CHAPTER - I

1. INTRODUCTION

1.1 Schiff bases and their chemistry

Compounds containing an azomethine group (–CH=N–) are known as Schiff bases. They are usually formed by the condensation of a primary amine with a carbonyl compound according to the following scheme:

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

where R may be an aliphatic or an aromatic group. Schiff bases of aliphatic aldehydes are relatively unstable and are readily polymerizable while those of aromatic aldehydes, having an effective conjugation system, are more stable.

Condensation of amines with aldehydes and ketones have numerous applications which include preparative use, identification, detection and determination of aldehydes or ketones, purification of carbonyl or amino compounds, or protection of these groups during complex or sensitive reactions.

An amino group is found in simple amines and Schiff bases obtained from aromatic amines are known as anils. Schiff bases are generally bi- or tri-dentate ligands capable of forming very stable complexes with transition metals. In chemistry, Schiff bases find a versatile use; some of them are the basic units in certain dyes, whereas, some are used as liquid crystals in organic synthesis, Schiff base reactions are useful in making carbon–nitrogen bonds.

1.2 Biological Importance of Schiff bases

Schiff bases appear to be important intermediates in a number of enzymatic reactions involving interaction of an enzyme with an amino or a carbonyl group of the substrate. One of the most prevalent types of catalytic mechanisms in
biochemical processes involves condensation of a primary amine in an enzyme, usually that of a lysine residue, with a carbonyl group of the substrate to form an imine, or Schiff base.

Stereochemical investigations\textsuperscript{13} carried out with the aid of molecular models showed that Schiff bases formed between methylglyoxal and the amino groups of the lysine side chains of proteins can bend back in such a way towards the N atoms of peptide groups that a charge transfer can occur between these groups and the oxygen atoms of the Schiff bases. In this respect, pyridoxal Schiff bases derived from amino acids have been prepared and studied\textsuperscript{14}. Schiff bases derived from pyridoxal and amino acids are considered very important ligands from the biological point of view. Transition metal complexes of such ligands are important enzyme models. The rapid development of these ligands resulted in an enhanced research activity in the field of coordination chemistry leading to very interesting conclusions.

Certain polymeric Schiff bases have been reported which possess antitumor activity\textsuperscript{15}. The Schiff bases have the highest degree of hydrolysis at pH 5 and the solubility in water is also highest at this pH. The antitumor activity of the bases towards ascetic tumours increases considerably with a slight increase in water solubility. Another important role of Schiff base structure is in transamination\textsuperscript{16}. Tranminases appear to have the same prosthetic group, i.e., pyridoxal phosphate, which is non–covalently linked to the enzyme protein.

The biosynthesis of porphyrin, for which glycine is a precursor, is another important pathway, which involves the intermediate formation of Schiff base between keto group of one molecule of δ–amino levulinic acid and ε–amino group of lysine residue of an enzyme.
1.3. **Schiff base transition metal complexes**

There are certain metallo–elements without which the normal functioning of the living organism is inconceivable. Among these metallo–elements so called, ‘metals of life’, four members form an ‘island’. These are Na, Mg, K and Ca. Among the transition elements are V, Cr, Mn, Fe, Co, Ni, Cu and Zn. These elements are present at trace and ultra trace quantities and play vital roles at the molecular level in a living system. These transition elements are known to form Schiff base complexes.

In fact metal–Schiff base complexes have been known since the mid nineteenth century\(^1\) and even before the general preparation of Schiff base ligands themselves\(^2\). Metal–complexes of Schiff bases have occupied a central place in the development of coordination chemistry after the work of Jorgensen and Werner\(^3\). Ettlings isolated a dark green crystalline product from the reaction of cupric acetate, salicylaldehyde and aqueous ammonia. Schiff prepared complexes from the condensates of urea and salicylaldehyde. Delepine\(^4\) prepared complexes by reacting metal acetate, salicylaldehyde and a primary amine in alcohol and demonstrated a 2:1 stoichiometry. However, there was no comprehensive, systematic study until the preparative work of Pfeiffer and associates\(^5\). Pfeiffer and his coworkers\(^6\)–\(^14\) reported a series of complexes derived from Schiff bases of salicylaldehyde and its substitution products\(^15\). Dubsky and Sokol\(^16\) isolated N–N–bis–Salicylidene ethylenediamine Cu(II) and Ni(II) complexes and formulated their structure.
1.4 Chemistry and biological importance of Schiff base transition metal complexes

A comprehensive review\textsuperscript{35} covers much of the Schiff base chemistry known up to 1966 and it has been followed by others\textsuperscript{36–40}. Structure and mechanism of the formation of such complexes and stereochemistry of four coordinate chelate compounds from Schiff bases and their analogues have been discussed in a review\textsuperscript{41}. Schiff base complexes can be classified in a number of ways, as:

Mononuclear, binuclear and polynuclear on the basis of the number of metal atoms present, and as monodentate, bidentate and polydentate. The use of metal complexes of quinquedentate Schiff bases, such as the salicylaldimines, as bidentate chelating agents to form binuclear and trinuclear centers has been well documented. Complexes of Ni(II), Co(II) and Cu(II) with Schiff base ligands derived from various $\beta$–diketones and triamines have been reported. Visible spectral results and ESR studies on the Cu(II) complexes indicate that they are five coordinates with geometries intermediate between trigonal–bipyramidal and square–pyramidal.

Schiff base complexes of Cu(I) and Cu(II) from 2–thiophene–aldehyde and alkylamines\textsuperscript{42}, Cu(II) complexes of chloramphenical Schiff bases\textsuperscript{43} and biomimetic Cu(II) complexes of Schiff bases formed between pyridoxal and various biogenic amines\textsuperscript{44} have been prepared and studied by spectroscopic and magnetic measurements.

A novel class of Schiff base–metal complexes derived from aldoses and amino acids has been reported by Iqbal et al\textsuperscript{40}. These complexes have been found to be active against rat paw–oedema as a model of inflammation.

Binuclear copper systems are implicated in wide variety of biochemical processes, especially in transport and multielectron redox reactions of molecular
oxygen. A number of mononuclear planar Cu(II) complexes have been found to exist as dimers in crystals and in solutions. A study of ferro- and antiferro-magnetic coupling in Cu(II) complexes with tridentate Schiff bases may lead to a better understanding of the phenomenon in magnetically condensed complexes. Two tetrameric Cu(II) complexes with Schiff bases derived from acetylacetone and isomeric α-amino alcohol have been reported. Metal complexes have also been reported with other ligands mixed with Schiff bases.

Of all the Schiff base complexes, those derived from salicylaldimines have been thoroughly studied so far. A variety of physiochemical investigations on these complexes provide a clear understanding of their stereochemical and electronic properties. The advantage of the salicylaldimine ligand system is the considerable flexibility of the synthetic procedure, which has resulted in the preparation of a wide variety of complexes with a given metal whose properties are often dependent on the ligand structure.

The chemistry of Schiff base complexes has developed rapidly in the last 30 years, solving problems related to stereochemistry and fertilizing related fields in coordination chemistry. Stereochemistry and electronic factors largely govern the reactivity and stability of chelate compounds. The stereochemistry and the electronic structure of chelates determine many properties, such as their redox properties, reactivity and ability to form adducts. These properties are important for understanding many catalytic processes and phenomena occurring in living organisms.

Another review discusses the mechanism of formation and structure of Schiff base complexes and stereochemistry of four coordinate chelate compounds and their analogues. The configurations of the chelate group in the four-coordinate complexes may be square planar tetrahedral distorted tetrahedral or distorted...
pyramidal with the metal atom at the apex. The configuration depends primarily on
the nature of the metal atom and also on the magnitude and symmetry of the ligand
field. Schiff base complexes of Cu(II) are believed to be key intermediate of
pyridoxal dependent enzymes. Consequently a number of studies of the Schiff bases
derived from amino acids have been reported during pyridoxal as the cocondensent.

In the last few decades, mixed ligand complexes have been extensively
studied in solution as well as in the solid state.\textsuperscript{51,52} Ternary complexes are found to
be more stable than binary complexes. Steric effect and back donation have also
been invoked to account for the preferred formation of mixed ligand complexes.\textsuperscript{53}
Some new mixed ligand ternary complexes of Cu(II), Ni(II), Co(II), Zn(II), Sm(III),
Th(IV) and UO\textsubscript{2}(VI) with the Schiff base derived from salicylaldehyde and the
sulpha drug sulphabenzamide, [N–(Salicylidene)sulphabenzamide](LH) and the
heterocycle base 1,10 phenanthroline (Phen) have been synthesized and
characterized by IR, NMR, diffuse reflectance spectra, and thermal magnetic and
molar conductance measurements. Thermal analysis indicate the presence of lattice
and coordinated water molecules in the complexes which is also supported by the
IR spectral data. The coordination by the azemethine nitrogen is inferred by the
upfield shifting of the –CH=N– signal in the NMR spectra and the shift of υ(C=N)
to lower wave number in the IR–spectra upon complexation. The Schiff base ligand
(LH) acts as a monobasic bidentate ligand in complex formation.

The presence of anion viz CH\textsubscript{3}COO\textsuperscript{−}, or NO\textsubscript{3}\textsuperscript{−} in the coordination sphere is
also inferred by the IR spectral data and conductance measurement. The general
composition of the complexes are found to be [M(L)(Phen) (OAc)(H\textsubscript{2}O)] where
M=Cu(II), Ni(II), Co(II), Zn(II) or UO\textsubscript{2}(VI), [Sm(L)(Phen)(OAc)\textsubscript{2}(H\textsubscript{2}O)\textsubscript{2}]H\textsubscript{2}O and
[Th(L)(Phen)(NO\textsubscript{3})\textsubscript{3}(H\textsubscript{2}O)]\textsubscript{4}H\textsubscript{2}O where ACOH=acetic acid and LH=[N–
(Salicylidene) sulphabenzamide]. The coordination chemistry of Schiff bases as
multidentate ligands gained much importance for more than two decades because of their use as models in biological systems.\textsuperscript{(55–58)} There is enormous interest presently in the field of coordination chemistry of later ‘3d’ transition metals with Schiff bases. They have also been used as biological models,\textsuperscript{59} oxygen carriers and drugs.\textsuperscript{60} Transition metal complexes of 1,10–phenanthroline (phen), 2–2\textsuperscript{1–}bipyridyl (bpy) or their modified variants are widely employed in several research areas including bioinorganic and bio–medical chemistry.\textsuperscript{61–68} Metal complexes of the Schiff bases have been widely studied due to their unusual magnetic properties, novel structural features and relevance to biological systems.\textsuperscript{69} In view of this a series of copper(II) complexes of mixed ligands with Schiff bases derived from 2–amino phenol/2–amino benzoic acid with substituted benzaldehydes and 1:10–phenanthroline have been synthesized. Microanalytical, magnetic susceptibility IR, UV–vis; CV, ESR and mass spectral techniques have been used to confirm the structure of these complexes.

Their low electrical conductance values indicate that all the complexes are non electrolytes. The monomeric nature of the complexes is evidenced from their magnetic susceptibility values. Electronic and EPR–spectra of the complexes suggest that they have distorted octahedral geometry. The electrochemical behaviour the anodic and cathodic potential and the number of electron transfer have been calculated using cyclic voltammogram. The synthesized compounds have been tested against microorganism such as Escherichia coli bacillus subtilis, micrococcus luteus and protens vulgaris. A comparative study of the MIC (minimum inhibitory concentration) values of the ligands and the complexes indicate that the complexes exhibit higher antibacterial activity than the free ligand and control.
Some new chromium(III) heterochelates having different coordination environment synthesised by the reactions of \([\text{Cr}^{\text{III}}(\text{L}_1)^1(\text{Py})\text{Cl}]_2\text{H}_2\text{O}, \[\text{Cr}^{\text{III}}(\text{L}_2^2)(\text{Py})\text{Cl}]\text{H}_2\text{O}\) and \([\text{Cr}^{\text{III}}(\text{L}_3^3)(\text{Py})\text{Cl}]\text{(ClO}_4^4)_2\) (where \(\text{L}_1^1\) and \(\text{L}_2^2\) are diamines of quadridentate Schiff base and \(\text{L}_3^3\) is a neutral bidentate Schiff base) with acetylacetone (H.Sal) N–Phenylsalicylaldimine (H–Salan) anthranilic acid (Hana), picolinic acid, (H–pica), ortho amino phenol (Hoap) and orthoamino thiophenol (H–oatp) by a common general route are reported. The elemental analysis molar conductances, magnetic susceptibilities, molecular weights and spectroscopic data (IR, UV–vis) characterize the newly synthesized complexes.\(^{71}\)

Iron(III) complexes of the Schiff base 1,2–Dihydro–1,5–dimethyl–2–phenyl– 4–formyl (benzhydrazide)–3H–pyrazol–3–one \([\text{Fe(DPFBP)}_2\text{X}]\text{X}_2\) where \(\text{X} = \text{ClO}_4^4\) or \(\text{NO}_3^–\) and \([\text{Fe(DPFBP)}_2\text{X}]\text{X}\) (X=SCN, Cl or Br) have been synthesized and characterized by elemental analysis, electrical conductance in non aqueous solvents infrared and electronic spectra as well as magnetic susceptibility measurements. In these complexes DPFBP acts as a neutral bidentate ligand coordinating through the azomethine nitrogen and the carbonyl oxygen of the pyrazolone ring. The molar conductance of the complexes in DMF, methanol and nitrobenzene are in the range suggested for 1:2 electrolytes for perchlorate and nitrate complexes while the thiocyanate, chloride and bromide complexes behave as 1:1 electrolytes. The electronic spectra of the complexes exhibit a band in the region 19230–20080 cm\(^–1\) due to \(^6\text{A}_{1g}–^4\text{T}_{1g}\) consistent with octahedral Fe(III) complexes. The molar magnetic moment of the complexes varies in the range 5.61–6.05 B.M. indicate of octahedral geometry\(^{72}\). Manganese(III) Schiff base complexes of the type \([\text{Mn(SB)}\text{OAc}]\text{H}_2\text{O}\) where SB is derived from 4–benzoyl and 4–acetyl substituted 1–phenyl–3– methyl–2–pyrazolin–5–one and various diamines viz,
ethylene diamine (en) propylene diamine (pn), butylenes diamine (bn) and hexylene diamine (hexn) have been prepared and their physico–chemical properties studied. They are non electrolyte in nature and their magnetic moments are close to 4.9 B.M. indicating spin free type nature of the complexes and the absence of dry kind of exchange interaction. From IR, NMR and TGA data, presence of water molecule of crystallization is indicated. Electronic spectra show one charge transfer band and more than one d–d transition on the basis of analytical and physical data, the complexes are suggested to have five coordinated structures with square pyramidal configuration. 73

The template reactions of 2:6–Diamino pyridine or 1:8–Diaminonaphthalene with diacetyl or benzil in the presence of vanadyl(IV) produce N₃O₂ or N₂O₂ open chain complexes as a result of [2+1] Schiff based condensation. These complexes contain free ketonic group. Therefore the reactions of these complexes with diamines (O–phenylene diamine and 4–methyl–o–phenylene diamine) have been studied in presence of glacial acetic acid which cause ring closure and formation of macrocyclic complexes. The complexes so obtained have been characterized on the basis of elemental analysis, conductance magnetic moment and spectral (electronic, IR and ESR) data. The probable structures of the complexes are suggested. 74

Condensation reactions between carbonyl compounds and primary amines have played an important role in the synthesis of new macrocyclic ligands 75–79 usually not necessarily, such reactions are conducted in the presence of a suitable metal ion which may serve to direct the condensation preferentially to cyclic rather than oligomeric/polymeric products (the kinetic template effects) or to stabilize the macrocycle once formed (the thermodynamic template effect). The application 80–82 of macrocyclic compounds in bioinorganic chemistry, catalysis, extraction of metal
ions from solution and the activation of small molecules gave impetus to this endeavour.

VIC–Dioximes containing mildly acidic hydroxyl groups and slightly basic nitrogen atoms are amphoteric and their transition metal complexes have been widely studied as analytical reagents. They have also been examined as compounds with columnar stacking, which is thought to be the reason for their semiconducting properties. Crown ether compounds first synthesized by Pedersen who described their ion binding properties have been a focus of interest. This is because of their possible chemical and biological applications and their unusual ion binding capability, solvation and transport effects.

A new quadridentate ligand 3,8-Dimethyl–5,6-benzo(15–Crown–5)–4,7-diazadeca–3,7–diene–2,9–dione dioxime (H₂L) has been synthesized by the reaction of 4,5-diaminobenzo (15–Crown–5) with diacetyl monoxime). The dibromo complexes of this ligand [Co(HL)Br₂] have been prepared by the direct reaction of H₂L with COBr₂.6H₂O. Pseudo–halogeno complexes [XCO(HL)Br], where X=CN⁻, SCN⁻, N₃⁻ or Lewis base complexes [LCO(HL)Br]ClO₄ and L–pyridine have been synthesized as a result of the axial lability of [Co(HL)Br₂]. Alkyl and benzyl cobalt(II) complexes [RCO(HL)L], RMe or Ph CH₂ have been prepared by the oxidative addition reaction of in–situ generated Co(I) form of [Co(HL)Br₂) complex with MeI or PhCH₂Br and a Lewis base in inert condition. In addition the heterodinuclear complex containing the oxime to dianion as bridging ligand and 2,2'-bipyridine (L) as end–capping ligand has been synthesized by using [Ni(HL)ClO₄] as the ligand for ML²⁺ center. The structures of the dioxime and its complexes are proposed on the basis of elemental analysis ¹H and ¹³C–NMR and MS–spectral data complexes with stoichiometry [Ni(L)X₂] where L– is a
tridentate ligand 1,5-bis (benzimidazol-2-yl)-3-thiapentane have been synthesized and characterized. The presence of an electronic absorption band in the region ≥ 25000 cm⁻¹ is indicative of six coordinated tetragonal complex in solution. The parameter 10 Dq varies as: X = NO₃⁻ > CH₃COO⁻ > HCOO⁻ > SCN⁻ > Cl⁻. ¹H–NMR contact shifted resonances lie in the range of −19.0 to +55.0 ppm typical of high spin Ni(II) and do not show any significant dependence on Dq. The sign of the contact shifts is indicative of a dominant σ-spin delicalisation mechanism the same is confirmed by the shifts of the 13C–NMR data which lie in the range of +74.0 to +181.0 ppm with respect to TMS (Tetramethyl silane). No doubling of peaks is observed in the NMR–spectra, implying a mirror plane or C₂-axis of symmetry in the complexes. The E₁/₂–data indicate that the case of reduction follows the order Cl > NO₃ > CH₃COO⁻. Macrocyclic complexes have been widely studied in coordination chemistry as they selectively form strong polynuclear complexes with a variety of metal ions. The amide macrocyclic ligands are of interest because their metal complexes function similarly to porphyrin analogues in catalyzing organic oxidations.

Several groups are currently engaged in the synthesis of polyamide macrocycles. In most of the polyamide macrocyclic complexes of the two potential donor atoms amide nitrogen and oxygen only amide nitrogen is engaged in coordination and not the oxygen. In most of the cases the polyamide macrocycles thus formed on reduction with B₂H₆ or LiAlH₄ lead to the formation of the corresponding polyazamacrocycles which may be used to further construct various macrocyclic systems. The formation of macrocyclic complexes mainly depends on the size of the internal cavity and rigidity of the macrocycle formed.
The silicon–phthalocyanine complexes are of great importance because of their attractive properties like high tinctorial power, semiconductivity, photoconductivity catalytic activity, chemical inertness and high thermal stability\(^{102-104}\) synthesis and study of electrically conductive mono–molecular as well as polymeric substances are currently of great importance. Most of the studies reported so far have focused on polymeric solicon phthalocyanines. Substituted silicon phthalocyanones have been relatively\(^{105-109}\) less studied with respect to the electrical conductivity. In addition to the apparent hexa coordination of silicon, study of the structural features, effect of doping and the electrical properties may help in suitably modifying phthalocyanine complexes\(^{106}\) for use as electronic devices. The complexes dichloro (phthalocyanino)silicon [SiPCCl\(_2\)] and bis (p–nitrophenoxy) (Phthalocyanino) silicon [SiPc(p–NPO)\(_2\)] exhibit enhanced electrical properties on iodine doping. This may be due to the arrangement of the planar phthalocyanine molecules with decreased inter planar distance along with crystallographically similar environments and the presence of non–integral formal oxidation state.\(^{110-121}\)

**1.5 Planing of the Proposed work:**

There is no report so far on the direct synthesis of bimetallic polynuclear complexes. These have been prepared in a step wise reaction of metal complexes (metallo ligands) containing either a coordinating atom with the non bonded electron pair which are sufficiently nucleophilic or a functional group which can further coordinate to another metal centre. Taking these aspects into consideratation we have chosen few compounds such as sodium 2:6–Diacetyl–4–chlorophenolate; 2,6–Diacetyl–4–Methyl phenolate; N,N,N\(|\rangle\),N\(|\rangle\)-Tetrakis [(4\(|\rangle\)-Methyl–2–Benzi
diazolyl)methyl]–1,2–Ethane Diamine; Bis (4\(|\rangle\)-methyl picoline amide azine; 4\(|\rangle\)-methyl picoline amide 4\(|\rangle\)-methyl 2–Acetyl pyridine azine; 3,6–bis–(2–pyridyl)

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pyridazine; Glyoxal bis (picoline amide) diazine; 2:6–Diformyl–p–cresoldioxime; 2,9–bis (2–Ethane thiazolinyl)–1,10–phenanthroline; 4,5–Dihydroxy–3,6–bis (2–carboxy phenyl azo)–2,7 naphthalene disulfonic acid; 4,5–Dihydroxy–3,6–Bis (2–Carboxy–4–methyl phenyl Azo 2,7–naphthalene disulphonic acid; and N,N,N\text{\textsuperscript{1}},N\text{\textsuperscript{4}}–Tetrakis (2–methylene 4\text{\textsuperscript{1}}–methyl benzimidazolyl)–1,3–Diamino propane–2–ol and isolated their Cu(I), Cu(II), Mn(II), Co(II), Ni(II) & Zn(II) complexes under different sets of condition, and characterized them on the basis of elemental analysis spectral, magnetic conductivity, thermal studies; X–ray diffraction reflectance spectra; ESR and Mass spectra.
CHAPTER—I
REFERENCES