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Synthesis Of Schiff Bases And Their Metal Complexes: A Comparative Study Of Antimicrobial Activity

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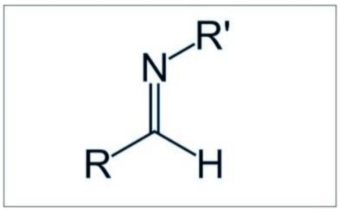
Abstract: Schiff bases are important organic compounds containing an azomethine group (–C=N–) formed by the condensation reaction between primary amines and aldehydes or ketones. These compounds possess significant biological activities and have the ability to form stable complexes with transition metal ions such as zinc, copper, nickel, cobalt, and iron. In the present study, a Schiff base was synthesized using benzaldehyde and aniline, followed by preparation of its zinc metal complex. The synthesized compounds were comparatively evaluated for their antimicrobial activity using a bread preservation test. The Schiff base showed moderate inhibition of fungal growth, whereas the metal complex demonstrated enhanced antimicrobial activity and improved bread preservation ability. The increased activity of the metal complex may be attributed to the chelation effect, which enhances lipophilicity and penetration into microbial cells. The study concludes that Schiff base metal complexes possess better antimicrobial potential than free Schiff base ligands and may serve as promising compounds for future antimicrobial applications.

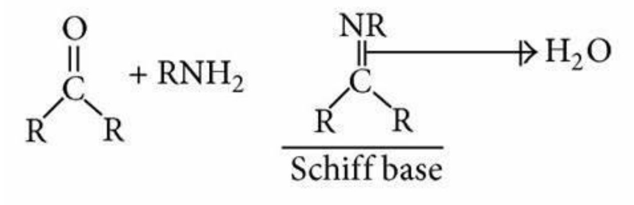
Index Terms - Schiff base, Metal complex, antimicrobial activity, Azomethine group, Benzaldehyde, Aniline, Zinc complex, Chelation, Bread preservation test.

I. Introduction

SCHIFF BASE, ALSO REFERRED TO AS IMINE OR AZOMETHINE, IS A NITROGEN ANALOGUE OF AN ALDEHYDE OR KETONE IN WHICH AN IMINE OR AZOMETHINE GROUP HAS TAKEN THE PLACE OF THE CARBONYL GROUP (C=O).



Under certain circumstances, a primary amine reacts with an aldehyde or a ketone to generate a Schiff base. Because Hugo Schiff was in charge of the research into aldehyde, which led him to create the Schiff test.[1] Amines can attack the electrophilic carbon atoms of aldehydes and ketones nucleophilically. This reaction results in a molecule where the C=O is swapped out for a C=N bond.



Compounds that are utilized as ligands to create coordination complexes with metal ions are typically referred to as Schiff bases. Certain complexes are found in nature, such as corrin, but most Schiff bases are synthetic and are utilized in the preparation of several significant catalysts, including Jacobsen's catalyst.[2] There are several unique naming schemes for these compounds. The aniline-derived Schiff base, where R_3 is a phenyl or substituted phenyl group, is known as anil, while bis-compounds are frequently referred to as salene-type compounds.

The formation of metal complex powder from Schiff base involves the reaction of the prepared Schiff base ligand with suitable metal salts such as copper, zinc, nickel, cobalt, or iron salts. These complexes are generally obtained as colored crystalline or amorphous powders with good stability. The coordination of the metal ion with the ligand often enhances the biological, chemical, and physical properties of the compound compared to the free Schiff base.[3]

Schiff Base are a group of organic compounds containing an imine or azomethine group (>C=N–), produced by the reaction between primary amines and aldehydes or ketones. These compounds were first discovered by Hugo Schiff and are named after him. The azomethine group is responsible for their important chemical and biological properties.[4]

Schiff bases are widely used in coordination chemistry because they easily bind with transition metal ions such as copper, zinc, nickel, cobalt, and iron to form stable metal complexes. The nitrogen atom present in the imine group acts as a donor atom and helps in complex formation. These metal complexes generally show improved chemical stability and biological activity compared to free Schiff bases.[5]

Schiff base metal complexes have gained considerable attention because of their various biological activities, including antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, and anticancer effects. The enhanced biological activity is mainly due to increased lipophilicity and better interaction with microbial cells after coordination with metal ions.[6]

In addition to medicinal uses, Schiff bases and their metal complexes are also important in catalysis, analytical chemistry, dyes, pigments, corrosion prevention, agriculture, and electrochemical sensors. Their wide range of applications and strong coordination ability make them an important area of research in modern chemistry and pharmaceutical science.[7]

This review mainly discusses the synthesis of Schiff bases and their metal complexes and compares their antimicrobial activities. The study suggests that metal complex formation improves the antimicrobial potential of Schiff bases, making them promising compounds for future therapeutic applications.[8]

II. Chemical Structure of Schiff Base:

A Schiff base is an organic compound containing an azomethine or imine functional group (>C=N–), formed by the condensation of a primary amine with an aldehyde or ketone. Its general chemical structure is:

$$R - CH = N - R'$$

where **R** and **R′** may be alkyl, aryl, or heterocyclic groups. In Schiff bases, the carbonyl group (>C=O) of aldehydes or ketones is replaced by the imine group (>C=N–), which is responsible for their chemical reactivity and metal-binding ability.

This azomethine nitrogen acts as a donor atom and helps in the formation of stable metal complexes with transition metals such as copper, zinc, nickel, cobalt, and iron. Schiff bases are therefore widely used in coordination chemistry and medicinal chemistry.[9]

III. Antimicrobial Significance:

Schiff bases and their metal complexes possess significant antimicrobial activity against various bacteria and fungi. The presence of the azomethine group (>C=N–) plays an important role in inhibiting the growth of microorganisms. Schiff bases act by interfering with microbial cell processes, while their metal complexes often show enhanced activity due to increased lipophilicity and better penetration through the microbial cell membrane.

Coordination of Schiff bases with metal ions such as copper, zinc, nickel, cobalt, and iron improves their biological effectiveness by increasing stability and facilitating interaction with microbial enzymes and proteins. This enhanced antimicrobial action makes Schiff base metal complexes useful in the development of new antibacterial and antifungal agents, especially against drug-resistant microorganisms.Because of their broad-spectrum activity and potential pharmaceutical applications, Schiff bases and their metal complexes are widely studied in medicinal chemistry and drug development.

IV. Applications of Schiff Bases and Metal Complexes:

Schiff bases and their metal complexes have wide applications in pharmaceutical, analytical, agricultural, and industrial fields due to their excellent coordination ability and biological activities. The presence of the azomethine group (>C=N–) and donor atoms such as nitrogen, oxygen, and sulfur allows Schiff bases to form stable complexes with transition metals.

In medicinal chemistry, Schiff bases and their metal complexes exhibit important biological activities such as antimicrobial, antifungal, antiviral, anti-inflammatory, antioxidant, and anticancer effects. These properties make them useful in the development of new therapeutic agents.

In analytical chemistry, they are used as chelating agents for the detection and estimation of metal ions. In catalysis, metal complexes of Schiff bases act as effective catalysts in various organic reactions. They are also used in dyes, pigments, corrosion inhibitors, polymers, and electrochemical sensors. In agriculture, some Schiff base complexes are used as fungicides and pesticides.[10]

V. Schiff Base–Metal Complex:

Transition metals readily form complexes with Schiff bases, and these compounds are widely used as chelating ligands in coordination chemistry. Schiff base metal complexes have attracted great scientific interest for many years because of their stability and wide range of applications. Donor atoms such as nitrogen (N), oxygen (O), and sulfur (S) present in Schiff bases play an important role in coordinating with metal ions, similar to their function in many biologically important metalloproteins and metalloenzymes.

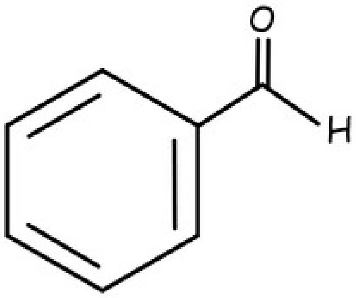
Schiff bases form stable complexes with transition metals such as copper, zinc, nickel, cobalt, iron, chromium, manganese, and vanadium. These metal complexes are important in industrial applications and show a broad spectrum of biological activities including antibacterial, antifungal, antiviral, antimalarial, antiproliferative, and anticancer properties. Many Schiff base metal complexes also exhibit excellent catalytic activity in various chemical reactions, even in the presence of moisture.

The biological activity of these compounds is often influenced by the coordinated metal ion, which enhances their effectiveness. Their ability to act as multidentate ligands has increased interest in their coordination chemistry. Certain metals such as sodium, magnesium, potassium, calcium, iron, cobalt, nickel, copper, and zinc are essential for the normal functioning of living organisms and play vital roles even in trace amounts at the molecular level.[11]

Schiff base metal complexes have been known since the nineteenth century and gained major importance in coordination chemistry after the work of scientists like Jorgensen and Werner. Hugo Schiff also prepared metal-salicylate complexes with primary amines. In recent years, binuclear and polynuclear transition metal complexes have gained attention in fields such as bioinorganic chemistry, magnetochemistry, catalysis, material science, and superconductivity. Transition metals are preferred because of their ability to adopt different coordination geometries and exist in multiple oxidation states, making them highly versatile in complex formation.[12]

VI. Benzaldehyde - aniline schiff base:

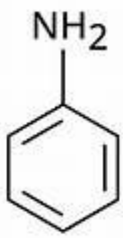
Benzaldehyde (C6H5CHO)



Benzaldehyde

Benzaldehyde is an organic compound that contains a benzene ring attached to a formyl group (–CHO). It is the simplest aromatic aldehyde and is widely used in various industrial applications. Benzaldehyde is a colorless liquid with a characteristic almond-like smell. It is the main component of bitter almond oil and can be obtained from several natural sources.[13]

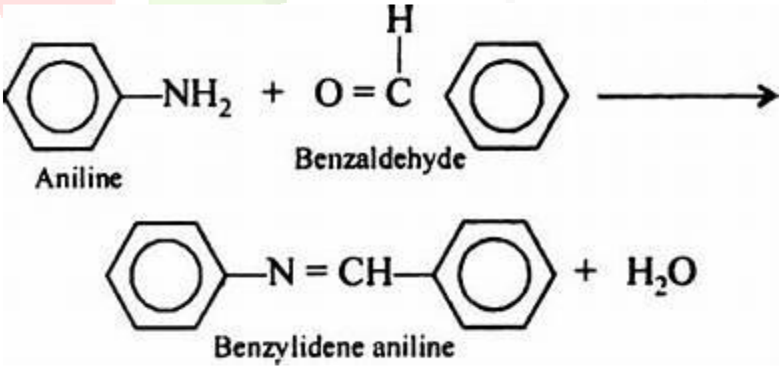
Aniline(C6H5NH2)



Aniline

Aniline is an organic compound made up of a phenyl group attached to an amino group (–NH_2), making it the simplest aromatic amine. It is widely used in the production of precursors for polyurethane and various other industrial chemicals. Aniline has a characteristic odor similar to rotten fish, which is common among volatile amines. It is also highly flammable and burns with a smoky flame, which is typical of aromatic compounds.[13]

When benzaldehyde reacts with aniline it will form Benzylidene aniline with elimination of water molecule.



Schiff bases formed from the reaction of an amino compound and a carbonyl compound are an important class of ligands that coordinate with metal ions through the azomethine nitrogen atom. These compounds have been widely studied because of their strong metal-binding ability and biological importance. In azomethine derivatives, the C=N bond plays a vital role in biological activity. Many azomethine compounds have been reported to show significant antibacterial, antifungal, anticancer, and other pharmacological activities. In this project, zinc (Zn) was used to prepare the metal complex with the Schiff base.

VII. Synthesis of Benzaldehyde–Aniline Schiff Base:

10 mL of benzaldehyde and 10 mL of aniline were measured using a measuring cylinder and poured into a 100 mL beaker containing crushed ice. The beaker was placed over an ice bath and the mixture was stirred well using a glass rod. A yellow solid precipitate was formed. The resulting mixture was filtered using filter paper and the precipitate was dried. The dried solid obtained was the benzaldehyde–aniline Schiff base.[11]

VIII. Synthesis of Schiff Base–Metal Complexes:

1.81 g of Schiff base (0.01 mol) was dissolved in a minimum quantity of 10 mL ethanol. Separately, 1.36 g of zinc chloride (0.01 mol) was dissolved in a minimum quantity of distilled water. About 5 drops of ammonia solution were added to the zinc chloride solution, and the mixture was shaken well. The Schiff base solution was then mixed with the metal salt solution and refluxed for 1 hour using a water condenser. After refluxing, crushed ice was added to the reaction mixture, resulting in the precipitation of the metal complex. The precipitate formed was filtered using filter paper and dried at room temperature. The final dried product obtained was the Schiff base–zinc complex.[9]

IX. Reaction Mechanism of Schiff Base Formation and Metal Complex Formation:

1. Mechanism of Schiff Base Formation

Schiff bases are nitrogen-containing organic compounds characterized by the presence of an azomethine group (–C=N–). These compounds are generally prepared by reacting a primary amine with an aldehyde or ketone in an alcoholic medium. The synthesis involves nucleophilic addition followed by dehydration, leading to formation of the imine linkage.[14]

- General Reaction

$R\text{-}NH_2 + R'\text{-}CHO \rightarrow R\text{-}N{=}CH\text{-}R' + H_2O$

Step 1: Formation of Carbinolamine Intermediate

Initially, the lone pair of electrons present on the nitrogen atom of the primary amine attacks the electrophilic carbon atom of the carbonyl group. This results in the formation of an unstable tetrahedral intermediate called carbinolamine.[15]

- Reaction

$R\text{-}CHO + R'\text{-}NH2 \rightarrow R\text{-}CH(OH)\ NH\text{-}R'$

- Explanation

* The carbonyl carbon possesses partial positive charge and acts as an electrophile.
* The amine nitrogen behaves as a nucleophile because of its lone pair electrons.
* A temporary tetrahedral intermediate is produced during the reaction.

Step 2: Proton Rearrangement

After formation of the intermediate, proton transfer takes place within the molecule. This rearrangement stabilizes the intermediate and prepares it for elimination of water.[16]

- Explanation

* Protonation of the hydroxyl group occurs.
* The intermediate becomes more reactive toward dehydration.
* Molecular rearrangement increases stability of the system.

Step 3: Dehydration and Imine Formation

In the final step, a molecule of water is eliminated from the intermediate, resulting in formation of the azomethine or imine bond (C=N), which is the characteristic functional group of Schiff bases.[17]

- Reaction

$R\text{-}CH(OH)\ NH\text{-}\ R' \rightarrow R\text{-}CH{=}N\text{-}R' + H_2O$

- Explanation

* Elimination of water converts the intermediate into a stable Schiff base.
* The newly formed C=N bond is responsible for many biological and coordination properties of Schiff bases.

2. Mechanism of Metal Complex Formation

Schiff bases are capable of acting as ligands because the nitrogen atom of the azomethine group contains a lone pair of electrons. These ligands coordinate with metal ions such as Cu^{2+}, Zn^{2+}, or Ni^{2+} to form stable metal complexes[18]

- General Reaction

$2L + MCl_2 \longrightarrow [ML2] + 2Cl^-$

Where:

* L = Schiff base ligand
* M = Metal ion such as Cu^{2+}, Zn^{2+}, or Ni^{2+}

Step 1: Coordination Between Ligand and Metal Ion

The lone pair electrons present on the azomethine nitrogen are donated to the vacant orbitals of the metal ion, resulting in formation of a coordinate covalent bond[19]

- Reaction

$L: + M^2 \rightarrow L + M^{2+}$

- Explanation

* Schiff base functions as an electron donor (Lewis base).
* Metal ion accepts the electron pair and acts as Lewis acid.
* Coordinate bond formation stabilizes the metal ion.

Step 2: Chelate Complex Formation

Two ligand molecules usually coordinate with one metal ion to produce a stable chelated complex structure.[20]

- Reaction

$M^2 + 2L \rightarrow [ML_2]^{2+}$

- Explanation

* Chelation increases rigidity and stability of the complex.
* Delocalization of electrons occurs over the chelate ring.
* Lipophilic nature of the complex increases, improving biological activity.

Chelation Theory

Chelation theory explains the enhanced biological activity of metal complexes. During coordination, the positive charge of the metal ion becomes partially shared with donor atoms of the ligand. This decreases the polarity of the metal ion and increases lipophilicity of the complex. As a result, the metal complex can penetrate microbial cell membranes more effectively, leading to improved antimicrobial action compared to the free Schiff base.[21]

X. Comparative Study Between Schiff Bases and Metal Complexes:

Sr.No	Parameter	Schiff Base	Metal Complex
1.	Structure	Contains azomethine (-C=N-) group	Metal ion coordinated with Schiff base ligand
2.	Colour	Usually pale yellow or crystalline	Often dark coloured due to metal coordination
3.	Solubility	More soluble in organic solvents	Less soluble due to chelation
4.	Stability	Moderate stability	Higher thermal and chemical stability
5.	Biological Activity	Shows antimicrobial activity	Enhanced antimicrobial activity
6.	Melting Point	Lower melting point	Higher melting point

7.	Electrical Nature	Non-conductive	May show conductive behaviour
8.	Magnetic Property	Usually non-magnetic	Can exhibit magnetic properties

Table No:1 Comparative Study Between Schiff Bases and Metal Complexes

Comparative Study of Schiff Base Powder and Metal Complex Antimicrobial Powder Using Bread Preservation Test

To evaluate the antimicrobial efficiency of the synthesized compounds, a bread preservation experiment was carried out using Schiff base powder and its corresponding metal complex powder. Bread samples were separately treated with both compounds and kept under similar environmental conditions for observation of fungal growth and spoilage.[21]

XI. Observations from Bread Test

The untreated bread sample showed visible fungal growth within a few days, indicating normal microbial contamination. The bread treated with Schiff base powder showed delayed fungal growth compared to the untreated sample, demonstrating moderate antimicrobial activity. However, the bread treated with the metal complex antimicrobial powder remained fresh for a longer duration and showed very little fungal contamination.

Table No:2 Observations from Bread Test

Sr.No	Parameter	Schiff Base Powder	Metal Complex Antimicrobial Powder
1.	Antimicrobial Activity	Moderate	Strong
2.	Fungal Growth on Bread	Reduced	Highly Reduced
3.	Bread Preservation Ability	Moderate	Excellent
4.	Stability	Good	Better Stability
5.	Biological effectiveness	Moderate	Higher

This result indicates that the antimicrobial activity increased significantly after formation of the metal complex.[22]

Explanation of Enhanced Activity of Metal Complex

The higher antimicrobial activity of the metal complex may be due to the chelation effect. During complex formation, the Schiff base ligand coordinates with the metal ion, which can increase the penetration of the compound into microbial cells. This interaction affects important cellular processes of microorganisms and slows their growth.

The metal ion also contributes to biological activity by interacting with proteins and enzymes present in microbial cells. As a result, the metal complex becomes more effective than the Schiff base alone in controlling microbial contamination.[23]

XII. Importance of Schiff Bases in Research

Schiff bases are compounds containing an azomethine group (–C=N–), formed by condensation of primary amines with aldehydes or ketones. These compounds are widely investigated because of their important biological and chemical properties.

Some important applications include:

- Antibacterial and antifungal studies
- Drug development research
- Preparation of metal complexes
- Catalytic applications
- Analytical chemistry
- Material science studies

Metal complexes derived from Schiff bases are especially important because they often show improved biological activity compared to free ligands.[23]

Relevance of Bread Preservation Test

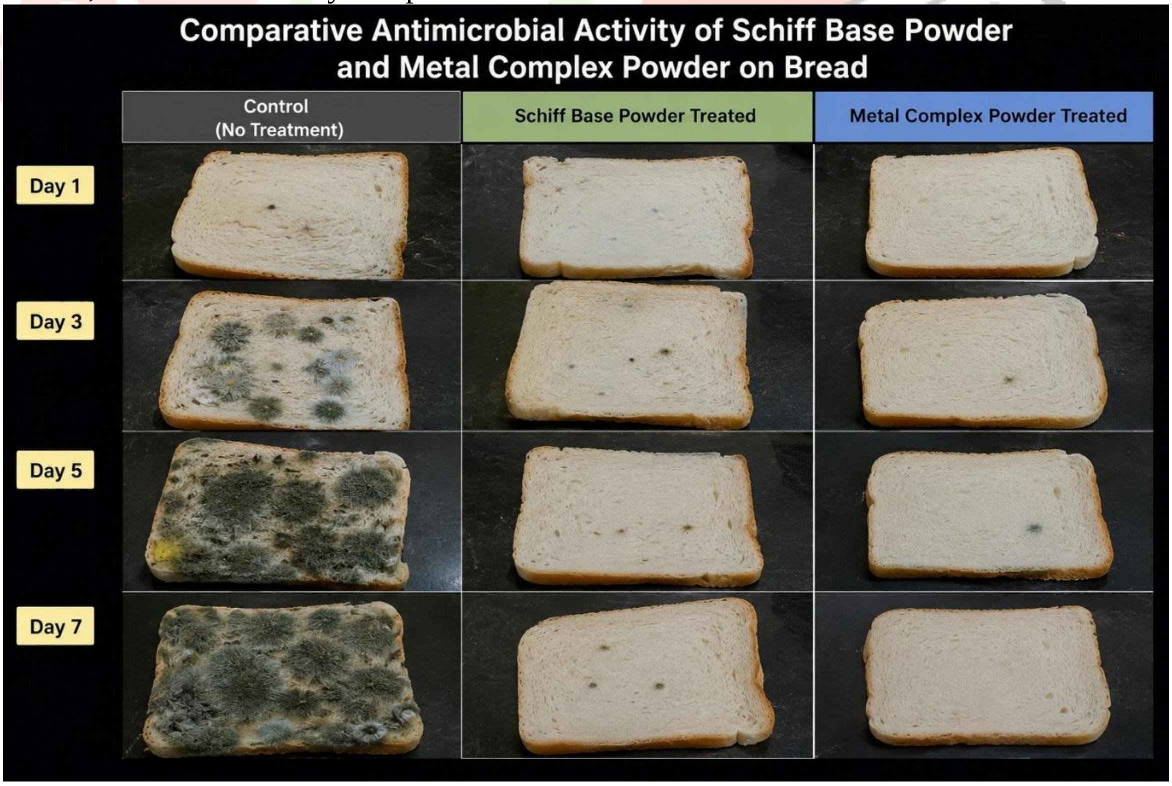
The bread preservation method is a simple and economical technique used to evaluate antimicrobial properties. Reduction in fungal growth on bread indicates the ability of the synthesized compounds to inhibit microbial activity.

In this project, the bread test successfully demonstrated the comparative effectiveness of both synthesized powders and supported the antimicrobial potential of the metal complex.[24]

XIII. Result and Discussion:

The comparative antimicrobial study using the bread preservation test showed that the synthesized Schiff base metal complex exhibited better antimicrobial activity than the free Schiff base. The untreated bread sample showed rapid fungal growth, while the bread treated with Schiff base powder showed only moderate inhibition of fungal contamination. In contrast, the bread treated with the zinc metal complex remained fresh for a longer duration and showed very little fungal growth.

The enhanced activity of the metal complex may be due to the chelation effect, which increases lipophilicity and improves penetration of the compound into microbial cells. The metal ion also enhances interaction with microbial enzymes and proteins, resulting in stronger antimicrobial action. Therefore, Schiff base metal complexes demonstrated superior bread preservation ability, higher biological effectiveness, and better stability compared to the Schiff base alone.



XIV. Conclusion:

The comparative bread preservation study showed that the synthesized metal complex antimicrobial powder exhibited stronger antimicrobial activity than the Schiff base powder. The Schiff base demonstrated moderate inhibition of fungal growth, while the metal complex significantly reduced microbial contamination and improved preservation of bread. The enhanced activity may be attributed to coordination between the Schiff base ligand and metal ion, which improves biological effectiveness. Therefore, Schiff base metal complexes can be considered promising compounds for future antimicrobial applications.

XV. Reference:

1.Dr.S.Arockia Edwin Xavier,N B Srividya "Synthesis and study of Schiff base ligands"- published 2014.

2. https://en.m.wikipedia.org/wiki/Schiff_base

3. Singh, K., Barwa, M. S., & Tyagi, P. (2006). Synthesis, characterization and biological studies of Co(II), Ni(II), Cu(II) and Zn(II) complexes with bidentate Schiff bases derived by heterocyclic ketone. *European Journal of Medicinal Chemistry*, *41*(1), 147–153.

4. S. Arockia Edwin Xavier and N. B. Srividya, Synthesis and Study of Schiff Base Ligands (2014).

5. C. M. Da Silva et al., Schiff Bases: A Short Review of Their Antimicrobial Activities, Journal of Advanced Research, 2011.

6. N. Raman et al., Synthesis and Antimicrobial Studies of Schiff Base Metal Complexes, Transition Metal Chemistry, 2001.

7. D. N. Dhar and C. L. Taploo, Schiff Bases and Their Applications, 1982.

8. K. C. Gupta and A. K. Sutar, Catalytic Activities of Schiff Base Transition Metal Complexes, 2008.

9.Da Silva, C. M., Da Silva, D. L., Modolo, L. V., Alves, R. B., De Resende, M. A., Martins, C. V. B., & De Fátima, Â. (2011). Schiff bases: A short review of their antimicrobial activities. *Journal of Advanced Research*, *2*(1), 1–8.

10.Raman, N., Kulandaisamy, A., Shunmugasundaram, A., & Jeyasubramanian, K. (2001). Synthesis, structural characterization, redox and antimicrobial studies of Schiff base copper(II), nickel(II), cobalt(II), manganese(II), zinc(II) and oxovanadium(II) complexes. *Transition Metal Chemistry*, *26*(1–2), 131–135.

11.Joshi, K. T., & Pancholi, A. M. (2012). Schiff base: A versatile pharmacophore. *International Journal of Research in Pharmacy and Chemistry*, *2*(4), 933–944.

12.Dhar, D. N., & Taploo, C. L. (1982). Schiff bases and their applications. *Journal of Scientific and Industrial Research*, *41*, 501–506.

13.Gupta, K. C., & Sutar, A. K. (2008). Catalytic activities of Schiff base transition metal complexes. *Coordination Chemistry Reviews*, *252*(12–14), 1420–1450.

14. PubChem. (2026). Benzaldehyde. National Center for Biotechnology Information. Retrieved from

15. Advanced Organic Chemistry March, J. *Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 4th Edition, Wiley-Interscience.

16. Organic Chemistry Morrison, R.T., Boyd, R.N. *Organic Chemistry*, 6th Edition, Prentice Hall.

17. Inorganic Chemistry Shriver, D.F., Atkins, P.W. *Inorganic Chemistry*, Oxford University Press.

18. European Journal of Medicinal Chemistry Research reports describing antimicrobial potential of Schiff base metal complexes.

19. Journal of Coordination Chemistry Studies on coordination behavior and structural characterization of Schiff base complexes.

20. Transition Metal Chemistry Publications related to synthesis and biological activity of transition metal complexes.

21. Textbook of Pharmaceutical Chemistry Medicinal and pharmaceutical importance of Schiff bases and metal coordination compounds.

22. [ScienceDirect](https://www.sciencedirect.com)Research articles related to Schiff bases and antimicrobial metal complexes.

23. [MDPI Journals](https://www.mdpi.com)Studies on biological activity of Schiff base metal complexes.

24. [PubMed Central (PMC)](https://pmc.ncbi.nlm.nih.gov) Open-access scientific literature on transition metal complexes and antimicrobial activity.