Schiff bases in the present kinetic conditions. It is also proposed to isolate the products in order to confirm the target results. It is hoped that the study would go a long way in understanding the kinetics and mechanism of oxidation of Schiff bases by MnO₄⁻ as model study of biological oxidations.
BIBLIOGRAPHY


38
4166.
(b) J. Colloid. Interface Science, 19 (1964) 722.
Enzymic and non enzymic Catalysis”, Published by Ellis Harwood Ltd.,
Chichester, Chapter-5, (1978).
94. E.A.G. Aniansson, S.N. Wall, M. Almgen, H. Hoffmann, I. Kielmaan,
905.
(1965) 1043.
1534; (b) M. Manabe, H. Kawamura, A. Yamashita and S. Tokunaga,
Surface Active Agents and its Application in Chemistry and Biological


138. P. Sipponen, Histochemistry, 64 (1979) 297.


44