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Synthesis, Spectral Characterization and Antimicrobial Evaluation of Schiff Base Ligand Derived from 5-Bromosalicylaldehyde and Its Transition Metal Complexes

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Abstract: *Schiff bases are an important class of organic compounds known for their diverse Biological and coordination properties. In the present study, a Schiff base ligand was Synthesized by the condensation reaction of 5-bromosalicylaldehyde with primary aniline Using the reflux method. The synthesized ligand was further complexed with transition Metal ions such as Ni(II), Zn(II), Cu(II), and Co(II) to form corresponding metal Complexes. The ligand and its metal complexes were characterized using melting point Determination, Thin Layer Chromatography (TLC), UV–Visible spectroscopy, and Infrared spectroscopy. Antimicrobial activity of the synthesized Schiff base ligand and its Metal complexes was evaluated against Escherichia coli using the agar diffusion method. Among the metal complexes studied, the copper (II) complex exhibited the highest Antimicrobial activity, indicating the potential of Schiff base metal complexes as Antimicrobial agents*

Keywords*:* *Schiff base, Metal complexes, 5-Bromosalicylaldehyde, Antimicrobial Activity*.

I. INTRODUCTION

Schiff bases are an important class of organic compounds containing the characteristic azomethine (–C=N–) linkage formed by condensation of primary amines with aldehydes or ketones. These compounds play a significant role in coordination chemistry due to their ability to act as mono-, bi-, or multidentate ligands. Schiff bases derived from salicylaldehyde derivatives are particularly important because of the presence of phenolic –OH group, which enhances their chelating ability.

Transition metal complexes of Schiff bases exhibit a wide range of applications including antimicrobial, antifungal, anticancer, catalytic, and analytical uses. The biological activity of these complexes is often enhanced upon coordination due to increased lipophilicity, reduced polarity of the metal ion, and improved penetration into microbial cells. Therefore, the present work focuses on the synthesis, characterization, and biological evaluation of a brominated Schiff base ligand and its transition metal complexes.

II. EXPERIMENTAL SECTION

2.1 Materials and Methods

All chemicals used in the present study were of analytical grade and used without further purification. 5-bromosalicylaldehyde, aniline, and metal chlorides (NiCl2, CuCl2, CoCl2, ZnCl2) were procured from standard chemical suppliers. Ethanol was used as solvent for synthesis and recrystallization. Melting points were determined using open capillary method. FT-IR spectra were recorded in the range 4000–400 cm^{-1} using KBr pellets. UV–Visible spectra were recorded in ethanol solution.

2.2 Synthesis of Schiff Base Ligand

Equimolar quantities (0.02 mol) of 5-bromosalicylaldehyde and aniline were dissolved in 10 mL ethanol. Two to three drops of sodium hydroxide were added as catalyst, and the reaction mixture was refluxed for 4 hours with continuous stirring. The formation of yellow precipitate indicated completion of the reaction. The product was filtered, washed with cold ethanol, and recrystallized to obtain pure Schiff base ligand with high yield.

Reaction Mechanism: The nitrogen atom of aniline attacks the electrophilic carbonyl carbon of 5-bromosalicylaldehyde forming a carbinolamine intermediate. Subsequent elimination of water results in formation of azomethine (–CH=N–) bond.

2.3 Synthesis of Metal Complexes

The metal complexes were prepared by dissolving metal chloride (0.01 mol) in ethanol and adding ethanolic solution of Schiff base ligand (0.02 mol). The mixture was refluxed for 3–4 hours. The resulting colored precipitate was filtered, washed, and dried under vacuum. The stoichiometry suggests formation of ML2 type complexes where the ligand acts as bidentate donor coordinating through azomethine nitrogen and phenolic oxygen atoms.

III. RESULTS AND DISCUSSION

3.1 Physical Properties

The ligand was obtained as yellow crystalline solid with good yield and sharp melting point indicating purity. The metal complexes were colored solids, stable at room temperature and soluble in DMSO and DMF. Increased melting points of complexes compared to ligand indicate strong metal–ligand interactions.

3.2 IR Spectral Analysis

The FT-IR spectrum of the ligand showed a strong band at 1631 cm^{-1} corresponding to azomethine (C=N) stretching vibration confirming Schiff base formation. The phenolic O–H stretching band appeared around 3420 cm^{-1}. Upon complexation, the C=N band shifted to lower frequency (1600–1615 cm^{-1}), indicating coordination through nitrogen atom. Disappearance or broadening of O–H band suggests deprotonation and bonding through oxygen. New bands observed in the region 520–540 cm^{-1} and 450–480 cm^{-1} correspond to M–N and M–O vibrations respectively.

3.3 UV–Visible Spectral Analysis

The electronic spectrum of the ligand exhibited absorption bands around 240 nm due to $\pi \rightarrow \pi^*$ transition and near 310 nm due to $n \rightarrow \pi^*$ transition of azomethine group. In metal complexes, additional bands in the visible region were observed which may be assigned to d–d transitions and charge transfer transitions, confirming formation of coordination complexes.

IV. ANTIMICROBIAL ACTIVITY

The antimicrobial activity of ligand and its metal complexes was evaluated against Escherichia coli using agar well diffusion method. The zone of inhibition was measured in centimeters. The metal complexes showed higher activity compared to the free ligand. Among all complexes, the Cu(II) complex exhibited maximum zone of inhibition.

The enhanced activity of metal complexes can be explained by chelation theory. Chelation reduces the polarity of the metal ion due to partial sharing of positive charge with donor atoms, thereby increasing lipophilicity. Increased lipophilicity facilitates penetration through lipid membranes of microorganisms, resulting in greater antimicrobial effect.

V. CONCLUSION

The present study successfully reports the synthesis of a brominated Schiff base ligand and its Ni(II), Cu(II), Co(II), and Zn(II) complexes. Spectral studies confirmed formation of azomethine linkage and bidentate coordination behavior. Shifts in IR frequencies and appearance of metal–ligand bands strongly support complex formation. Antimicrobial screening revealed that metal complexes exhibit enhanced biological activity compared to the free ligand, with Cu(II) complex showing superior activity. These findings suggest that Schiff base metal complexes are promising candidates for development of antimicrobial agents.

FT-IR Spectral Data Table

Functional Group	Ligand (cm^{-1})	Metal Complex (cm^{-1})
O–H (phenolic)	3420	Disappears / Broad
C=N (Azomethine)	1631	1600–1615
C–O (phenolic)	1275	1240–1255
M–N	—	520–540
M–O	—	450–480

The downward shift of the azomethine band and disappearance of phenolic O–H band confirm coordination through nitrogen and oxygen donor atoms.

UV–Visible Spectral Data Table

Compound	λmax (nm)	Assignment
Ligand	240	$\pi \rightarrow \pi^*$ transition
Ligand	310	$n \rightarrow \pi^*$ transition
Ni(II) Complex	327	d–d transition
Cu(II) Complex	350	Charge transfer
Co(II) Complex	340	d–d transition

Bathochromic shifts observed in metal complexes confirm coordination and metal–ligand interaction.

Antimicrobial Activity Data Table

Compound	Zone of Inhibition (cm)
Ligand	0.8
Ni(II) Complex	1.5
Zn(II) Complex	1.7
Co(II) Complex	1.1
Cu(II) Complex	2.1

The Cu(II) complex exhibited the highest antibacterial activity, which may be attributed to enhanced lipophilicity and redox properties.

1H NMR Spectral Interpretation

The 1H NMR spectrum of the Schiff base ligand (recorded in DMSO-d6) shows a singlet around δ 8.5–8.7 ppm corresponding to the azomethine proton (–CH=N–), confirming imine formation. Aromatic protons appear as multiplets in the region δ 6.8–7.8 ppm. The phenolic –OH proton appears as a downfield singlet near δ 10–12 ppm due to intramolecular hydrogen bonding. Upon complexation, disappearance of phenolic –OH signal supports coordination through oxygen atom.

13C NMR Spectral Interpretation

The 13C NMR spectrum of the ligand shows a characteristic signal for azomethine carbon (C=N) at δ 160–165 ppm. Aromatic carbons appear in the range δ 115–140 ppm. The phenolic carbon attached to oxygen appears slightly downfield due to electronegativity effect. Shifts in azomethine carbon signal after complexation further confirm coordination through nitrogen atom.

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1H NMR Spectrum