INTRODUCTION
It is during the past fifty years that one thing has become quite clear and cannot escape the notice of any researcher or keen student of chemistry. The development is the coordination among different branches of chemistry. The chemistry of complex compounds has encompassed a number of domains of chemistry and has become a bridge to combine closely and logically the inorganic, organic, physical and other branches of chemistry. In this way, it expresses the unity of chemistry as the science dealing with the structure of matter. The countless theories and methods used here explain the popularity of this domain among the scientists. The theories of coordination embrace a wide range of interatomic, interionic and intermolecular reactions in the solid phase\(^1\) as well as in solution\(^2-3\). The chemistry of complex compounds has thus become the most suitable ground on which to develop and at the same time to verify a number of theories and above all the theories of chemical bond and structures of compounds thereby, attracting considerable attention from the chemists, physicists and even mathematicians. The progressive development of the valence bond theory\(^4-9\), viz. the crystal field theory\(^10-13\) and further the ligand field and molecular orbital theories\(^19-30\) developed on the basis of quantum chemistry\(^31-35\) allows chemists to relate the electronic structures and configurations of complex compounds to their physical and chemical properties.

1.1 IMPORTANCE OF COORDINATION CHEMISTRY

The significance of the coordination compounds in various branches of theoretical and applied chemistry and allied fields is now recognised. In quantitative analysis, coordination compounds are widely used in gravimetric, volumetric and colorimetric determinations as well as in polarimetry and microscopy. It is generally said that “The chemistry of
solutions is the chemistry of complexes.” Coordination compounds are widely used in electrodeposition, deposits obtained from the simple salt solutions are sometimes loose, nonadherent, coarsely crystalline and generally undesirable, while metal deposits from appropriate complex salt solutions are often smooth, adherent and of high protective and decorative value. As a consequence of the ability of coordinated metal ions to influence many of the complex reactions upon which the vital processes of living organisms depend, coordination compounds of many varieties are found widely distributed in nature, chlorophyll, blood pigments, metallo-proteins, metallo-enzymes, many vitamins, cytochrome etc. are the few examples of this series. In the past few decades the importance of coordination in dyeing has been recognised. Most dyestuffs are synthetic organic compounds, and, of these, the large class of metal-dye compounds called "dye-lakes" are of great interest to the coordination chemists. Coordination phenomenon is used in water softening by “tying up” alkaline earth ions in soluble complex ions and thus preventing the formation of precipitates. The acetyl acetonates of metals are used in the purification of metals.

The chemistry of complexation has also got great importance in the field of pharmaceutical science. If the ligand forms a stable, water soluble metal chelate, it is said to be a sequestering agent. Sequestration (Latin : to remove) is the supression of a property or reaction of a metal without removal of that metal from the system or phase by any process of precipitation or extraction and is usually accomplished by chelation.

Biological materials are often dependent on formation of metal chelates. The stabilization of insulin with zinc; the enzymatic bond formation and rupture processes of carbohydrates and nucleoproteins the iron in heme, magnesium in chlorophyll and cobalt in vitamin B<sub>12</sub> are examples of systems
in which metal chelate complexes are essential for biological activity. Many enzymes contain metals which are essential for the activity of the enzyme system. Removal of metal or lack of the metal can inactivate the enzyme and therefore, trace amounts of copper, zinc, manganese, cobalt etc. are required for biological processes. Cobalt is found associated in vitamin B\textsubscript{12}, copper with enzyme tyrosinase, zinc in carbonic anhydrase, molybdenum occurs in xanthine dehydrogenase.

The applications of coordination compounds have also extended in many important fields such as laboratory, industry particularly for the identification and separation of chemical elements, preparation of reactor materials, extraction of elements, preparation of "fine chemicals" such as perfumes, paints, and pigments, agricultural chemicals, food additives, sweeters etc. molecular analysis, enantioselective catalysis and chiral catalysis are also the important fields in which coordination compounds play important role. Day by day, new developments are being made in coordination chemistry and in future, this branch will definitely open new doors in the modern scientific world.

1.2 COORDINATION BEHAVIOUR OF AMINO ACIDS

Amino acids are amphoteric (amphiphilic) in nature with a hydrophilic aminocarboxylate end and a hydrophobic side chain as shown below.

\[
\begin{align*}
R & \quad \text{Hydrophobic end} \\
\text{H} & \quad \text{hydrophilic end}
\end{align*}
\]

The R group of amino acid may vary widely with respect to its polarity, structures, size, electric charge and solubility in water. All the amino acids except one (glycine) have an asymmetric carbon atom, the $\alpha$-carbon, to which four different substituent groups are bonded.
The side group in amino acids is usually non-coordinating but its nature seems to be more important at least in two ways. The hydrophobicity of the side chain governs the solubility of amino acids in non-aqueous solvents and also the stabilisation of the concerned amino acid metal chelate in solution.

In cases where the so-called hydrophobic end possesses coordinating oxygen or nitrogen donor sites, the amino acid may show ambidentate behaviour. The amino acids glycine, α-alanine, L-leucine, L-valine and iso-leucine behave as bidentate ligands coordinating through carboxyl oxygen and nitrogen.

1.3 IMPORTANCE OF AMINO ACIDS AND THEIR COMPOUNDS

Metal complexes of amino acids have found useful applications in chemical, biological and pharmaceutical fields. Hence, their importance has grown. The amino acid compounds are biologically active creating considerable interest in their metal complexes. Amino acids form strong complexes with transition metal ions, therefore, they play an important role to excrete the excess of pollutants in vivo. In human blood and serum the concentrations of various metal ions are fixed. Whenever the concentration of various essential metals increase in blood and serum as a result of uptake of polluted water or infected food, human beings, suffer from several disease such as cancer of the bladder, breast, intestine, leukemic system, lungs, ovary, pancreas, prostate, rectum and skin. In addition to these transition metals are most active carcinogens. The concentration of these pollutants can be reduced by ligand therapy. These ligands are L-amino acids but in order to obtain the optimal dosage of these ligands, formation constants for pollutants L-amino acids complex should be available for computer calculations and the specificity of the administered drugs for pollutants compared to the essential metal must be known.
1.4 BIOCHEMICAL IMPORTANCE OF MIXED LIGANDS COMPLEXES WITH AMINO ACIDS

The structural relationship of amino acids with proteins is responsible to a good extent for their biochemical importance and also that of their complexes with the metal ions present in body fluid. Although, it is difficult to reproduce in vitro exact structural conditions existing in the biosystems, it may, however, be responsible to mimic them by choosing simple models. The mixed ligand complexes of the type [metal- dipy-amino acid] or [metal-phen. amino acid] have been regarded as simple models for the ternary system like [metal ion-enzyme ATP] or [metal ion-enzyme-inhibitor]53-54.

It has been commented55 that “Biochemistry is the coordination chemistry of living systems”. The role of metal ions in biological systems has been discussed in several texts56-60. Mixed ligand complexes play a central role in such systems, in recent years to assemble information on their formation61-64 and stability65-67 and on the mutual influence of two ligands bound to the same metal ion. Although Cu (II) has received greater attention56-65 in studying such mixed ligand complexes. Some data are available on Co(II), Ni(II) and Zn(II) systems65, 66, 68-70 and even on Mn(II) mixed ligand complexes53-71.

A few example may be cited to indicate the important role played by the ternary complexes. The ternary system [Cu(II)-histidine-albumin] is involved in the transport phenomenon across biological membranes72. The [Cu(II) histidine threonine] is another ternary system which plays an important role in metal ion transfer in biological systems72-73. Dopa acts as a neurotransmitter and is used in the treatment of Parkinsonism74. It has been suggested that chelation with Cu(II) and Zn(II)
checks its decarboxylation which may help in improved transport of dopa to brain. Glutamine and its metal complexes play a significant role in cancer therapy^{75-76}.

Mixed ligand complexes containing nucleotides and amino acids as co-ligands have also been considering to be of great interest with regard to biological systems^{77-78}.

Intramolecular hydrophobic stacking interactions in ternary complexes containing amino acids^{40-79} appear to be important for the synthesis of proteins and determination of the amino acids sequence.

Aromatic amino acid residues are often used in the active center of the enzyme, e.g. a tryptophanyl group in heavy meromycin^{80-81}.

1.5 BIOCHEMICAL CHARACTERISTICS OF TRANSITION METALS

The coordination chemistry of biometals is a special branch of bioinorganic chemistry, puts forward a number of problem which are of great interest for biochemistry, medicinal chemistry and coordination chemistry. Though, metals constitute about 3 % of the human body weight but the intricate biological systems depend very much upon metals. Hence looking at these new biochemical concepts it is necessary to draw attention to coordination chemistry researches and to focus upon metal complexes as being a new wide range of possibilities, worthy of consideration by therapeutic researches.

Manganese is an essential element. Manganese is present in all living organisms. The primary uses of manganese in medicine are as antiseptics and germicides. Manganese is a cofactor in a number of enzymatic reactions, particularly those involved in phosphorylation, cholesterol and fatty acids synthesis^{82}. 
Zinc is ubiquitous and is considered as an essential trace element. It is necessary for normal growth and development in mammals. Zinc is present in a number of metallo enzymes including carbonic anhydrase, glutamic dehydrogenase, lactic dehydrogenase and alkaline phosphatase\textsuperscript{82}. Therapeutically, zinc compounds are used as topical astringents, dermal products and antiseptics.

Cadmium is one of the most toxic metal in the environment to which industrialised civilization has exposed itself. Zinc has a complex mechanism which controls its concentration throughout the body\textsuperscript{83}. Furthermore, cadmium has a chemistry similar to that of zinc and so the normal processes of zinc metabolism can be blocked and distorted by cadmium\textsuperscript{84}. In biological systems the interrelationship of zinc and cadmium are very important, because the total (Zn+Cd) content is fixed\textsuperscript{84}. In living being, cadmium is bound to the protein metallothionein\textsuperscript{85}. The binding of cadmium to this protein is less than mercury but greater than zinc. The cadmium compounds are used as antisebora-heic agent and in treating syphilis\textsuperscript{82}.

1.6 SIGNIFICANCE OF BIO-INORGANIC COMPLEXES IN DESIGNING ANTIDOTES AGAINST METAL TOXICITY

Antidotes are remedies which counteract the effects of poison\textsuperscript{86}. They are divided into mechanical, chemical and physiological antidotes. Specific antidotes are rarely necessary and there are few available, although in appropriate circumstances the administration of an antidote may sometimes be life saving.

Chelating agents used in heavy metal poisoning provide the best example of antidotal action\textsuperscript{87}. The chelation of a substance usually involves the formation of a complex with a five or six membered ring.
There is no suitable antidote available so far for metal toxicity. Some of the antidote available for the treatment of metal poisoning are dimercaprol, EDTA and NTA have deleterious properties of their own which not only affect the status of the living being but also contribute to a fatal outcome.

In our case amino acids viz glycine, α-alanine, L-valine, L-leucine, L-asparagine and L-glutamine form complexes with selected metals and it is well known that there is no side effects of amino acids in the body, therefore, these amino acids might be used as antidotes for treating metal toxicity.

The work on synthesizing the antidotes of metal poisoning is in progress. Till now, many metals poisoning antidotes are to be synthesized e.g. Cd is one of them has no suitable antidote.

1.7 IMPORTANCE OF STABILITY CONTANTS OF METAL COMPLEXES

The term “stability” describes the amount of association that occurs in solution containing two or more component species in equilibrium. The more stable the resultant complex, the greater is the association that will occur under a given set of conditions.

Just as knowledge of the dissociation constant of acids and bases has done much to systematise our understanding of the behaviour of these substances in all kind of systems, so a knowledge of stability constant has done much to rationalise our understanding of the behaviour of metal complexes in solution. The condition required for complete formation of a complex may be predicted on the basis of its stability constant. Information about the concentration of different species of metal complex in equilibrium...
mixture is invaluable in the study of analytical separation procedures, solvent extraction, ion exchange method or chromatography. It is equally important in the study of the role of metal chelate in biological systems.

The overall and stepwise stability constants give a measure of the values of free energy associated with a reaction. The corresponding changes of entropy of a complex formation may be obtained by combining the stability constant with enthalpy change of complex formation, which is best measured calorimetrically but may also be obtained by determining the stability constant at a series of temperature. These parameters have great significance in chemical technology (in hydrometallurgy and electrochemistry) and in chemical analysis.

1.8 THEORIES OF COMPLEX FORMATION

A number of theories have been given time to time to explain the formation of complexes between metal and ligands but the most important theories are given below in brief.

(a) Werner's Coordination Theory

An understanding of coordination compounds and their properties began with the work of Alfred Werner in 1893, Werner proposed an interpretation of coordination compounds which emphasized the number and nature of groups attached to the central metal ion. This theory replaced the older concept of Brezellius (1819), Grahm (1837), Claus (1856), Blomstrand (1969) and Jorgenson (1878-1894), and became a fundamental part of the theory of valence formulated by G.N. Lewies. According to Werner,

1. Most elements show two types of valency
   (a) Primary (i.e. Principal) and
   (b) Auxillary (i.e. Secondary)
2. Primary valencies are those which a metal exercises in the formation of its simple salts and the secondary valencies are those which a metal exercises towards a neutral molecule or an anion in the formation of complex ion.

3. Secondary valencies are directed in space and hence compounds are capable of exhibiting the phenomenon of isomerism.

4. The number of ligands which are arranged around the central metal ion is called the coordination number. Although this theory explains the structure and stereochemistry of complexes but could not give any theoretical background for the two types of valencies and this has been a reason why this theory was not accepted up to 1916.

Later on, Lowry and Sidgwick explained Werner's ideas with the help of electronic theory of valency.

(b) The Valence Bond Theory

One viewpoint is stressed by the valence bond theory chiefly developed for complexes by Pauling. In this theory, it is considered essential that a number of orbitals on the central metal atom is equal to the number of ligands be made available to form coordinate covalent bonds with orbitals on the ligands. Furthermore, by using criterion that maximum angular overlap of two orbitals forms the strongest covalent bond, it is shown that the original atomic orbitals should be hybridized to form a new set of equivalent bond orbitals with definite directional properties.

Pauling theory has rendered valuable services to the understanding of main features of coordination chemistry and has ability to provide reasonable qualitative explanations but this theory was criticized by many workers as it fails to
1. account for the relative energies of different structures and
   coordination numbers.

2. explain the magnetic properties of covalent and ionic
   compounds.

3. interpret absorption spectra of complexes in the visible
   region and reaction paths for substitution reactions.

4. predict the geometry of coordination compounds.

(c) **The Valence Shell Electron-Pair Repulsive Theory**

This theory links valence bond theory and electrostatic theory
and is very useful to predict the geometry of molecules or complexes of
non-transition elements and also d⁰, d⁵ and d¹⁰ transition metal. This theory
is based on the ideas of Sidgwick and Powell¹⁰¹ and has been elaborated by
Nyholm and Gillespie¹⁰². For the non-spherically symmetric transition
metals, this theory is not so useful, although this theory very well explains
the stereochemistry of complexes but does not deal with other properties
such as bond length.

(d) **The Electrostatic Theory**

Van Arkel and D-Boer¹⁰³, and particularly, Garrick¹⁰⁴ following
the pioneering ideas of Kossel, Magnus and Tajans, showed that a fairly
simple electrostatic picture of complexes, assuming point charges and
dipoles could account for many of their properties.

The parameters needed were the charges and sizes of the central
ion and the charges, dipole moments, polarizabilities, and sizes of ligands.
By using the ordinary potential energy equations of electrostatics,
quantitative calculations could be made for various coordination numbers
and stereochemistries.
This theory fairly well explains the electrostatic character of complexes but could not explain many forces such as London attraction forces\textsuperscript{105} and many properties of complexes\textsuperscript{106}.

(e) The Crystal field Theory

This theory was developed by Bathe\textsuperscript{107}, Schlapp and Penny\textsuperscript{108} and by Van Vleck\textsuperscript{109}. Hartmann\textsuperscript{110} used this theory to explain d-d spectra of complex in the visible region. Orgel\textsuperscript{111} was the first to emphasize the consequences of the theory for the stability of coordination compounds of the transition elements.

The essence of the theory is that the five d-orbitals which are degenerated and equal in energy in the gaseous metal ion, become differentiated in the presence of the electrostatic field due to the ligand. It is the symmetry of this field, or its regular geometric properties, which gives the name of this theory. Though originally applied to crystalline solids, it is equally applicable to any orderly arrangement of the electrically interacting particles such as a single complex. In particular, those orbitals lying in the direction of the ligand are raised in energy with respect to those lying away from the ligand. By preferentially filling the low lying levels, the d-electrons can stabilize the system, as compared to the case of random filling of the d-orbitals. The gain in bonding energy achieved in this way is called the crystal field stabilization energy (C.F.S.E.). It is caused by the distribution of charge around the central atom of the complex not being symmetrical as assumed in the earlier electrostatic calculations. If the d-orbitals were occupied equally, the resulting electron density would have spherical symmetric.

Although, crystal field theory explains well many things such as the stereochemistry\textsuperscript{112} of the complexes magnetic properties,\textsuperscript{113}
stabilities, redox potentials\textsuperscript{114}, coordinate bond energy\textsuperscript{115} and effective ionic charge,\textsuperscript{116} but it fails to explain the formation of complex involving bonds, the resolution of asymmetric complexes into their optically active modifications and several properties of coordinate compounds.\textsuperscript{76}

(f) **The Molecular Orbital Theory**

J.H. Van Vleck\textsuperscript{19} was the first to apply this theory in complex formation. The electrons are assumed to move in molecular orbitals which extend over all the nuclei of the system. The molecular orbitals themselves are taken for convenience, as linear combination of atomic orbitals. In the event that a given atomic orbital (A.O.) overlaps appreciably with only one other A.O., the pair may be regarded as forming a localized molecular orbital holding as many as two electrons. This would correspond to the usual conception of a chemical bond. This explains many properties of complexes\textsuperscript{106} but still has some drawbacks. These are:

1. The usual one of any quantum mechanical approach to complex systems that quantitative calculations of the energy can not be made and

2. The disappearance of the nice pictures of chemically bonded atoms so useful to the chemists. The latter difficulty can be partly avoided by the use of L.M.O.'s.

1.9 **SURVEY OF RELEVANT LITERATURE**

For the present investigation, the literature of some transition metal complexes with L-amino acids and picolines has been surveyed.

Transition metals occupy the position in the modern periodic table in the sub-groups IB, IIB, IIIB, IVB, VB, VIB, VIIB and VIII form four transition series. The first series (3d) starts from $^{21}\text{Sc}$ to $^{30}\text{Zn}$ and the second
(4d) starts from $^{39}$Y to $^{48}$Cd. The third series begin with $^{57}$La to $^{71}$Lu followed by $^{72}$HF to $^{80}$Hg and the fourth series starts from $^{89}$Ac to $^{103}$Lw followed by $^{104}$Ku. $^{105}$Ha to the elements of atomic number 112 (to be discovered).

In the modern periodic table, these elements serve as a bridge between the highly electropositive 's' and highly electronegative 'p' block elements, therefore, their properties are intermediate between that 's' and 'p' blocks elements. These elements have many physical and chemical properties in common such as metallic character, melting and boiling points, density, reactivity, ionization potentials, colour, variable valency, catalytic and magnetic properties and ability to form complexes.

The coordination chemistry related to the role of metal ions and their complexes in biochemistry has been reviewed extensively$^{56-59}$.

The study of binary and ternary complexes in solution have attracted attention in recent years, these complexes are encountered in several important areas of chemistry such as environmental industrial medicinal and analytical field.

A brief account of the literature surveyed on some recent publications having relevance to the present investigation has been given in the following paragraph.

Glasston and Hammel$^{117}$ have reported pK values of histidine.

Shade et al$^{118}$ have studied the nature of bonding of L-histidine with metal ion.

Lehninger$^{119}$ studied the histidine complexes with metal ions.

Maley and Mellor$^{120}$ reported the Cu and Co complexes of histidine, glycine, alanine valine and leucine. The stability trend of these complexes have been discussed.
Pleticha\textsuperscript{121} reported the polarography of iron groups metals in presence of a few amino acids.

Albert et.al\textsuperscript{122} have studied the enthalpy and entropy changes in the metal ligand complexation of Cu, Zn with tryptophane, alanine and ATP.

Li and Doody\textsuperscript{123} have reported Mn and Zn complexes with L-arginine. Mn and Zn formed 1:1, 1:2 and 1:3 complexes with L-arginine.

Ellenbogen\textsuperscript{124} reported pk values of histidine, arginine and L-citrulline.

The histidine complexes with different metal ions were found in literature\textsuperscript{125}.

Some transition metal complexes with tyrosine using different techniques have been reported in the literature\textsuperscript{126-127}.

Li and Manning\textsuperscript{128} reported Zn, Cd and Pb complexes with histidine, methionine and cysteine. They determined $\log K_1$, and $\log K_2$ values also by polarographic technique.

Some references regarding the proline complexes with metal ion have also been found in literature\textsuperscript{129}.

Some compounds of Fe and proton dissociation constants of arginine were reported by Perrin\textsuperscript{130}.

Li and White\textsuperscript{131} reported histidine complexes with some metal ions.

Some complexes of tryptophane and hydroxy tryptophane have also been reported in the literature\textsuperscript{132}.

Pelletier\textsuperscript{133} reported the Fe, Co, Ni, Mn Zn and other metal complexes of arginine over the range of 17-40°.
Rao and Subramanyam\textsuperscript{134} have investigated the Cd complexes with glycine, DL-valine, DL-alanine, L-asparagine and L-glutamic acid using polarographic technique.

Pysz Jr et al\textsuperscript{135} studied some complexes of Cd with amino acids. They observed that the stability of complexes decreased with increase of size of the chelating ring.

The structural properties of Cr complexes with various amino acids were reported by Khan and Malik\textsuperscript{136}. They took arginine hydrochloride, methionine, glycine, alanine, asparagine, serine, leucine, lysine, valine and aspartic acid as the ligands.

Chakravorty et al\textsuperscript{137} have reported histidine complexes with transition metal ions.

Some histidine complexes with different metal ions have also been reported in the literature\textsuperscript{138-139}.

Hussain et al\textsuperscript{140} have reported Cr complexes with various amino acids.

Lenz and Martel\textsuperscript{141} have determined the stability constants of Ag, Cu, Co, Hg, Mg, Sr and Pb with some amino acids. They also determined the acids dissociation constants.

Martin and Mathen\textsuperscript{142} have studied histidine complexes with metal ion.

Sharma and Mathur\textsuperscript{143} reported some amino acid complexes.

Desai and Kabadi\textsuperscript{144} have determined successive formation constants of pyridine, β-picoline and γ-picoline.

Quintin and coworkers\textsuperscript{145} have studied tryptophane complexes with different metal ions.
Suffet and Purdy\textsuperscript{146} investigated Cd complexes with tryptophane.

Reference of proline complexes has been traced out in the literature\textsuperscript{147}.

Perrin and Sharma\textsuperscript{148} have studied histidine complexes with metal ions.

Some histidine complexes with different metal ions have also been reported in the literature\textsuperscript{148-149}.

Some amino acids complexes with different metal ions have also been reported in the literature\textsuperscript{150-151}.

Sigel\textsuperscript{152} reported Co, Ni and Zn complexes with $\gamma$-picoline.

Nazarova\textsuperscript{153} has determined the first stepwise stability constants of Cd with pyridine, $\beta$-picoline, quinoline, 3-bromopyridine, and Et-nicotinate and compared their dissociation constants.

Israeli and coworkers\textsuperscript{154} have studied histidine complexes.

Aihara et al\textsuperscript{155} have reported amino acid complexes with some metal ions.

Gaur and Sharma\textsuperscript{156} reported complexes of Cd with $\beta$ and $\gamma$-picoline by polarographic technique.

Pantani and Francesco\textsuperscript{157} have studied the picoline complexes of Co, Ni and Zn by polarography, Spectrophotometry, potentiometry and amperometric titrations.

Das and Rao\textsuperscript{158} have reported Mn complexes with $\beta$ and $\gamma$-picoline and 4-vinyl pyridine.

Maggio et al \textsuperscript{159} studied the complex formation between bis (salicylaldoximate) Ni(II) and $\alpha$, $\beta$ and $\gamma$-picoline in benzene solution.

Raju and Mathur\textsuperscript{160} investigated histidine complexes.
Childs and Perrin\textsuperscript{161} have studied the Mn complexes of proline. The histidine complexes with metal ions were found in literature\textsuperscript{162-163}.

Some amino acids complexes with different metal ions have also been reported in literature\textsuperscript{164-165}.

Girdhar\textsuperscript{166} and coworkers have investigated proline complexes. Some complexes of tryptophane and hydroxy tryptophane have also been reported in literature\textsuperscript{167}.

Potentiometric studies on the complexation of Mn, Zn, Co, Ca, Hg and Cu with arginine, citrulline and ornithine have been done\textsuperscript{168}.

Chidambaram and Bhattacharya\textsuperscript{169-170} investigated the solution stabilities of Ni and Vo with $\alpha$ and $\beta$-alanine, leucine, glycine, isoleucine and valine, the solution stabilities lie in the order of ligand basicity.

Cu complexes of histidine have been extensively investigated in solution\textsuperscript{171-172}.

Khan and coworkers\textsuperscript{173} have studied complex formation between methionine and different metal ions.

Malik and Aslam\textsuperscript{174} have discussed some structural properties of arginine.

Watt et al\textsuperscript{175} reported Cu and Zn complexes of methionine. Some references regarding Cu complexes of histidine have been found in literature\textsuperscript{176-178}.

Lal and Christian\textsuperscript{179} reported the Ni complexes with tryptophane in triton X-100.

Barnes and Pettit\textsuperscript{180} have studied histidine complexes. Some transition metal complexes with tyrosine have been reported in literature\textsuperscript{181-182}. 
Proline complexes have been reported in the literature\textsuperscript{183-184}. Bhattacharya and Sharma\textsuperscript{185} have investigated Ni, Cd and Mg complexes with pyridine, $\alpha$, $\beta$ and $\gamma$-picoline. Weber and Simeon\textsuperscript{186} reported tryptophane and hydroxy tryptophane complexes.

Cu complexes of histidine have been investigated in solution\textsuperscript{187-188}. The histidine complexes with different metal ions were found in literature\textsuperscript{189}.

Sigel\textsuperscript{190} reported Cu complexes of histidine.

Reference regarding the methionine complexes have been reported in the literature\textsuperscript{191}. Some transition metal complexes with tyrosine have been reported in the literature\textsuperscript{192}.

Walker and Williams\textsuperscript{193} reported the formation constants of Cd with various amino acids potentiometrically.

Farooq and Ahamed\textsuperscript{194} have studied methionine complexes with different metal ions.

Weber\textsuperscript{195} has reported the formation constants of some tyrosine and tryptophane derivatives.

Cu and Pd complexes involving Cu acidic and or basic amino acids has been examined from their circular dichroism, $^1$H-NMR spectra and isolation of various ternary complexes\textsuperscript{196}.

Joshi and Bhattacharya\textsuperscript{197} studied the stability of the Cd, Cu, Ni and Zn complexes with aspartic acid, glycine, leucine or $\alpha$ or $\beta$-alanine.

Haq and Khan\textsuperscript{198} reported Cu complexes with L-hydroxy proline.

Pettit et al\textsuperscript{199} studied Cu complexes of histidine in solution.

Amino acid complexes with Pd and Cu have been investigated by some workers\textsuperscript{200-201}.
Marker and coworkers\textsuperscript{202} investigated proline complexes.

Some references regarding the complex formation between methionine and different metal ions have also been reported in the literature\textsuperscript{203-204}.

Das Gupta and Pathak\textsuperscript{205} studied Ni complexes with pyridine, $\beta$-picoline and $\gamma$-picoline in the temperature range of 25\textdegree{}-40\textdegree{}C polarographically.

Gaur et al\textsuperscript{206} have determined the values of stability constants of Zn complexes with L-hydroxy proline.

Natrajan and coworkers\textsuperscript{207} have reported Cu complexes of histidine.

Some complexes of tyrosine with transition metal ions have been reported in the literature\textsuperscript{208-209}.

The polarographic study of Cd with glycine and histidine complexes was made by Islam and Bhat\textsuperscript{210}.

Goodman et al\textsuperscript{211} studied Cu complexes of histidine.

Yamauchi and Odam\textsuperscript{212} have reported Cu and Pd complexes involving an acidic or basic amino acid.

Sandhu and Kumar\textsuperscript{213} studied the formation of complexes with Ni, Cd, Zn, Pb and Cu with N-benzoylglycyl-L-leucine potentiometrically. The thermodynamic parameters have also been determined.

A potentiometric and spectrophotometric studies on the complexes of Cu with tyrosine containing dipeptides i.e. L-tyrosyl-glycine, L-tyrosyl- D- leucine, glycytyrosine etc have been discussed\textsuperscript{214}.

Saxena and Sharma\textsuperscript{215} investigated a stability trend of Zn, Hg, and Cd complexes with valine potentiometrically.
Gargley and Farkas\textsuperscript{216} reported binary complexes of Cd with amino acids by pH metric and colorimetric technique.

Polarographic study on the complexes of Cu, Co, Ni and Mn with methyl guanidioacetic acid has been discussed. The order of stability with respect to metal ion has been observed with Mn forming least stable complex and Cu the most stable\textsuperscript{217}.

Mayadeo and Bhattacharya\textsuperscript{218} have studied the complex formation of Cu, Zn, Ni Co and Mg with 2-hydroxy-1-naphthalidinesulphamethoxazole pH-metrically. The Irving-Williams order of stability has been observed with Mg forming the least stable complexes.

Rainer and Rode\textsuperscript{219} have reported Cd and Hg complexes with proline, glycine, alanine and leucine pH-metrically.

Il' Ysova and coworkers\textsuperscript{220} determined complex formation constants for Co, Ni, Cu and Zn with methyl methionine and methionine.

Nourmand and Meissami\textsuperscript{221} reported methionine complexes of Cd by potentiometrically.

Felman and Dasilva\textsuperscript{222} have determined the polyaminocarboxylate chelates with transition metal ions and the chelates stability have been reported to be invariably dependant on the denticity of the ligand and the number and size of the rings formed.

Casella and Gullotti\textsuperscript{223-224} investigated Cu complexes of histidine in solution.

Nourmand and Meissami\textsuperscript{225} have studied Cu complexes with proline, serine, threonine and tyrosine in their D and L forms.

Nadhim Al-Ani and Olin\textsuperscript{226} studied Cu complexes with proline, serine, threonine and tyrosine in their d and l forms.
Coli and coworkers\textsuperscript{227} have investigated Cu complexes of histidine.

Cu complexes with many simple histidine containing oligopeptides have been investigated\textsuperscript{228}.

Ishiguro et al\textsuperscript{229} investigated the formation of glycinate complexes with Ni in water and in aqueous dioxane-water medium by potentiometric and colorimetric studies.

Mayadeo and Banavali\textsuperscript{230} have determined the formation constants of the complexes of some biologically important trace metals with bidentate ligands.

Gaizer et al\textsuperscript{231} have reported the protonation and complex formation of cis and trans isomer of alycyclic amino acids with Ni, Cd, Cu and Hg.

Dubey and Nepal\textsuperscript{232} have investigated the complex formation of Zn, Co, Fe, Mn, Ni and Cu with catechol and pyrogallol by pH-metry.

Malhorta and Coworkers\textsuperscript{233} have studied kinetics and mechanism of the interaction between Co and L-tyrosine.

Kala and Ram Reddy\textsuperscript{234} reported Cu and Ni complexes with proline and hydroxy proline.

Malhotra and Prakash\textsuperscript{235} have also studied amino acid complexes.

Khatri and Singh\textsuperscript{236} have investigated the Zn complexes of tryptophane, polarographically.

The dissociation constants and stability of glycine, glutamine, $\alpha$-alanine, L-leucine, L-valine and L-asparagine have been determined pH metrically and spectrophotometrically in ethylene glycol and water at 298K by Lahiri et al\textsuperscript{237}. 
The [Cu(II). A. dopa] complexes, where A=ATP, alanine and glycine, have been investigated potentiometrically and spectrophotometrically by Mainer and his coworkers\textsuperscript{238}. Nair and Coworkers\textsuperscript{239} have studied histidine complexes. Verma and Verma\textsuperscript{240} have studied the Cu complexes with glycyl-glycine and amino acids by pH metric technique. Nema and Khan\textsuperscript{241} studied Cd complexes with amino acids by polarographic technique. Fridman et al\textsuperscript{242} studied Cu complexes with amino acids and other acids by spectrophotometric technique. Mohan and Coworkers\textsuperscript{243} have investigated Cu complexes of methionine, tryptophane, valine, phenylalanine and histidine at $\mu = 0.2$ M KNO$_3$. Cu complexes of L-leucine, L-valine, and L-nor-valine have been studied in water-dioxane medium\textsuperscript{244}. Madhav and Nemade\textsuperscript{245} have reported Cd complexes with glutamine and citrulline by polarographic technique. Ali and Patnaik\textsuperscript{246} reported several 1:1 and 1:2 aspartate complexes of Co, Ni, Cu and Zn using pH metric technique. Kamakshi et al\textsuperscript{247} studied Zn complexes of histidine, histamine and imidazole ligands. Masuda and Sugimori\textsuperscript{248} have studied the Cu complexes with several dipeptides containing phenylalanine or tyrosine residue. Daniele et al\textsuperscript{249} investigated the complexes of Cu with glycyl-L-histidyl-glycine by potentiometric colorimetric and circular dichroism technique.
Cu complexes with many simple histidine containing oligo peptides have been investigated by several methods\textsuperscript{250-257}.

Masuda et al\textsuperscript{258} have reported \textsuperscript{13}C-NMR spectral data as function of pH for mixtures of L-histidine and Zn nitrate.

Tanford and Shore\textsuperscript{259} have investigated Co complexes with arginine, In this paper some structural properties of arginine have been discussed.

Computer based analysis of the pH titration data on the Ni (II)-1, 3 diamino propane (A)-DL-2-aminobutyric acid, DL-3-aminobutyric acid, 4-aminobutyric acid and DL-4-amino-3-hydroxybutyric acid (B) systems shows the presence of NiAB and NiABH ternary complexes. This study was done by Neelakantan et al\textsuperscript{260}.

The interaction of thiamine hydrochloride with Cu(II), Zn(II), Ni(II) and different secondary ligands like tryptophane, phenylalanine and imidazole have been studied potentiometrically by Satyanarayana and his coworkers\textsuperscript{261}.

The thermodynamic functions of La(III) and Ce(III) with glutamic acid were determined potentiometrically in aqueous solution at 30°C and 40°C in an ionic strength of 0.1 M KCl. The stability constants, changes in free energy, enthalpy and entropy for complexes are reported by Agrawal and his coworkers\textsuperscript{262}.

Mn(II), Co(II) and Zn(II) complexes of glutathione have been prepared by Srivastava et al\textsuperscript{263}. All these complexes are 1 : 1, binuclear and octahedral in which the ligand glutathione acts as a hexadentate ligand coordinating with the central metal ion through oxygen, nitrogen and thiol groups.
Some ternary complexes of Cu with different amino acids have been reported in the literature\textsuperscript{264}.

Some ternary complexes of Cu with different amino acids have been reported in the literature\textsuperscript{265}.

Maria et al\textsuperscript{266} have studied mixed ligand complexes of serine and arginine with nitrotriacetic acid taking Cu, Ni, Co, Zn, Mn and Pb.

Griesser and Sigel\textsuperscript{267} have investigated mixed ligand complexes with 2, 2 bipyridyl as primary ligand and catechol, glycine and alanine as secondary ligands.

Parikh and Bhattacharya\textsuperscript{268} reported the mixed ligand complexes of Cu, Ni, Zn and Cd using histidine, iminoacetic acid or nitritriacetic acid and ethylenediamine using Irving Rossotti titration technique.

Some ternary complexes of Cu with different amino acids have been investigated\textsuperscript{269}.

Joshi and Bhattacharya\textsuperscript{270}, studied the ternary systems of Cu and Ni with histidine and thioglycolic acid, thiolactic acid, thiomallic acid, glycollic acid, lactic acid and malic acid.

Nauman and Sigel\textsuperscript{271}, investigated mixed ligand complexes with 2, 2 bipyridyl as primary ligand and catechol, glycine and alanine as secondary ligand,

Pettit and Swash\textsuperscript{272} studied some ternary complexes of Cu with different amino acids.

Brooker and Pettit\textsuperscript{273} investigated Cu LAH system at low pH values, where A=histidine, L-phenylalanine or tryptophane.

Studies of some mixed ligand complexes involving ligands of biological importance and transition metals have been reported by Tandon et al\textsuperscript{274}, They took 1, 10-phenanthroline and L-amino acids for their study.
Polarographic study of mixed ligand complexes of Cd with amino acids have been reported by Jain and Kapoor\textsuperscript{275}.

Mixed complexes of Zn with some substituted amines have been studied\textsuperscript{276}.

Bunel et al\textsuperscript{277} reported the mixed ligand complexes of Zn with 1, 10-phenanthroline and amino acids by spectrophotometric technique.

Singh and coworkers\textsuperscript{278} have studied the ternary systems involving amino acids, polarographically.

Nair and coworkers\textsuperscript{279} have reported Zn Complexes with histidine and imidazole or histamine.

Stacked ternary complexes of Co, Ni and with Salicylanilide, dithionion and tryptophane have been reported by Kushwaha and his coworkers\textsuperscript{280}.

Gergely and Farkas\textsuperscript{281} have studied ternary complexes of Cd with amino acids and 2-2, bipyridyl by pH metric and colorimetric techniques.

Sigel et al\textsuperscript{282} have determined formation constants of binary and ternary complexes of Cu with L-alaninamide and diethylenetriamine.

Emanuel and Bhattacharya\textsuperscript{283} have studied mixed ligand complexes of 1,10-phenanthroline, 2-2, bipyridyl etc. as primary ligands and histidine, histamine, tyrosine, dopa or phenylalamime as secondary ligands.

The complexation study of Cd and Pb with mixed ligand system have also been studied by polarographic technique\textsuperscript{284}.

Namal'tseva et al\textsuperscript{285} reported the mixed ligand complexes of transition metals with amino acid and ascorbic acid by pH and spectrophotometric technique.
Nigam and coworkers\textsuperscript{286} have studied ternary complexes of Cu, Co, Ni, or Zn with aspartic acid as primary ligand and uracil and thymine as secondary ligand by potentiometric technique.

Ostacoli and coworkers\textsuperscript{287} have studied Cu complexes with L-nor-adrenaline and glycine, alanine, L-arginine, L-ornithine, L-lysine, L-aspartic acid and 2-glutamic acid.

Deak and Gergely\textsuperscript{288} have investigated mixed ligand complexes of Cu or Ni with 1, 10-phenanthroline or 2-2', bipyridyl as primary ligands and histidine, histamine, tyrosine, tryptophane and dopa as secondary ligands.

Spectral and polarographic study of tennary complexes of Cu with glycyl-glycine and amino acids have been reported by Verma and his Coworkers\textsuperscript{289}.

Shrivastata and his coworkers\textsuperscript{290} have studied mixed ligand complexes of Cu, Co, Ni, and Zn complexes with glutamic acid as primary ligand and thymine and uracil as secondary ligands.

Reddy and Rao\textsuperscript{291} have determined the values of formation constants of Mn, Co, Cu, Ni, Zn, Mg, or Ca with cystidine as primary ligands and histidine, glycine, histamine or oxalic acid as secondary ligands.

Emanuel and Bhattacharya\textsuperscript{292} reported ternary complexes of Cu and Ni with 5-nitro-1, 10-phenanthroline or 2-2' bipyridylamine, 3, 4-dihydroxyphenylalanine, tyrosine, phenylalanine or tryptophane using potentiometric titration in dioxane-water solution.

Lingaih et al\textsuperscript{293} studied ternary complexes of dioxouranium with 2-hydroxy-l-naphthaldehyde and some amino acids.

Daniel and Coworkers\textsuperscript{294} investigated Cu complexes with L-nor-adrenaline and glycine, alanine, arginine, ornithine, lysine, aspartic
acid and glutamic acid. The formation constants have been determined by pH metric titrations at 25°C and 0.1 M KNO₃.

Rebello and Ram Reddy²⁹⁵ have reported a series of Cu and Ni complexes of the type M.(A/A'/A''). L, where A= glycine, alanine, phenylalanine, proline, hydroxy proline, picolinic acid, A'= catechol, picolinic acid- N-oxide, 4-methoxy picolinc acid-N-oxide and 4-ethoxy-picolinc acid-N-oxide, A'' = 2, 2'-bipyridyl, 1,10-phenanthroline and L= piperidine-2-carboxylic acid by potentiometric pH titration.

Devi and Ram Reddy²⁹⁶ have determined formation constants and thermodynamic parameters for the mixed ligand complexes of Cu with picolinic acid-N-oxide and amino acids like proline, hydroxyproline, glycine, alanine and phenylalanine.

Ternary complexes²⁹⁷ of Cu with glycine, proline, histidine, α or β-alanine and 2-methyl—4-(or 7)- nitrobenzimidazole etc. have been studied.

Gupta et al²⁹⁸ studied mixed ligand complexes of Cd with ascorbic acid and amino acid by polarographic technique.

Krishnarao and Coworkers²⁹⁹ have investigated Cu complexes with glycine, alanine, phenylalanine, proline, hydroxyproline and N-phenylanthranilic acid, potentiometrically

Singh and coworkers³⁰⁰, have done polarographic studies on mixed complexes of Cd with picolines and carboxylate ions.

Pitre et al³⁰¹ have investigated ternary complexes of Zn with γ-picoline and citraconic acid by polarography.

Bajpai and Saxena³⁰² reported mixed ligand complexes of d-block elements with α, α'-dipyridyl and amino acids by pH metric technique.

Khan studied the complexion between Cd and alanine as primary ligand and oxalic acid as secondary ligand by polarographic technique³⁰³.
The mixed ligand complexes\textsuperscript{304} of Zn, Cd, and Mn with adenosine-5' triphosphate and leucine, alanine, valine, nor-valine, iso-leucine, aspartic acid, uracil, thymine, methionine, threonine or serine have been studied.

Mohan et al\textsuperscript{305} have reported ternary Cu complexes containing imidazole as a primary ligand and amino acids as secondary ligands.

Satyanarayan and coworkers\textsuperscript{306} have determined formation constants of ternary complexes of Cu, Ni, Co and Zn with thiodipropionic and aspartic acid, histidine, tryptophane and ethylenediamine, pH metrically.

Khan and Nema\textsuperscript{307} reported the mixed ligand complexes of Cd with amino acids and formic acid by polarographic technique.

Fridman et al\textsuperscript{308} studied Cu complexes with amino acids and other acids by spectrophotometric technique.

Verma and Verma\textsuperscript{309} have studied the Cu complexes with glycyglycine and amino acids by pH metric technique.

Nema and Khan\textsuperscript{310} have determined stability constants of ternary complexes of Cd with some amino acids and acetic acid by polarographic techique.

Ternary complexes\textsuperscript{311} of Cu involving histidine and other amino acids or dipeptides have been studied.

Ullah and Bhattacharya\textsuperscript{312} reported ternary complexes of Cu with malonic, oxalic and amino acids.

Nema and Khan\textsuperscript{313} studied Cd complexes with amino acids by polarographic technique.

Khatoon and Kabir-Ud-Din\textsuperscript{314} reported 1 : 1 : 1, 1 : 2 : 1 and 1 : 1 : 2 complexes of Cd with amino acids and 2, 2'-bipyridyl by polarographic technique.
Pandey and Patel\textsuperscript{315} have investigated mixed ligand complexes of Cu with histidine, aspartic acid and glutamic acid as primary ligands and substituted imidazole as secondary ligands by pH metric techniques.

The stability data of ternary complexes of Zn with cysteine as primary ligand and histidine, imidazole as secondary ligand have been given by Adharani et al\textsuperscript{316} by potentiometric titration technique.

Ahamed and coworkers\textsuperscript{317} have reported some ternary complexes of salicylic acid and amino acids with Co, Ni and Cu using pH-metry.

Khan and Dodke\textsuperscript{318} reported Cd complexes of amino acids as primary ligands and some other acids as secondary ligand by polarographic technique.

Khan and Dodke\textsuperscript{319} reported Cd complexes of amino acids as primary ligands and some other acids as secondary ligands by polarographic technique.

Patel and Bhattacharya\textsuperscript{320-321} investigated homo-binuclear binary and ternary complexes of Cu with amino acids and N-bases by cyclic voltametry, potentiometry and spectrophotometry.

Khan and Khan\textsuperscript{322-323} have studied Cd and Zn complexes with amino acids as primary ligands and vitamin B\textsubscript{3} and vitamin B\textsubscript{1} as secondary ligands by polarographic technique.

Qureshi and Killa\textsuperscript{324} have investigated simple and mixed ligand complexes of Cu with some amino acids and tartrate anions by differential pulse polarography.

The stability constant values are interpreted by Banerjee et al\textsuperscript{325}, to obtain the solution structures of ternary complexes. pH-metry was used to study binary and ternary complexes of Cu(II) with L-glutamine, L-
glutamic acid, L-asparagine, DL-2-aminobutyric acid, DL-3-aminobutyric acid, 4-aminobutyric acid and 4-amino-3 hydroxybutyric acids as ligands.

Sharma and Singh\textsuperscript{326} have studied mixed ligand complexes of Co with diamines and amino acids.

The stability data of ternary complexes of Cd (II) with L-amino acid primary ligand and vitamin B\textsubscript{1} as secondary ligand have been determined by Khan et al\textsuperscript{327} by polarographic technique.

Khan and his coworkers\textsuperscript{328} have studied thermodynamic stability of Cd (II) complexes with some amino acids and 2-picoline. They took L-tyrosine, L-arginine, L-methionine and L-hydroxytryptophane for their study.

Jain and Khan\textsuperscript{329} have investigated the mixed ligand complexes of Zn(II) with L-amino acids as primary ligands and nicotinic acid as secondary ligand by polarographic technique.

Ansari and Khan\textsuperscript{330} reported the ternary complexes of Zn(II) with L-amino acids viz. L-tyrosine, L-arginine, L-methionine, L-hydroxy tryptophane, L-tryptophane, L-hydroxyproline, L-proline and L-histidine as primary ligands and $\gamma$-picoline as secondary ligand, polarographically.

Khan and his coworkers\textsuperscript{331} have studied mixed ligand complexes of Cd (II) with L-amino acids and vitamin B\textsubscript{1} by voltametric technique.

Vajhallya and Khan\textsuperscript{332} have determined the thermodynamic parameters of Zn (II) Complexes with some amino acids viz. L-lysine, L-ornithine, L-threonine, L-serine, L-phenylglycine, L-phenylalanine, L-glutamic acid and L-aspartic acid as primary ligands and $\alpha$-picoline as secondary ligand by polarographic technique.

Khan et al\textsuperscript{333} reported the electrode kinetics of mixed ligand complexes of Zn(II)-L-amino acidate-$\alpha$-picoline system. L-amino acids
were L-lysine, L-ornithine, L-threonine, L-serine, L-phenylalanine, L-glutamic acid and L-aspartic acid.

Khan and his coworker\textsuperscript{334}, have studied the electrode kinetics of Zn(II)-L- amino acids-\textgamma- picoline mixed system. They also determined kinetic parameters. L-amino acids L-lysine, L-ornithine, L-threonine, L-serine, L-phenylalanine, L-glutamic acid and L-aspartic acids were used as primary ligands in complex formation.

1.10 OBJECT OF THE PRESENT STUDY

A careful perusal of the above literature reveals that polarographic methods have not been used extensively for the ternary complex formation between Cd, Zn and Mn with glycine, \textalpha-alanine, L-leucine, L-valine, L-glutamine and L-asparagine, as primary ligands and \textalpha-picoline (2-methyl pyridine), \textbeta-picoline (3-methyl pyridine) and \textgamma-picoline (4-methyl pyridine) as secondary ligands. Hence it is thought worthwhile to undertake the systematic study of complex formation between these metals and ligands.

The value of stability constants (log\textbeta) and thermodynamic parameters such as enthalpy change (\textDelta H) free energy change (\textDelta G) and entropy change (\textDelta S) of these complexes are to be determined. The bonding between the metal and ligands, basicity and steric hindrance of ligands, affect the stability of complexes, therefore, these aspects have been discussed in a greater detail, and finally some conclusions will be drawn.

From the above study valuable informations regarding the complex formation, chemical reactions, equilibria effects of size, basicity, bonding, nature of various groups in the ligands, steric hindrance of ligands will be available that would be very much useful in analytical chemistry, inorganic chemistry, coordination chemistry, eletrochemistry and technology of non-ferrous and rare metals.
REFERENCES


5. Ibid, Chapter IV.


24. Ibid.


104. F.J. Garrick: Philly Meg., 1930, 9, 131.
     : Ibid, 1932, 14, 914.


