1.1. INTRODUCTION

The field of Bioinorganic Chemistry is still a rapidly growing area for research which despite its title it covers many disciplines of Chemistry and Biology. Modern Inorganic chemistry as it is today in its realm has grown into a full sized discipline due to the classical development of Schiff base metal complexes. Application of metal complexes in various fields of science is the driving force for the research and development of coordination chemistry. The reasons for the persistent interest in the complexes are many, but the important among them must be their role in various biochemicals, pharmaceutical, industrial and chemical processes. [1].

1.1.1. SCHIFF BASE LIGANDS

Schiff bases have been playing an important part in the development of Bio- coordination chemistry. The ligands, derived by condensation of a primary amine and an active carbonyl group, contain the azomethine group [2–4]. They form stable complexes with metal ions, especially if the amine and carbonyl compounds contain a second functional group sufficiently near the site of condensation to form five–six-membered chelate ring. Metal chelation is involved in many important biological processes where the coordination can occur between a variety of metal ions and a wide range of ligands. Many types of ligands are known, and the properties of their derived metal chelates have been investigated [5-6]. In recent years, metal complexes with Schiff bases have attracted considerable attention due to their remarkable antifungal, antibacterial, and antitumor activity [7].
1.1.2. HETEROCYCLIC SCHIFF BASE LIGANDS

Schiff bases were used as starting material for the synthesis of various bioactive heterocyclic compounds [8]. Schiff-base ligands with heterocyclic molecule and/or containing heteroatoms such as N, O, and S show a broad biological activity and are of special interest because of the variety of ways in which they are interacted to transition metal ions [9-10]. Transition metal complexes containing a heterocyclic Schiff base ligand are commonly found in biological media and play important roles in processes such as catalysis of drug interaction with biomolecules. Heterocyclic ligands containing nitrogen atom are drawing a great deal of attention in coordination and biology. Because of the versatility of their steric and electronic properties which can be modified by choosing appropriate ring substituents [11-12]. While changing the substituent in the ligand moiety, the biological activities also changes.

1.1.3. SCHIFF BASE METAL COMPLEXES AS ANTIMICROBIAL AGENTS

Microbial infections remain the major cause of death over the world. Emergence of multi-drug resistant to different infectious organisms like M.tuberculosis made the condition most alarming. Therefore, there is an urgent demand for a new class of antimicrobial agent with a different mode of action and it led medicinal chemists to explore a wide variety of chemical structures. Among the Schiff bases, heterocyclic aldehydes containing Schiff bases and their metal complexes are important due to their remarkable antimicrobial activities [13]. Hence it is worthwhile to study the synthesis of heterocyclic Schiff bases and their metal complexes for various applications. In general, when the antimicrobial activity of metal complexes is concerned, the following five principal factors may be considered:
i. The chelate effect,  

ii. The nature of the ligands,  

iii. The total charge of the complex;  

Generally the antimicrobial efficiency decreases in the order  

   cationic > neutral > anionic complex  

iv. The nature of the counter ion in the case of the ionic complexes,  

v. The nuclearity of the metal center in the complex;  

1.1.4. BIOLOGICAL IMPORTANCE OF METAL IONS  

1.1.4.1. Biological relevance of Copper  

Copper in complexes exit Cu(I), Cu(II) and Cu(III) forms. Cu(III), being very easily reduced, is generally regarded as uncommon. It has now received importance because of its involvement in some biological processes [14].  

Cu is an essential micronutrient required by all life forms. Cu is a transition metal and hence involved in a variety of biological processes viz., embryonic development, mitochondrial respiration, regulation of hemoglobin levels as well as hepatocyte and neuronal functions. Being a transition metal, Cu gets biologically converted between different redox states namely oxidized Cu (II) and reduced Cu (I). This unique attribute has made Cu metal to get manifested as an important catalytic co-factor for a variety of metabolic reactions in biological systems. Several reviews [15-19] highlighted the participation of Cu in a myriad cellular activities and physiological processes such as cellular respiration, iron metabolism, biosynthesis of neurotransmitter, and free radical detoxification. Therefore, it is worth recalling that Cu is vital for normal healthy functioning of organisms.
Copper is the third most abundant trace metal in the body [behind iron and zinc], the total amount of copper in the body is only 75-100 milligrams. Copper is present in every tissue of the body, but is stored primarily in the liver, with fewer amounts found in the brain, heart, kidney, and muscles [20].

Cu being a transition metal is ubiquitously engaged in biological systems to derive electrons through its participation in several enzymatic reactions. Upon bestowing the significance of Cu in biological systems, an elaborate mechanism is set forth by nature for maintaining Cu homeostasis. As a consequence, a wide variety of proteins viz., family of Cu bearing proteins, cuproenzymes, Cu transporters and Cu chaperone proteins have been manifested for enabling Cu to show its relevance in biological health. In addition, understanding the role of Cu in hepatic and neuronal functions and also in angiogenesis keeps progressing with the advent of novel molecular tools. The studies on genetic defects in Cu metabolism causing abnormalities are providing insights leading to the possible prognostic cues to alleviate the sufferings.

![Diagram of Copper Levels and Response](image)

**Fig. 1.** Influence of Cu deficiency or excess on the response of organisms.
(1) Physiological efficiency,
(2) Tolerable levels with inbuilt compensatory mechanisms,
(3) Therapeutic symptoms leading to fatal diseases.

The early observation of Walker, Griffen [21], Sorensen [22] says that copper possess an anti-inflammatory and anti-ulcer activity. Brown et al [23] and others prepared a range of Cu(I) and Cu(II) complexes with both active and inactive ligands were studied with their biological activities.

1.1.4.2. BIOLOGICAL ROLE OF NICKEL
Sources of Nickel

Nickel is contained in many foods. Beans, soybeans, lentils split and green peas have fairly high amounts. Nickel is essential trace element for many species. Chicks and rats raised on nickel-deficient diets have liver problems. Enzymes known as hydrogenases in bacteria contain nickel. It is also important in plant ureas.

The essentiality of Ni has not been established for higher plants, but many beneficial effects of Ni on plant growth have been reported. Evidence from several laboratories suggests that Ni is essential for animals, but its function has not been defined.

High levels of Ni in plant growth media are phytotoxic, and possible beneficial effects of Ni on plant growth are poorly defined and not understood. Nickel reportedly is required for growth of a bacterium (Alcaligenes (Hydrogenomonas) eutrophus, a cyanobacterium (Oscillatoria) and a green alga (Chlorella vulgaris), but its function is unknown. In higher plants, Ni is required for optimum growth of certain pine tree species and some Ni accumulator species
of Alyssum, but its function is not known. Slight increases in the growth of a number of plant species were attributed to low levels of Ni. Germination of seed of several species was stimulated by treatment with Ni salts [24].

Nickel is an essential component of the enzyme urease isolated from lackbean seeds but the function of urease is not clear. Some higher plants require Ni when they are cultured with urea as the only source of N (soybean tissue cultures and Lemna, Spirodea and Wolffia species). Some researchers suggested that in higher plants urease might have functions other than the hydrolysis of urea, such as the utilization of carbamoyl, ureido, or amidino moiety of urea. Ni might be required for the mobilization of stored seed-nitrogen through ureides or arginine during early stages of seedling growth.

Several families of plants, including species of Leguminosae, accumulate large amounts of ureides. In soybeans, the ureides (allantoin and allantoic acid) are the major forms of nitrogen translocated from nodulated roots to tops of plants and are important in seed development. The only catabolic pathway known for allantoin and allantoic acid is through their enzymatic degradation to urea and glyoxylic acid. For use of urea-N in anabolic processes plant cells hydroitize urea to NH$_3$ and CO$_2$ by the action of urease which requires Ni. Apparently Ni might be required by nodulated legumes that translocate large amounts of N from roots to tops via ureide compounds [25].

1.1.4.3. Manganese in Biology

Manganese forms compounds from -1 to +7 oxidation states. Compounds having Mn in +2 oxidation state are the most stable. Manganese also forms distorted
square planner and octahedral complexes. The chemistry of manganese compounds has received attention in recent years due to their significant role as redox active site in several biochemical processes [26]. Manganese has potential applications to chemical modified magnetic materials [27]. Manganese reacts with Schiff base ligand to form mononuclear and multinuclear manganese complexes. Manganese is an essential trace element for all forms of life. It accumulates in mitochondria and is essential for their function. The manganese transport protein, transmanganin, is thought to contain Mn(III). Several metalloenzymes are known: arginase, pyruvate carboxylase and superoxide dismutase [28-29].

1.1.4.4. Biological role of Cobalt

Cobalt can be found in many foods, especially those that have high levels of vitamin -B$_{12}$, including liver, clams, oysters, lean beef, eggs, milk, yogurt, chicken, and cheese. Cobalt is also available in supplement form, usually as a tincture or type of mineral water. There are no recommended daily intake levels for cobalt, because it is only found in trace amounts. However, because it is chemically bonded to vitamin- B$_{12}$ in the body, people who are deficient in vitamin B$_{12}$ are ultimately deficient in cobalt [30-31]. In the human body, cobalt works with vitamin- B$_{12}$ in the form of cobalamin. Cobalt increases the body's ability to absorb and utilize vitamin-B$_{12}$. Previous research has shown that cobalt may be effective in treating conditions such as anemia and certain infectious diseases, and that it helps maintain and repair the myelin sheaths that surround nerve cells. Cobalt also plays a role in the regulation and stimulation of certain enzymes, and is sometimes used by the body as a substitute for zinc [32-34].
1.1.5. DNA CLEAVAGE

Compounds having the ability to bind and cleave double stranded DNA under physiological conditions are of importance for their utility as diagnostic agents in medicinal applications and for genomic research [35]. Transition metal complexes are able to induce damage to nucleic acids may find useful applications. It is an important aspect of biotechnology and drug design [36] and it provides efficient tools in molecular biology to study DNA and RNA structure and function [37].

DNA cleavage can take place two distinctly different processes, via, oxidation or hydrolytic cleavage pathways. The normal way nature achieves this is by hydrolysis of phosphodiester bonds in the backbone of DNA, a reaction that is catalyzed by nuclease enzymes. In this way, 3'-and 5'-ends of the new separate oligonucleotide strands are obtained which can be recognized and reconnected by enzymes of the ligase family (hydrolytic pathway). Complexes having metal ions with strong Lewis acidity could show facile hydrolytic cleavage of DNA thus modeling the activity of restriction enzymes [38].

In oxidative cleavage, modifications of the nucleobases or the deoxyribose sugar unit by redox processes or reactive chemical species can lead to degradation products in which ultimately the phosphodiester bond is also broken. However, such reactions are usually associated with pathological processes or the action of DNA-directed drugs, since such strand breaks cannot easily be connected again by DNA processing enzymes. Metal complexes showing oxidative cleavage of DNA have the potential for foot printing and therapeutic applications. Oxidative cleavage of DNA could be achieved either through chemical nuclease activity in which the complex is
reacted with an external oxidizing/ reducing agent or on photoactivation of the complex which acts as a photosensitizer to generate reactive species to cleave DNA. Currently transition metal complexes cleaving DNA on photo-irradiation in visible light induced cleavage of DNA are of interest in the chemistry of photodynamic therapy (PDT) of cancer [39].

The mechanism of oxidative cleavage of metal complexes is as shown in following reaction. In oxidative cleavage metal(II) is oxidized by hydrogen peroxide to generate a hydroxide anion and a hydroxyl radical. The metal(III) form then reacts with superoxide to generate to metal(II) form under production of oxygen.

\[
\begin{align*}
M^{2+} + H_2O_2 & \rightarrow M^{3+} + \cdot OH + OH^- \\
M^{3+} + O_2^- & \rightarrow M^{2+} + O_2 \\
H_2O_2 + O_2^- & \rightarrow \cdot OH + OH^- + O_2
\end{align*}
\]

The gel electrophoresis experiment of DNA cleavage gives an assessment of changes in the nucleic acid conformation through its changes in gel mobility. Super coiled form (form I) DNA can be distinguished from nicked DNA (form II) in an agarose gel because of their differing mobilities; the fastest migration will be observed for the super coiled form (SC). If one strand is cleaved, the supercoiled will relax to produce a slower moving open circular form (OC). If both strands are cleaved, linear form (form III) will be generated that migrates in between. The diagram of DNA cleavage is shown in fig. 1.
1.1.6. ANTIBACTERIAL ACTIVITY

The discovery and development of antibiotics are among the most powerful and successful achievements of modern science and technology for the control of infected diseases. Metal based drugs represent a novel group of antimicrobial agents with potential applications for the control of bacterial infections. This inspires synthetic chemists to search for new metal complexes for bioactive compounds.

The bacteria are assumed to be one of three morphological forms, spheres (cocci), rods (bacilli) or spirals although there is much variation in each group. The morphology of a bacterium is maintained by a rigid cell wall and it is the nature of this cell wall that allows us to divide into two basic groups, Gram-positive bacteria and Gram-negative bacteria.

Fig. 3. Gram positive (+) and Gram negative (-) bacteria
Gram staining is the application of a crystal violet dye to a culture of bacteria. Bacteria that retain the color of the dye are called Gram positive; bacteria that don’t are Gram negative. The fig.2. Shows Gram-positive, Staphylococcus aureus at the top and Gram-negative, Pseudomonas aeruginosa at the bottom.

Gram-positive and Gram-negative bacteria have similar internal, but very different external structures. The cytoplasm of the bacterial cell contains the DNA chromosome, the mRNA, ribosomes, proteins, and metabolites. The cell wall structure of Gram-positive and Gram-negative bacteria is as shown in fig. 3.

Fig. 4. Cell wall structure of Gram positive and Gram negative bacteria

Here we used two gram positive (Bacillus subtilis, Staphylococcus aureus) and two gram negative (Pseudomonas aeruginosa, Salmonella typhi) bacteria. The general idea of above four pathogenic bacteria is briefly discussed below.

1.1.6.1. GRAM POSITIVE BACTERIA

Bacillus subtilis

In 1872, Ferdinand Cohn, a contemporary of Robert Koch, recognized and named the bacterium Bacillus subtilis. The organism is Gram-positive, capable of growth in the presence of oxygen and forms a unique type of resting cell called an
endospore. The morphology structure of Bacillus subtilis is shown in fig. 4. The organism represented what was to become a large and diverse genus of bacteria named Bacillus, in the family Bacillaceae. Although this species is commonly found in soil, more evidence suggests that B. subtilis is a normal gut commensal in humans.

![Morphology structure of Bacillus subtilis](image)

**Fig. 5. Morphology structure of Bacillus subtilis**

Bacillus subtilis are rod-shaped bacteria [40]. The cell wall is a rigid structure outside the cell. It is composed of peptidoglycan, which is a polymer of sugars and amino acids. The peptidoglycan that is found in bacteria is known as murein. Other constituents that extend from the murein are teichoic acids, lipoteichoic acids, and proteins. The cell wall forms the barrier between the environment and the bacterial cell. It is also responsible for maintaining the shape of the cell and withstanding the cell's high internal turgor pressure [41]

**Staphylococcus aureus**

Staphylococcus aureus was first identified in Aberdeen Scotland (1880) by the surgeon sir Alexander Ogston in pus from surgical abscesses. The morphology
structure of Staphylococcus aureus is as shown in fig. 5. Staphylococcus is a group of bacteria that can cause a multitude of diseases as a result of infection of various tissues of the body. It is the most common cause of staph infections. It causes a variety of suppurative infections and toxinoes in humans. It is estimated that 20 % of the human population are long terms carriers of S.aureus [42]. It is a spherical bacterium, frequently part of the skin flora, found in the nose and on the skin. S. aureus can cause a range of illness from minor skin infections, such as pimples, impetigo, boils, cellulitis folliculitis, carbundes, scalded skin syndrome and abscesses to life threatening diseases such as pneumonia meningitis, osteomyelitis, endocarditis, toxic shock syndrome, bacteremia and sepsis [43].

Fig. 6. Morphology structure of Staphylococcus aureus

S.aureus is a successful pathogen due to a combination of bacterial immune-evasive strategies is the production of carotenoid pigment staphyloxanthin, which is responsible for the characteristic golden color of S.aureus colonies. This pigment acts as a virulence factor, primarily by being a bacterial antioxidant which helps the microbe evade the reactive oxygen species which the host immune system uses to kill pathogens [44].
1.1.6.2. GRAM NEGATIVE BACTERIA

Escherichia coli

Escherichia coli, also known as E. coli is a bacterium that is commonly found in the gut of endotherms (warm blooded organisms). German pediatrician and bacteriologist, Theodor Escherich discovered the bacterium in 1885, hence its name. E. coli is now classified as part of the Enterobacteriaceae family of gamma-proteobacteria.

![Image of Escherichia coli](image)

**Fig. 7. Morphology structure of Escherichia coli**

Several types of E. coli exist as part of the normal flora of the human gut and have many beneficial functions, such as the production of vitamin K₂. They also prevent harmful bacteria, known as pathogenic bacteria, from establishing themselves in the intestine. Bloody diarrhea is common in confirmed cases of E. coli infection, but the bacteria also should be considered a possible cause of non-bloody diarrhea [45].

**Klebsiella pneumoniae**

Klebsiella was named after the German bacteriologist Edwin Klebs (1834–1913). Klebsiella pneumoniae is a Gram-negative, non motile, encapsulated, lactose fermenting, facultative anaerobic, rod shaped bacterium. Although found in
the normal flora of the mouth, skin, and intestines [46], it can cause destructive changes to human lungs if aspirated.

![Morphology structure of Klebsiella pneumoniae](image)

**Fig. 8. Morphology structure of Klebsiella pneumoniae**

*K. pneumoniae* can cause the disease Klebsiella pneumonia. They cause destructive changes to human lungs inflammation and hemorrhage with cell death (necrosis) that sometimes produces a thick, bloody, mucoid sputum (currant jelly sputum). The most common infection caused by Klebsiella bacteria outside the hospital is pneumonia, typically in the form of bronchopneumonia and also bronchitis.
1.2. LITERATURE SURVEY

Fatima et al [47] have synthesized and characterization of some transition Metal Complexes of Thio-carbohydrazone Schiff Bases. From the elemental analysis, molar conductivity, magnetic susceptibility measurements, IR and $^1$H-NMR spectral data it was possible to assign the mode of coordination of the ligands to metals and to suggest possible geometries for the prepared complexes.

Bhattacharjee et al [48] have reported neutral tetradeutate Schiff base derived from furfuraldehyde and hydrazine hydrate and its complexes with VO(II), Fe(III), Co(II), Ni(II), Cu(II) and Zn(II) have been prepared and characterized by physical, spectral and analytical studies. An octahedral geometry were proposed for the Fe(III) and Co(II) complexes and a square pyramidal geometry for the VO(II) complex. While Ni(II), Cu(II) and Zn(II) complexes possessed a square planar geometry, the redox behaviour of the complexes was examined by cyclic voltammetric studies.
Mishra et al [49] have synthesized the coordination complexes of Co(II), Ni(II) and Cu(II) derived from 2-thiophenecarboxylidene-3-chloro-4-fluoroaniline and 2-thiophenecarboxylidene-4-fluoroaniline by conventional as well as microwave methods. Geometry of the complexes has been determined by XRD analysis.

Mohammed et al [50] have synthesized a number of zinc(II) and cadmium(II) complexes with two Schiff base ligands derived from the condensation of furfuraldehyde with butylamine and hexylamine. The complexes were characterised by standard procedures. These studies revealed the action of both ligands as neutral bidentate chelating ligands, formed Complexes with tetrahedral structure.

\[
M=\text{Zn(II)} \text{ or Cd(II)}; \quad X=\text{Cl}^-, \text{NO}_3^-, \frac{1}{2} \text{SO}_4^{2-}; \quad R=\text{-CH}_3 \text{ or -CH}_2\text{CH}_2\text{CH}_3
\]
Heecheol Kim et al [51] have reported the Polymeric electrodes for lead ion based on N, N'-bis-thiophen-2-ylmethylenepyridine-2,6-diamine as an ion carrier. The good sensitivity and selectivity towards lead ion are attributed to the strong complexation of lead ion to N,N'-bis-thiophen-2-ylmethylenepyridine-2,6-diamine which has geometrically the proper cavity to coordinate to the ligand.

Deshpande et al [52] have reported the synthesis of new Schiff base complexes which are obtained by the condensation of 2-amino-4, 6-dimethyl benzothiazole with 2-Hydroxy-naphthalene-1-carbaldehyde, 3-Methyl-thiophene-2-carbaldehyde and Cu(II), Co(II), Mn(II), Fe(II), Cr(II) and Ni(II) chloride. The Schiff bases and the complexes were characterized by spectral methods. The ligands and their metal complexes were screened for antibacterial activity.

Tantarul et al [53] has synthesized by the condensation of 4-aminoantipyrine with pyrrole-2-carboxaldehyde and salicylic acid hydrazide with 2-hydroxyacetophenone, respectively. Their structure has been proven using spectral
methods and elemental analysis. The compounds were evaluated for toxicity. All tested compounds are nontoxic at lower concentration. The most active compound was Cu(II) complex at dose of 10 mg/kg.

Binding interaction of a water soluble cobalt(II) complex of a Schiff base derived from o-phenylenediamine with calf thymus DNA has been investigated by Shahabadi et al.\textsuperscript{54} Co(II) complex most likely interact with DNA in an electrostatic binding mode.

Aliyu \textsuperscript{55} reported the reaction of ethanolic solutions of 2-aminobenzoic acid and 2-thiophenecarboxylddehyde gave a Schiff base. Stability of the complexes were discussed.

Srivastava et al.\textsuperscript{56} have reported Bivalent transition metal complexes of tridentate Schiff base ligands. The synthesized Schiff bases and their transition metal
complexes were evaluated for their antibacterial activity. Schiff bases which were inactive before complexation became more active upon coordination with mentioned bivalent transition metal ions.

Mishra et al [57] have reported VO(II), Fe(II), Co(II), Cu(II) and Zn(II) metal complexes of Schiff bases derived from 2-thiophenecarboxaldehyde. The aim of this study is to observe the impact of chelation on the therapeutic value of the bioactive organic compounds. The antimicrobial and insecticidal screening results also indicate that the metal complexes showed better antimicrobial and insecticidal agents as compared to the Schiff bases.

Seshaih et al [58] have reported synthesis, characterization and antibacterial activity of Cu(II) and Fe(III) complexes of a new tridentate Schiff base ligand. From the EPR spectra an octahedral geometry has been proposed for Cu(II) complex.
Vijaya Sekhar et al [59] have reported synthesis and characterization of metal complexes of a novel Schiff base. The Fe(III), Ru(III), Co(II), Ni(II), Cu(II), Pd(II), Zn(II), Cd(II) and Hg(II) complexes of a Schiff base derived from pyrazine-2-carboxamide and thiophene-2-carbaldehyde have been synthesized and structurally characterized by various physico-chemical data.

Mohamed et al [60] have reported Metal complexes of Schiff bases derived from 2- furancarboxaldehyde and o-phenylenediamine and 2-thiophencarboxaldehyde and 2-aminothiophenol. The activity data show the metal complexes to be more potent antibacterials than the parent Schiff base ligand against one or more bacterial species.
Salameh et al [61] have reported, Schiff base derived from the reaction of 2,5-thiophenedicarboxaldehyde and o-amino benzenethiol gives 2,5-bis(benzothiazolidin-2 yl)thiophene. Schiff base reacted as a neutral ligand with Pb(II) and a dianion with Cu(II), Ag(I), Cd(II), Pb(II), and Zn(II). The behavior of Hg(II), Ru(II), Pt(II), Rh(III), and Ni(II) involved the opening of the thiazoline rings of the ligand.

Tayim et al [62] have synthesized the condensation of o-aminothiophenol with 2-thiophenecarboxaldehyde yields 2-thiazolin-2 ylthiophene, rather than the expected Schiff base. However, upon reaction with metal ions, the thiazoline rearranged to the expected thiolate Schiff base. Complexes of Schiff base with Ni(II),Cu(II), Zn(II), Cd(II), Pb(II), Ag(I), and Pd(II) were isolated and characterized.

Kolwalkar et al [63] have reported the Schiff base derived from the reaction of the aldehydes, 3-hydroxybenzaldehyde and 5-nitrosalicylaldehyde, with the amines, aniline and o-aminothiophenol, and their complexes with VO(II), Co(II), and Ni(II), were prepared and characterized by elemental analyses, magnetic measurement and electronic absorption data.

Khalifa et al [64] have reported the Complexes of Ni(II), Co(II), Cu(II), Zn(II), Pd(II), and Pb(II) with Schiff base derived from isatin with
2-aminothiophenol, were synthesized and characterized by elemental analyses, molar conductance, magnetic moments, $^1$H-NMR, IR, and electronic spectra studies.

Spinu et al [65] have reported the synthesis of Metal complexes, Fe(II), Co(II), Ni(II), Cu(II), Zn(II), or Cd(II), from the Schiff base formed by the condensation of 2-thiophenecarboxaldehyde with 2-aminopyridine. The Schiff base and its metal chelates have been screened for their in vitro antibacterial activity. The metal chelates were shown to possess more antibacterial activity than the uncomplexed Schiff base.

Saxena et al [66] have synthesized the Schiff base ligand was prepared from furfuraldehyde with 4-amino-5-mercapto-5-triazole and characterized by spectral methods. Based on these studies octahedral structures have been assigned to these complexes.

Gladiola Tantar et al [67] have reported the biological evaluation of some new Schiff bases and their Cu(II) and Mg(II) complexes. Their structure has been proven using spectral methods. The compounds were evaluated for toxicity
degree and for their anti-inflammatory activity using carrageenan induces rat paw edema bioassay. The most active compound was Cu(II) complex at dose of 10 mg/kg.

Kiran Singh et al. [68] have reported Antimicrobial spectra and Schiff bases. The synthesized compounds were characterized by elemental and spectral methods.

![Structural Formula](image)

R= -CH₃, -CH₂CH₃

Natarajan et al. [69] have reported the synthesis, characterization, electrochemistry, catalytic and biological activities of ruthenium (III) complexes with bidentate N, O/S donor ligands. An octahedral structure has been tentatively proposed. All the new complexes were found to be active against the bacteria such as E. coli, Pseudomonas, Salmonella typhi and Staphylococcus aureus. The activity was compared with standard Streptomycin.

Belal et al [70] have reported Spectral characteristics of some Schiff bases derived from 2-furfuraldehyde. The geometry of all the complexes were determined by spectral and analytical techniques.
Raman et al [71] have reported Novel metal based Antimicrobial Agents of Copper(II) Complexes: Synthesis, Spectral Characterization and DNA Interaction Study. A comparative study of MIC values of the Schiff base ligands and their complexes indicates that the complexes exhibit higher antimicrobial activity than the free ligands. An electrochemical study of the copper complexes containing electron withdrawing substituted ligands reveals that they prefer to bind to DNA in Cu(II) rather than Cu(I) oxidation state.

\[ \begin{align*}
\text{R}^+ &: \text{NO}_2^-, \text{Cl}, \text{H}, \text{-OCH}_3, \text{-OH}; \text{Y} = \text{O,NH} \\
\end{align*} \]

Feng et al [72] have reported a series of metal complexes with new tridentate Schiff base derived from salicylaldehyde and furfuraldehyde with o-phenylenediamine have been prepared and characterised by physical and chemical methods. Electronic spectra, room temperature magnetic moment values, ESR and X-ray photoelectron spectroscopy studies suggest an octahedral geometry for all the complexes, where low molar conductance values are in accord with their non-electrolytic nature. The thermal stability of the complexes is discussed and the ligand-to-metal bonding modes discussed.
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