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Synthesis, Characterization and Study of Microbiological Activity of Some Transition Metal Ion Complexes with [N - (o - hydroxy benzylidene) Pyridine - 2 - Amine] (NOHBPA)

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ABSTRACT

A Schiff base ligand derived from o - hydroxy benzaldehyde and 2 - amino pyridine and its transition metal complexes with Fe(II), Cu(II), Ru(III) and Rh(III) have been synthesized which were characterized by elemental analysis, molar conductance, magnetic susceptibility, electronic spectra, IR and ESR spectroscopy. The metal complexes are coloured, solid and non - hygroscopic in nature. The Schiff base ligand exhibits tridentate nature, coordination through azomethine nitrogen, phenolic oxygen and nitrogen of pyridine ring to the metal ions. On the basis of electronic spectral analysis and magnetic susceptibility values, geometry of complexes were proposed to be octahedral. The molar conductivity data of complexes suggests their non - electrolytic nature. The ligand and metal complexes have been screened for their microbiological activity.

Keywords: Schiff base (NOHBPA), Metal Complexes and Microbiological activity.

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INTRODUCTION

Schiff bases are an important class of ligand in the field of coordination chemistry [1]. During the past two decades, considerable attention has been paid to the chemistry of the metal complexes of Schiff bases containing nitrogen and other donor atoms [2-5]. A large number of Schiff bases and their metal complexes have been found to possess important biological and catalytic activity [6-7]. Due to their great flexibility and diverse structural aspects, wide ranges of Schiff bases have been synthesized and their complexation behaviour was studied [8]. Schiff bases are also used as an efficient reagent in trace analysis of some metal cations [9-10].

In the present paper, metal complexes of Fe(II), Cu(II), Ru(III) and Rh(III) with Schiff base ligand derived from *o*-hydroxy benzaldehyde and 2- amino pyridine have been synthesized and these complexes were characterized by elemental analysis, magnetic susceptibility, molar conductivity measurements, electronic spectra, IR, and ESR spectrum to determine the mode of bonding and geometry. The microbiological activities of the ligand and their metal complexes have also been studied.

MATERIALS AND METHODS

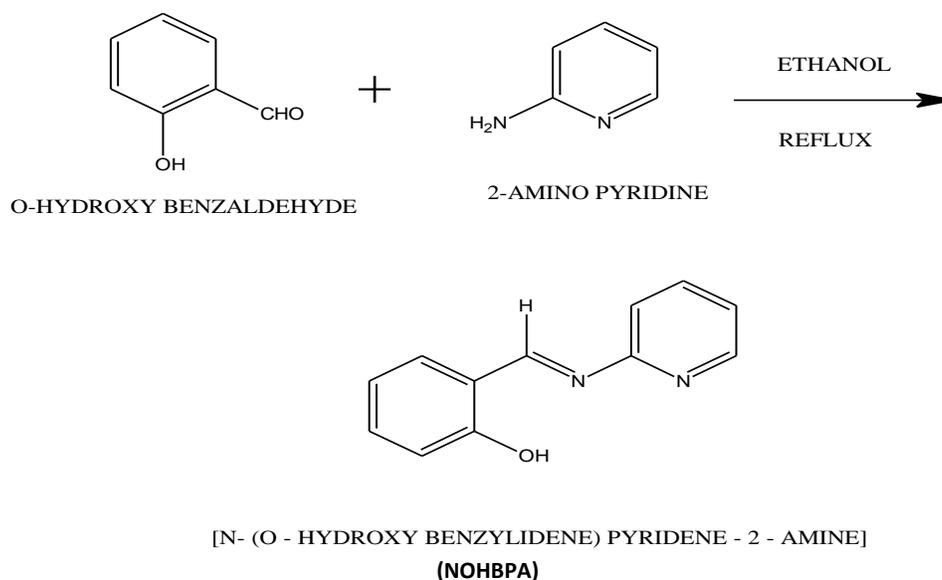
Experimental

All the used chemicals and solvents were of AR grade and were used without further purification. All the reagents used for the preparation of Schiff base and metal salts were obtained from Loba chemie. The percentage compositions of the elements (CHNO) of the compounds were determined using an Elementar Vario Micro Superuser (CHNS) analyzer. The metal contents of the complexes were analyzed by ICPAES (Inductive coupled plasma atomic emission spectroscopy) in an Iris Intrepid II XSP model instrument. The Infrared spectra were recorded as potassium bromide (KBr) discs using 8400S FTIR Perkin Elmer Spectrophotometer. The electronic Spectrum of complexes were recorded on ELICO SL -159 UV-Vis Spectrophotometer. The Electron spin resonance spectra (ESR) were recorded on Varian E - 112 ESR Spectrometer at I.I.T. Mumbai. Melting point of ligand and their metal complexes were recorded using Differential Scanning Calorimeter (DSC) instrument. The molar conductivity measurements were made on ELICO CM - 180 model using methanol as the solvent. Magnetic susceptibility of complexes was measured by Gouy's method using mercury tetraisothiocyanatocobaltate as the callibrant.

Synthesis of ligand [N - (*o* - hydroxy benzylidene) pyridine - 2 - amine] (NOHBPA):

The Schiff base ligand NOHBPA was synthesized by refluxing equimolar amount of ethanolic solution of *o* - hydroxy benzyldehyde with 2 - amino pyridine for 5 - 6 hours. On cooling the reaction mixture, a sharp yellow crystal product separated out (yield 80%, m.p.70⁰-71⁰C) which was collected by filtration. The resulting NOHBPA was recrystallised using aqueous

ethanol as the procedure recommended by Vogel [11]. The purity of product was checked by TLC method and characterized by elemental and spectral analysis.



Preparation of complexes with Schiff base ligand (NOHBPA)

The complexes of Fe(II) and Cu(II)) were prepared by refluxing respective hydrated metal chloride in ethanolic solution of ligand in molar ratio of 1: 2 at pH 5 - 6. The resulting mixture was refluxed on water bath for 2 - 3 hrs. After cooling at room temperature, brown colored solid were separated out which was filtered, washed with water and then with ethanol. The resulting product was recrystallised and dried in vacuum desiccator over CaCl₂ anhydrous (yield 60 - 70%).

For the preparation of Ru(III) and Rh(III) complexes, respective hydrated metal chloride were refluxed with ligand in molar ratio of 1:3 at pH 4 - 6 on water bath for 5 - 6 hrs. Brownish Black coloured product separate out on cooling which was collected by filtration, washed with water and then ethanol. The resulting product was recrystallised and dried in vacuum desiccator over CaCl₂ anhydrous (yield 40 - 50%). All the metal Complexes were found to be insoluble in water and soluble in most of common organic solvents.

Biological Studies

Antibacterial and antifungal activity of ligand and their complexes have been determined by cup plate method. The stock solution of each compound was prepared by dissolving 20 mg of compound in methanol and the volume was made up to 10ml with same solvent. The stock solution of 2000ppm of each compound thus prepared on active ingredient basis was kept at room temperature till used. Sterile Mueller Hinton agar plates for bacterial test cultures and Sabourauds agar plates for fungus *Candida albicans* were seeded with 1ml of 24 hour old, 0.1 O.D. cultures. Sabourauds agar plates were surface spread with 0.2 ml of 48

hour old *Aspergillus* culture. The compounds to be tested (50 μ l) were added to the wells punched in the above media. The plates were incubated at 37°C / R.T. for 48 hours depending on the cultures. The zone of inhibition around the wells was measured in millimeters.

RESULTS AND DISCUSSION

All the metal complexes are colored, solid, stable at room temperature and non-hygroscopic in nature. The Analytical and physical data of ligand and their metal complexes are recorded in Table - 1. The metal complexes exhibit 1:2 and 1:3 (metal-ligand) stoichiometry

Table - 1. The Analytical and physical data of ligand and Metal complexes

Compounds (Colour)	Molecular Weight	M.P.	% Elemental Analysis Found (Calculated)				μ_{eff} B.M.	Λ_m Ohm^{-1} $\text{cm}^2\text{mol}^{-1}$
			C	H	N	M		
NOHBPA (Yellow)	198.14	71°C	73.12 (72.73)	5.14 (5.05)	14.41 (14.14)	-		
[Fe(NOHBPA) ₂] (Brown)	450.13	> 300°C	64.01 (64.03)	3.90 (3.99)	12.40 (12.45)	12.40 (12.41)	5.15	38.80
[Cu(NOHBPA) ₂] (Brown)	457.82	177°C	62.90 (62.96)	3.90 (3.93)	12.20 (12.24)	13.80 (13.89)	1.78	30.20
[Ru(NOHBPA) ₃].H ₂ O (Brownish black)	710.52	60°C	60.80 (60.85)	3.75 (3.80)	11.80 (11.83)	14.20 (14.23)	1.81	24.10
[Rh(NOHBPA) ₃].H ₂ O (Brownish Black)	712.32	> 300°C	60.90 (60.97)	3.70 (3.79)	11.75 (11.80)	14.40 (14.45)	1.88	28.40

Infrared Spectral Analysis

Infrared spectra were recorded with a Perkin Elmer FTIR -8400S Spectrometer (4000-400 cm^{-1}) using KBr pellets. On the basis of this, the presence of important functional groups in the compound can be identified. The Infrared spectrum of the ligand was compared with the spectra of Fe(II), Cu(II), Ru(III) and Rh(III) complexes. The typical IR spectra were shown in Fig.1, 2, 3, 4 and 5 and data was summarized in Table-2 along their assignment.

The IR spectrum of the ligand shows broad band at 1610 cm^{-1} , which was assigned to $\nu_{\text{C}=\text{N}}$ stretching of azomethine group [12]. In complexes this band was shifted to lower regions, 1604 cm^{-1} , 1605 cm^{-1} , 1607 cm^{-1} and 1608 cm^{-1} for Fe(II), Cu(II), Ru(III) and Rh(III) complexes respectively, suggesting the coordination of azomethine nitrogen to metal atom in complexation [13]. This was due to the donation of electron density from Nitrogen to metal. IR spectrum of the ligand shows a weak band around 2750 - 3000 cm^{-1} due to intramolecular hydrogen bonded -OH group [14]. This band is absent in the spectra of complexes indicating the dissociation of the phenolic proton on complexation and involvement of phenolic anionic oxygen in coordination [15]. Moreover, the strong band at 1280 - 1270 cm^{-1} due to C - O (phenolic) in the ligand has been shifted to the 1330 - 1319 cm^{-1} in the spectra of complexes. The strong absorption band due to pyridine ring occurring at 1495 cm^{-1} $\nu_{\text{C-N-C}}$ has shifted to higher region by 25 - 40 cm^{-1} in the complexes showing the participation of nitrogen atom of

pyridine ring in the complexation [16]. The IR spectrum of Ru(III) and Rh(III) metal complexes exhibit a broad and strong absorption band in the region 3520 - 3170cm⁻¹ confirms the presence of $\nu(\text{OH})$ absorption for lattice water [17]. New bands were observed between 800 - 500 cm⁻¹ region in the complexes, which were absent in the spectrum of ligand. The bands between 500 - 565cm⁻¹ were assigned to stretching frequencies of $\nu(\text{M-O})$ [18], the band between 471 - 450 cm⁻¹ have been assigned to the stretching frequencies $\nu(\text{M-N})$ respectively [19-21].

Table-2: The important IR bands of the Ligand and Their Metal Complexes

Compound	$\nu(\text{-OH})$	$\nu(\text{C=N})$	$\nu(\text{C-N})$	$\nu(\text{C-O})$	$\nu(\text{M-N})$	$\nu(\text{M-O})$
NOHBPA	2800	1610	1495	1277	-	-
Fe(NOHBPA) ₂	-	1604	1534	1328	535	450
Cu(NOHBPA) ₂	-	1605	1531	1329	550	450
[Ru(NOHBPA) ₃].H ₂ O	3415	1606	1519	1319	561	471
[Rh(NOHBPA) ₃].H ₂	3438	1607	1519	1322	565	465

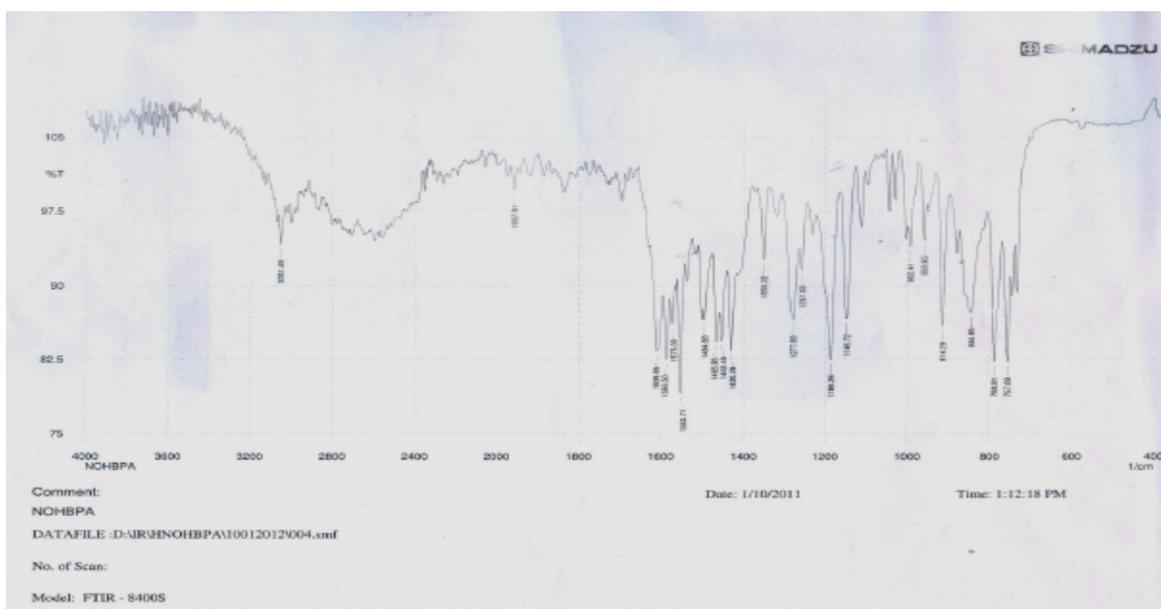


Figure-1: IR Spectrum of NOHBPA Ligand

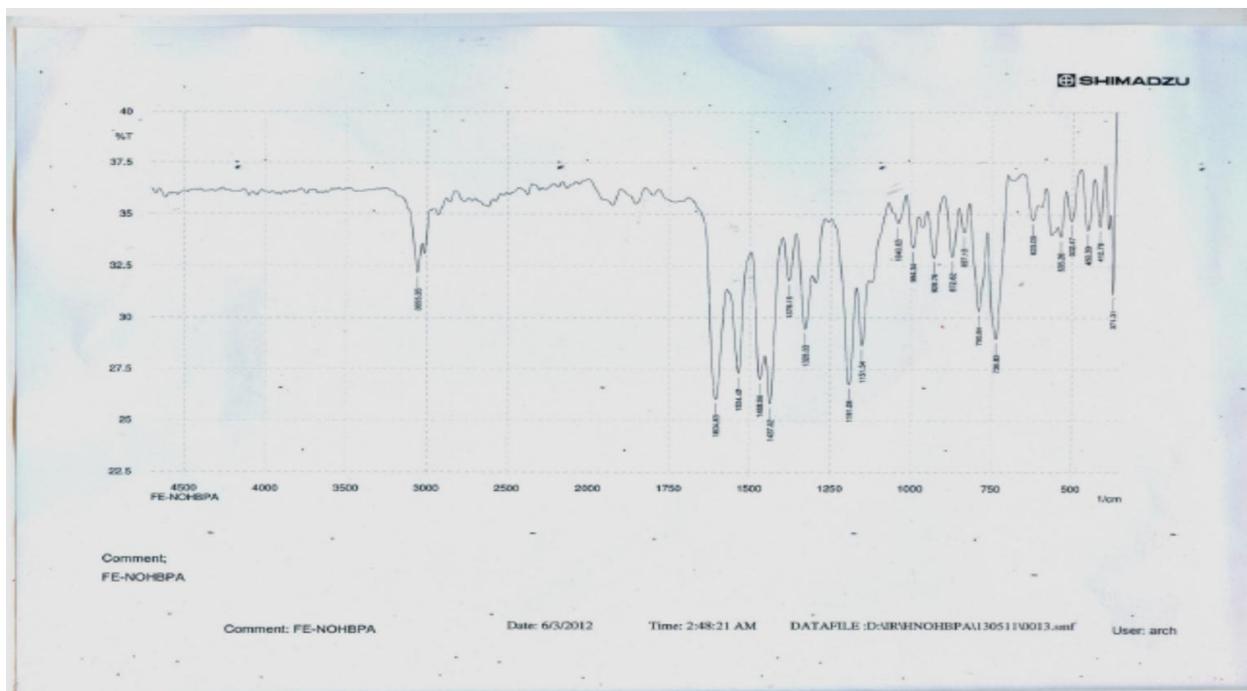


Figure-2: IR Spectrum of Fe(NOHBPA)₂ complex.

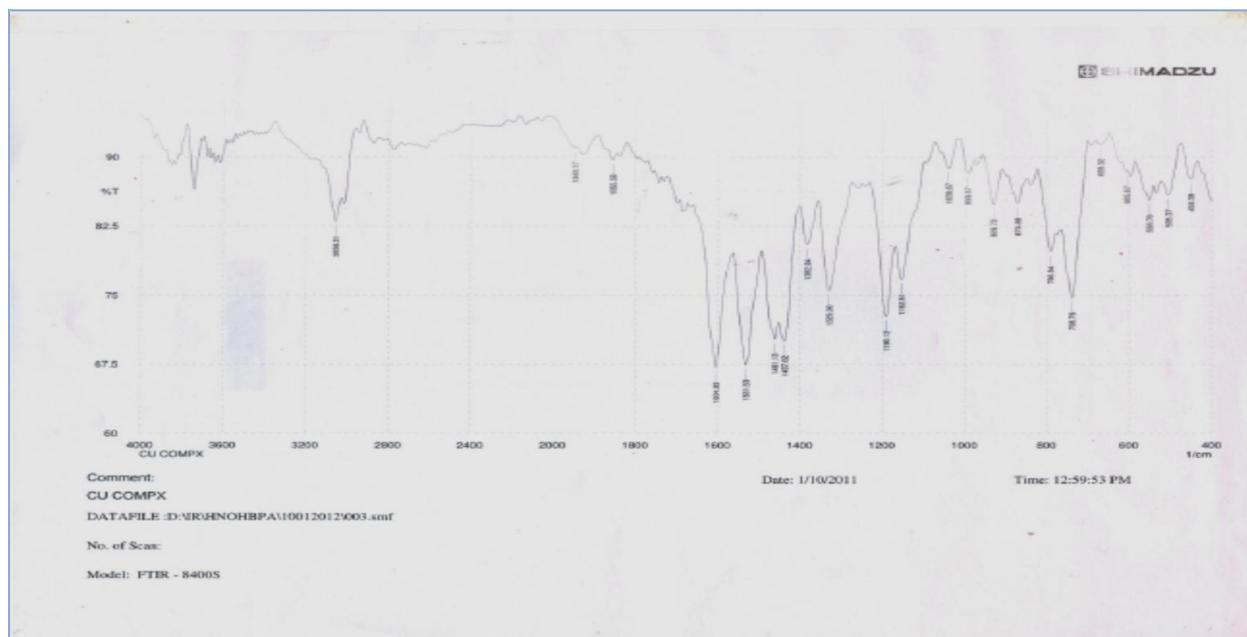


Figure-3: IR Spectrum of Cu(NOHBPA)₂ complex.

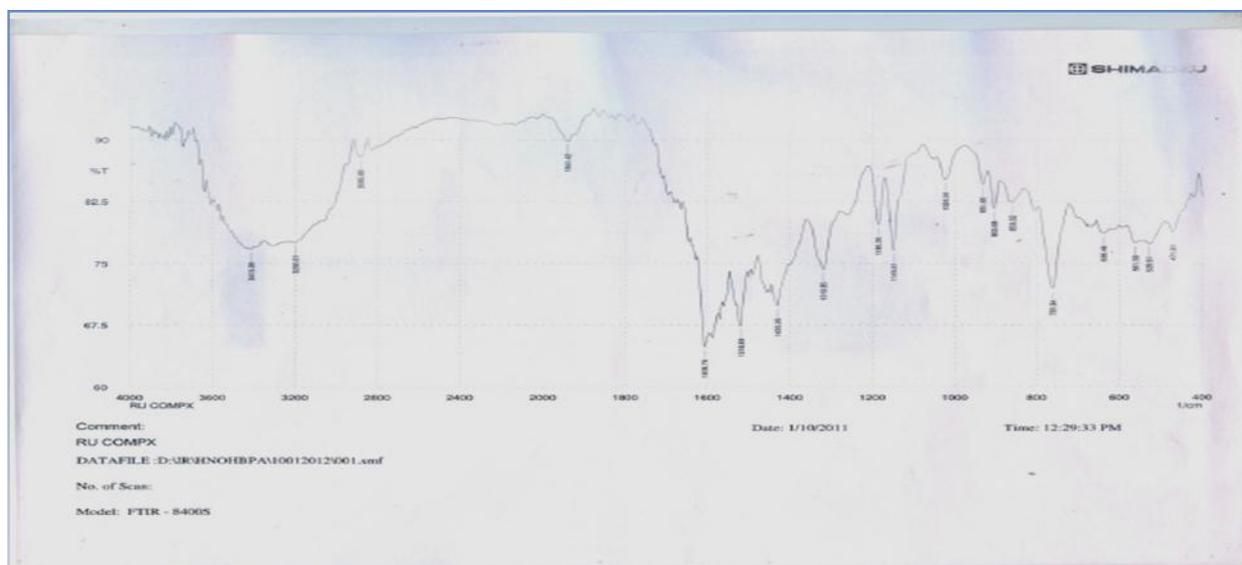


Figure-4: IR Spectrum of Ru(NOHBPA)₃.H₂O complex.

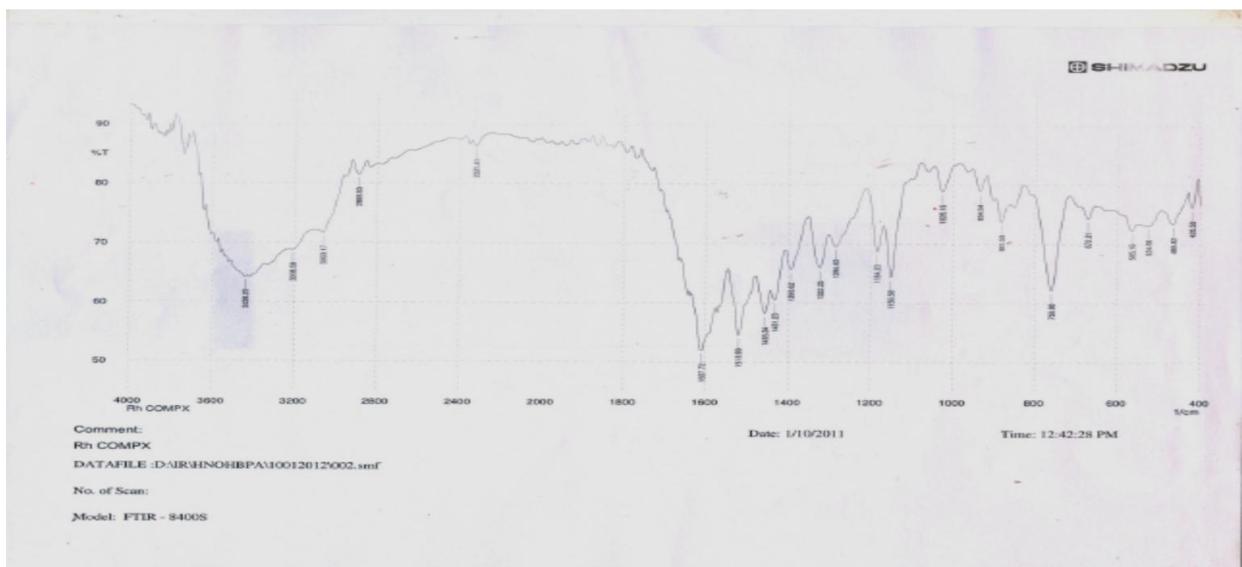


Figure-5: IR Spectrum of Rh(NOHBPA)₃.H₂O complex.

Molar Conductance

The molar conductance values of 1×10^{-3} M solution of metal complexes in methanol were measured at room temperature (Table - 1) using an ELICO Conductivity meter (cell constant 1.0 cm^{-1}). These values were compared with known molar conductivities [22-23] which indicates the non - electrolytic nature [24] of the complexes.

Electronic spectra and Magnetic susceptibility measurements of complexes

In UV-Visible electromagnetic radiation, the transitions are associated with the electronic energy levels of the compound under investigation. The electronic spectra were

recorded on ELICO SL - 159 UV-Visible Spectrophotometer. The transition metal ions occur in a variety of structural environments. Because of this, the electronic structures are extremely varied. The electronic structures have been identified with UV-Visible spectroscopy.

The nature of ligand field around the metal ion and the geometry of complexes have been deduced from the electronic spectra.

The electronic absorption spectra of Fe(II) complex exhibit the band around $18,867.92 \text{ cm}^{-1}$ (530nm) at room temperature which may be assigned to ${}^5T_{2g} \rightarrow {}^5E_g$ transition [25-26] suggesting octahedral geometry and paramagnetic nature of complexes which is further supported by the magnetic moment value 5.15 B.M. The Cu(II) complex exhibit the band at $18,518.52 \text{ cm}^{-1}$ (540nm) which is assignable to ${}^2E_g \rightarrow {}^2T_{2g}$ transition [26-27] suggesting octahedral geometry around Cu(II) ion. The Cu(II) complex showed magnetic moment value lie in the range 1.76 - 1.78 B.M. which is consistent with octahedral geometry.

The Ru(III) and Rh(III) complexes display band at 18181.18 cm^{-1} (550nm) and 19607.84 cm^{-1} (510nm) which may be assigned to ${}^2T_{2g} \rightarrow {}^4T_{2g}$ transition [28] suggesting octahedral geometry of complexes. The room temperature magnetic moment value of Ru(III) and Rh(III) complexes lie in the range of 1.73 - 1.90 B.M. attributed to Octahedral structure. Electronic Spectra and Magnetic Moment of the Complexes are listed in Table-3.

Table - 3. Electronic Spectra and Magnetic Moment of the Complexes

Compound	Band, λ max (nm)	assignments	μ_{eff} (B.M.)
[Fe(NOHBPA) ₂]	530	${}^5T_{2g} \rightarrow {}^5E_g$	5.15
[Cu(NOHBPA) ₂]	540	${}^2E_g \rightarrow {}^2T_{2g}$	1.78
[Ru(NOHBPA) ₃].H ₂ O	550	${}^2T_{2g} \rightarrow {}^4T_{2g}$	1.81
[Rh(NOHBPA) ₃].H ₂ O	510	${}^2T_{2g} \rightarrow {}^4T_{2g}$	1.88

Electronic Spin Resonance Spectra

ESR spectra of complexes provide information about the extent of the delocalization of unpaired electron. In the present study, the ESR spectra of complexes have been recorded on X - band at frequency 9.5 GHZ under the magnetic field strength 3400 gauss in DMF at room temperature (fig. 6 - 9) and their g_{\parallel} , g_{\perp} , g_{avg} , Δg , and G values have been calculated. The values of ESR parameters for Fe(II), Cu(II), Ru(III) and Rh(III) complexes viz. g_{\parallel} , g_{\perp} , g_{avg} , Δg , and G presented in Table - 4.

ESR spectra of the complexes revealed two g values (g_{\parallel} and g_{\perp}). the trend $g_{\parallel} > g_{\perp}$ shows that the unpaired electron is delocalized in $dx^2 - y^2$ orbital in the ground state of metal and spectra are characteristics of axial symmetry. The parameter g_{avg} was obtained by equation $[(g_{\text{avg}}) = 1/3 (g_{\parallel} + 2g_{\perp})]$. Kvelson & Neiman²⁹ have reported that, $g_{\parallel} > 2.3$ is the characteristics of an ionic environment and $g_{\parallel} < 2.3$ indicates a covalent character in metal ligand bonding. Applying this criterion, in the present compounds g_{\parallel} indicate the prevalence of covalent character in metal - ligand bond³⁰. The exchange coupling interaction has been explained by

Hathaway expression $G = (g_{\parallel} - 2) / (g_{\perp} - 2)$. According to Hathaway if the value of G is greater than four ($G > 4$), the exchange interaction is negligible whereas when the value of G is less than four ($G < 4$), a considerable exchange interaction is indicated in the complex. It is observed that G value for these complexes are less than four ($G < 4$), indicating considerable exchange interaction the complexes [31-32].

Table - 4. Electronic spin resonance parameters of the complexes

Metal complexes	g_{\parallel}	g_{\perp}	g_{avg}	Δg	G
$Fe(NOHBPA)_2$	2.266	2.084	2.145	0.182	3.156
$Cu(NOHBPA)_2$	2.282	2.078	2.144	0.204	3.634
$[Ru(NOHBPA)_3].H_2O$	2.250	2.076	2.135	0.173	3.226
$[Rh(NOHBPA)_3].H_2O$	2.331	2.146	2.208	0.185	2.264

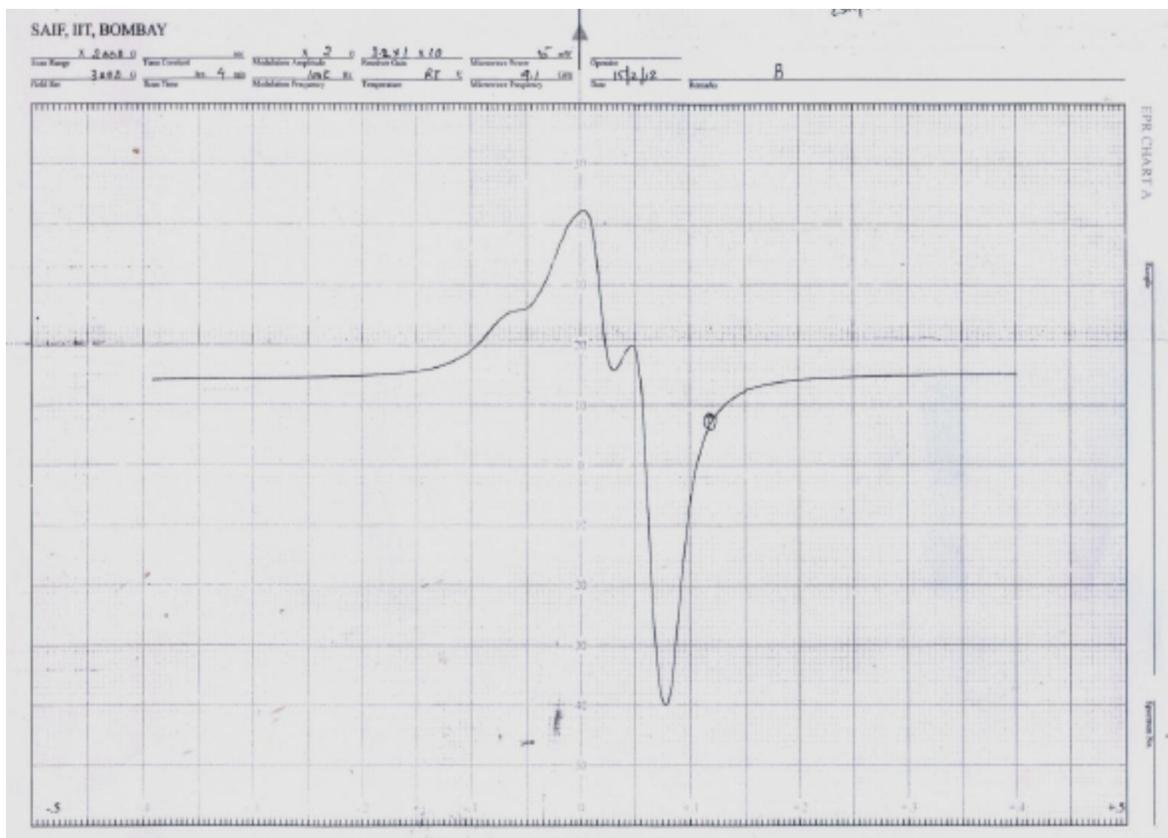


Figure-6: ESR Spectra of Fe(II) - NOHBPA complex

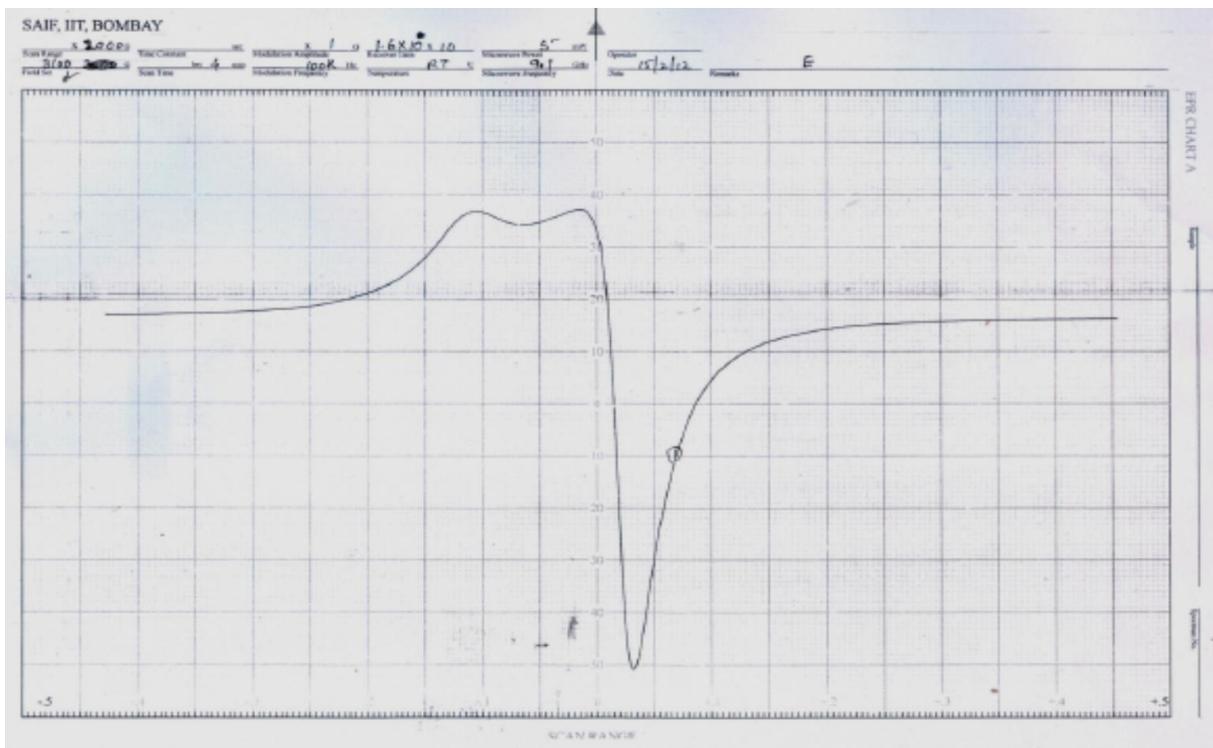
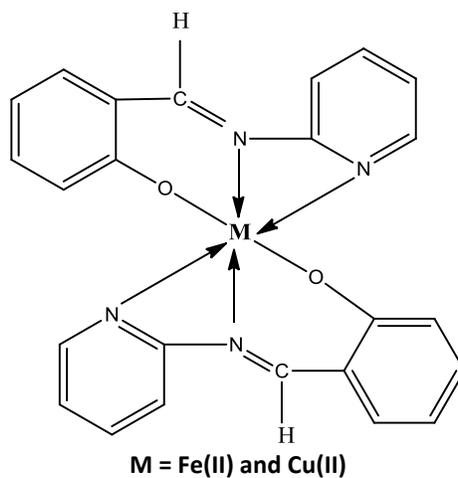
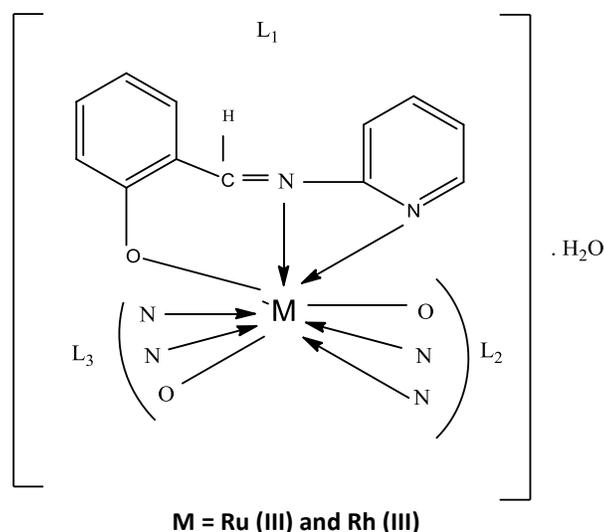


Figure-9: ESR Spectra of Rh(III) - NOHBPA complex

Proposed Structure of Complexes:





Biological Activity

Schiff base ligand and their metal complexes were screened for antibacterial activity against gram positive bacteria (*staphylococcus aureus* and *Corynebacterium diphtheria*), gram negative bacteria (*Escherichia coli* and *Klebsiella pneumonia*) and antifungal activity against (*Candidaalbicans* and *Aspergillus species*) by cup plate method [33-34]. The results of the biological activity of the metal complexes indicated the following facts.

A comparative study of the ligand and their complexes indicates that the metal chelates exhibited higher antibacterial and antifungal activity than that of the free ligand recorded in Table - 5. The increase in the biological activity of metal chelates was found due to the effect of metal ion on the metal chelates which could be explained on the basis of overtones concept and chelation theory. On chelation the polarity of the metal ion reduced to a greater extent due to the overlap of the ligand orbital and partial sharing of positive charges of metal ion with donor groups. It was further noted that the delocalization of electrons over the whole chelate ring enhanced the lipophilicity of the complexes. This increased lipophilicity³⁵ enhanced the penetration of the complexes into lipid membrane and blocking the metal sites on enzymes of microorganism. The activity was compared with zone of inhibition was measured in millimeters.

Table 5: Zone of inhibition of growth in millimeters after 48 hours of incubation

Complexes	Cultures					
	<i>S.a</i>	<i>C.d.</i>	<i>E.c</i>	<i>K.p</i>	<i>C.a</i>	<i>Asp.</i>
NOHBPA	12	10	09	11	-	11
[Fe(NOHBPA) ₂]	15	12	12	11	-	12
[Cu(NOHBPA) ₂]	17	14	10	12	11	12
[Ru(NOHBPA) ₃].H ₂ O	41	42	-	-	N.G	14
[Rh(NOHBPA) ₃].H ₂ O	46	41	-	-	N.G	18



CONCLUSION

It can be concluded from the results of above study that Schiff base ligand NOHBPA [N - (o - hydroxy benzylidene) pyridine - 2 - amine] acts as a very good tridentate complexing agent towards many transition metal ions during complexation. All the metal complexes showed enhanced microbiological activities as compared to ligand.

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