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Transition Metals-Amine Derivative Complexes with their Preparation, Characterization and Antimicrobial Evaluation

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Abstract

This paper reports the synthesis, characterization and antimicrobial evaluation of complexes prepared from different transition metals and Schiff's base ligand, 3-methoxy-4-hydroxyphenylmethyelene(2-hydroxyphenyl)amine synthesized from vanillin and 2-aminohpenol. The structural features of the resulting complexes and ligands were characterized by elemental analysis, magnetic susceptibility, molar conductance, Fourier Transform-Infra Red, UV-Vis (electronic spectra), and Atomic absorption spectroscopic methods. The FT-IR spectral data indicated the coordination of phenolic oxygen and azomethane nitrogen to the central metal ions. The results of electronic spectral studies and magnetic susceptibility measurements suggested an octahedral geometry for Zn(II), Ni(II), Cr(III), and Fe(III) complexes but square planar for Cu(II) complex. The ligands and their complexes were screened in-vitro for their antibacterial and antifungal activities against bacterial strains, (Escheria coli and Staphylococcus aureus) and fungal strains (Aspergillus niger and Colletotrichum gloeosporioides). The results demonstrated that the free ligand showed higher activities than the corresponding complexes in both bacteria and fungi, and comparable with the standard, suggesting the potential of the ligand for the use of antimicrobial test.

Keywords: antimicrobial activities; Schiff's base ligand; aminophenol; transition metal complexes.

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1. Introduction

Transition metal complexes of organic compounds are structurally known to possess considerable potential in many applications including pharmacological, diarrhea [1], analytical [2], catalytic [3], microbial [4], insecticidal, growth factors, food additive, tumor inhibitors [5] and cell divisions [6]. These multifarious features of complexes are either due to the unused coordination sites present on the metal and ligand systems, or due to the selective oxidation state of the complexed metal ions in the coordination sphere [7].

Among the variety of organic ligands, Schiff's bases named after Von Schiff are compounds with azomethine functional group (-C=N-) with N atom connected to an aryl or alkyl group are preponderant over others owing to high stability of their complexes with transition metals including Cu, Zn, Ni, Co, Cr and Fe [8]. Schiff's base in a broad sense is one having the general formula R1R2C=NR3, where R is an organic side chain. But some restrict the term to the secondary aldimines (azomethines where the carbon is connected to a hydrogen atom), thus with the general formula RCH=NR. The chain on N atom makes the Schiff's base a stable imine. Schiff's bases that contain aryl substituents are relatively more stable and more readily synthesized, while those containing alkyl substituents are relatively unstable [9]. Schiff's bases have acquired highest popularity as ligands among all the different classes of organic compounds owing to their multifarious roles in diverse fields of development. A few of the manifold distinguished features can be summarized to manifest their high importance. High electron donor ability and bathochromic properties of Schiff's bases have led to their use in analytical chemistry as gravimetric and colorimetric reagents and as metallic indicators in complexometric titration [10].

In industries azomethines and their complexes are popular pigments and dyes for cotton, wool, synthetic fibers and plastics [11]. Those bases having thermal stability up to 25 0C could be used as high temperature stabilizers for lubricating oils [12]. Oil soluble Schiff's bases have been used as sequestering agents to precipitate metal impurities of oils. Azomethines are effective inhibitors against acid corrosion of metals and alloys and as photographic developing agent precursors [9]. Schiff's bases having enolic groups are well known drying accelerators for varnishes and paints. Thin film of polyamide imides Schiff's base copolymers prepared at high temperatures and low pressures have been reported to possess strong fire resisting capacity [13]. In synthetic organic chemistry Schiff's bases have vital use as starting materials or as intermediates, anti-cancerous, anti-tuberculosis, anti-inflammatory, rust inhibitors, antibacterial, fungicidal, antiviral, and antibiotic [14]. Although a large number of complexes of transition and non-transition metals with a variety of Schiff's base derivatives as ligands have been synthesized, characterized and tested for their antimicrobial activities, to the best of our knowledge, complexes prepared from Cu(II), Zn(II), Ni(II), Cr(III) and Fe(III), and Schiff's base resulted from condensation of vanillin and orthohydroxyaniline have not been reported previously. Therefore in this work, we present the synthesis, characterization and antimicrobial study of the ligand as well as its complexes with the transition metals.

2. Materials and Methods

2.1. Reagents and Chemicals

All the chemicals used in this study were analytical grade. Solutions of PDA (potato dextrose agar), Mueller Hinton agar (MHA) were prepared in the laboratory. Solvents in synthetic work were used as supplied whereas in spectroscopic and thin layer chromatographic work all solvents were HPLC grade.

2.2. Characterization Techniques

Infrared spectra were recorded on Fourier Transform Infrared (FT-IR) spectrophotometer (prestige- 21) in the range 4000-200 cm^{-1}. C, H, N elemental analyses were performed with a Carlo Erba Model EA1108 analyzer. Molecular weights of the ligand and its complexes were determined by Rast's method using camphor as a solvent. The melting points of the synthesized compounds were determined in an open glass capillaries using Bibby Sterilin LTD, ST150SA, UK melting point apparatus. Electronic spectra were measured by using UV/Vis-SP65 SYANO spectrophotometer in 200-800 nm range. Magnetic susceptibility measurements were performed using MSB-AUTO, (Sherwood Scientific) magnetic balance. The molar conductivity measurements were carried out using Jenway digital conductivity meter (UK). Antimicrobial evaluation of the ligand and complexes was performed.

2.3. Synthesis of Ligands and Complexes

2.3.1. Synthesis of 3-methoxy-4-hydroxyphenylmethyelene (2-hydroxyphenyl) amine

The ligand, 3-methoxy-4-hydroxyphenylmethyelene(2-hydroxyphenyl)amine was prepared by the condensation reaction of vanillin and 2-aminophenol. Vanillin (7.6 g, 0.05 mol) and 2-aminophenol (5.8 gm, 0.053 mol) were mixed in dry alcohol, and then refluxed for 2 h in round bottom flask. Reaction mixture was concentrated by using rota vapor. Saddle brown solid was filtered out and washed with diethyl ether repeatedly to remove unreacted amine. Finally the product was recrystallized from alcohol, and dried in oven at 75 ^{0}C [15].

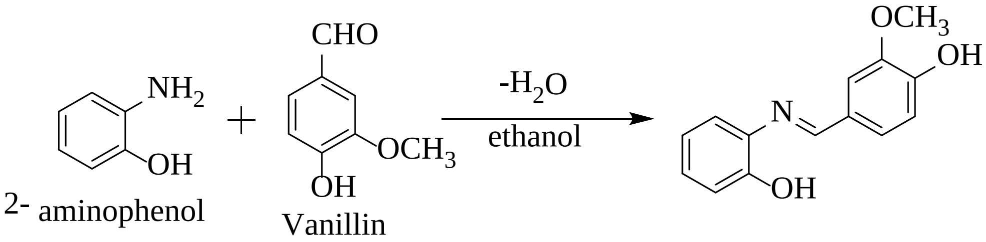

Figure 7: Synthesis of 3-methoxy-4-hydroxyphenylmethyelene (2-hydroxyphenyl) amine

2.3.2. Synthesis of the metal complexes

The metal complexes of Cu (II), Zn (II), Ni (II), Cr (III) and Fe (III) were prepared by mixing the saturated ethanolic solutions of the respective metal chlorides (0.005 mol) and the ligand (0.005 mol) in 150 mL beaker. The solution was heated in water bath at about 75 ^{0}C with continuous stirring to remove the solvent. After evaporation of the solvent, all the five complexes were washed several times with water to remove unreactive metal if any, to get the pure product. Finally, all the products were dried in air and recrystallized from ethanol

[15].

2.4. Antimicrobial Evaluation

Antimicrobial (antibacterial and antifungal) activities of the ligand and its complexes were tested in *vitro* against two bacteria and two fungi using disc diffusion method. The two bacteria and fungi were cultivated on Mueller hinton agar (MHA) and potato dextrose agar medium respectively. The degree of bactericidal and fungicidal activities was determined by measuring diameter of inhibition zone and compared with the standard drug *chloramphenicol* and *bavistin* respectively [16].

2.4.1. Inoculums preparation

The test bacterial strains, *Escherichia coli* (Gram-negative) and *Staphelococus aureus* (Gram-positive), were transferred from the stock cultures and streaked on mueller hinton agar (MHA) plates and incubated for about 24 h. Bacteria were transferred using bacteriological loop to autoclaved MHA that was cooled to about 45 ^{0}C in water bath and mixed by gently swirling the flasks. The medium was then poured to sterile Petri dishes, allowed to solidify and used for the biotest. To test antifungal activity, mycelia plugs from the stock cultures were transferred to PDA plates and incubated for 6 days. Then spores of the test fungi names were harvested by washing the surface of the colony using 10 mL sterile distilled water and transferred to 50 mL autoclaved PDA cooled to about 45 ^{0}C in a water bath. The medium containing spore suspension was poured to sterile plates, allowed to solidify and was used for the paper disc diffusion bioassay.

2.4.2. Antifungal Activity

Paper discs about 3 mm in diameter were cut from Watman-1filter paper with an office paper punch and placed in a beaker covered with aluminum foil and sterilized in an oven at 180 ^{0}C for 1 h. Aliquots of 10 µl and 20 µl of the sample solutions of ligand and its complexes were pipetted to the discs in three replications each. The paper discs impregnated with the sample solutions were then transferred using sterile forceps to PDA seeded with spore suspension of test fungi as described under inoculums preparation above. The petri dishes were incubated at 26 ^{0}C for 6 days. All the tests were performed in triplicate. The effectiveness of the samples was evaluated by measuring inhibition zone against the tested organisms.

2.4.3. Antibacterial Activity

Similar procedures were followed for testing antibacterial activities. Paper discs were transferred to Mueller Hinton agar (MHA) plate seeded with bacteria and incubated at 37 ^{0}C for 24 h. All the tests were performed in triplicate. Antibacterial activity was evaluated by measuring the zone of inhibition against the tested organisms.

3. Results and Discussion

Color, melting point, yield and analysis data of ligand and the corresponding complexes are presented in Table 1. The experimental values shown for the ligand and each of the complexes are in good agreement with the theoretical values (calculated ones). The proposed molecular formulae of the resulting complexes are in conformity with their molecular weights as indicated in Table 2.

Table 1: Formulae, molecular weight, color, melting point, yield and analysis data of ligands and complexes

Compound	MW	Color	Mp (^0C)	Yield (%)	Analysis			metal %
	Calc.				Calculated (Found) %			
	(Found)				C	H	N	
$C_{14}H_{13}NO_3$	243	SB	106±1	70	69.13	5.35 (6.63)	5.76 (5.09)	-
	(239)				(67.26)			
ZnC	585	DB	120±1	64	57.44	4.79	4.79	11.11
	(592.54)				(56.77)	(5.12)	(4.45)	(9.75)
CuC	854	D	>300	64	39.34	3.28	3.28	22.40
	(856.3)				(39.51)	(2.99)	(2.77)	(21.98)
NiC	651	B	115±1	64	51.61	5.53	4.30	9.10
	(661)				(52.57)	(5.27)	(3.95)	(9.15)
CrC	1215	DB	110±1	54.9	55.31	4.61	4.61	8.56
	(1203)				(54.05)	(5.11)	(4.18)	(8.20)
FeC	629.5	DB	222±1	76	53.38	4.76	4.44	8.89
	(631)				(52.03)	(4.67)	(4.01)	(8.60)

ZnC: $Zn(C_{14}H_{12}NO_3)_2\ (H_2O)_2]$; CuC: $[Cu_3(C_{14}H_{12}NO_3)_2C_{l4}]._2H_2O$; CrC: $[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$; NiC: $[Ni(C_{14}H_{12}NO_3)_2(H_2O)_2].4H_2O$; FeC: $[Fe(C_{14}H_{12}NO_3)_2(H_2O)Cl]._2H_2O$; MW: molecular weight; MP; melting point; SB: saddle brown; DB: dark brown; B: brown; D: dark

Table 2: Molecular weight determination data

Compounds	FPM (^{0}c))	DFPC*(ΔT_f) (^0C)	MW (g/mol)		Error (%)
			Calc.	Found	
$C_{14}H_{13}NO_3$	161.4	16.6	243	239.0	1.60
$[Zn(C_{14}H_{12}NO_3)_2\,(H_2O)_2]$	171.3	6.7	585	592.5	1.20
$[Ni(C_{14}H_{12}NO_3)_2(H_2O)_2].4H_2O$	172.0	6.0	651	661.0	1.50
$[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$	174.7	3.3	1215	1203.0	0.98

Freezing point of Camphor =178 ^0C, DFPC: Depression in freezing point of camphor; FPM: Freezing point of *mixture (camphor + complexes); MW: molecular weight: *Mixtures of freezing points are mean values of three observations*

Conductance of standard solutions of complexes of 1000 ppm concentration in ethanol was measured at room temperature and molar conductance was calculated (table 3). Molar conductance values reveal non-electrolytic nature of all the complexes [17]. For verification of conductometric results silver nitrate test on the solutions of complexes was also performed. On mixing the solutions of complexes with $AgNO_3$ solution in water- ethanol (3:2 v/v) white precipitate of AgCl was not obtained; absence of any ionic chlorine is consistent with their non-electrolytic nature. However, the presence of coordinated chlorine in complexes has been tested by decomposing the complexes with conc. HNO_3 and treating their acidic solutions with aqueous solution of $AgNO_3$. In the case of Cu (II), Fe (III) and Cr (III) complexes white precipitate of AgCl, soluble in NH_4OH, obtained indicating coordination of chlorine with these metals.

Table 3: Molar conductivity measurement data

Complexes	CC (µS)	SC. K (Ohm cm^2 mol^{-1})	MC (Ω^{-1}cm^2 mol^{-1})	EN
$[Zn(C_{14}H_{12}NO_3)_2 (H_2O)_2]$	5.30	5.247	3.09	ne
$[Cu_3(C_{14}H_{12}NO_3)_2Cl_4].2H_2O$	8.18	8.098	6.92	ne
$[Ni(C_{14}H_{12}NO_3)_2(H_2O)_2].4H_2O$	4.44	4.396	2.85	ne
$[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$	6.11	6.049	7.38	ne
$[Fe(C_{14}H_{12}NO_3)_2(H_2O)Cl].2H_2O$	6.90	6.831	4.29	ne

Cell constant (k) =0.99 Conductance of ethanol = 4 x 10^{-7} Ω^{-1}; CC: Conductance of complex; SC: Specific conductance x10^6 (conductance due to complex); MC: Molar conductance; EN: electrolytic nature; NE: non-electrolyte; E: electrolyte

The metal content in the complexes were determined using atomic absorption spectrophotometer (AAS). Metal percentage along with analysis data was used to determine the metal-ligand ratio in the complex. For this purpose, 20 mg of each complex were digested completely in conc. HNO_3 till nearly colourless solution was obtained and analyzed by AAS. The experimental percentage of metal in the complexes was found as:

$$\mathrm{M}\ (\%) = \frac{\text{Concentration (ppm) X Volume diluted to}}{\text{Mass of sample taken}}\, x \,\frac{100}{1000}$$

The data obtained from AAS (Table 4) shows that metal to ligand ratio in Zn (II), Ni (II), Cr (III) and Fe (III) complexes was 1:2 and in Cu (II) complex was 3:2 ratio.

Table 4: Atomic Absorption data of complexes

Compounds	MW	Conc. (ppm)	SA (nm)	% metal	
				Calc.	Found
$[Cu_3(C_{14}H_{12}NO_3)_2Cl_4].2H_2O$	854	43.95	0.379	22.40	21.98
$[Ni(C_{14}H_{12}NO_3)_2(H_2O)_2].4H_2O$	651	18.30	0.301	9.10	9.15
$[Fe(C_{14}H_{12}NO_3)_2(H_2O)Cl].2H_2O$	629.5	17.20	0.395	8.89	8.60
$[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$	1215	16.40	0.199	8.56	8.20
$[Zn(C_{14}H_{12}NO_3)_2 (H_2O)_2]$	585	19.50	0.690	11.11	9.75

MW: Molecular weight SA: Sample absorbance

3.1. FT-IR Spectra of ligands and complexes

In order to study the binding mode of ligand (Schiff's base) with metal ions in the complexes, the FT- IR spectrum of the free ligand was compared with the spectra of its complexes as presented in Figure 1, 2, 3, 4, 5 and 6. Bands at 3376 cm^{-1} and 3305 cm^{-1} assigned to phenolic ν (OH) in ligand spectrum (Figure 1) which have also been identified in complex spectra (Figure 2-6) in 3294-3447 cm^{-1} region with broad or doublet structure. Although appearance of phenolic ν(OH) bands in complex spectra does not show involvement of phenolic group of ligand in coordination, but appearance of new peaks in 527-596 cm^{-1} range which could be attributed to ν(M-O), coordination of one of the deprotonated phenolic group (most probably in ortho position to azomethine group) can also be evidence for its coordination. Substantial lowering in free ligand band at 1639 cm^{-1} corresponding to azomethine (C=N) stretching on complexation clearly indicates coordination of azomethine nitrogen with metal ions. A new band in 456-517 cm^{-1} in complex spectra supports the coordination of azomethine group of the ligand.

In the spectrum of Fe(III) complex a new band at 330 cm^{-1} assigned to terminal ν(Fe –Cl) whereas in Cr(III) and Cu(II) complexes new bands appeared at 244 cm^{-1} and 224 cm^{-1} indicating ν(M-Cl-M). The broad or double structure of peak (s) displayed by all the complexes except Zn(II) complex in 3294-3447 cm^{-1} could be due to mixing of two closely spaced peaks of phenolic ν(O-H) and symmetric and asymmetric stretching vibrations of lattice water [18]. The presence of lattice water in these complexes is supported by the presence of new peaks in 1640-1670 cm^{-1} region owing to symmetric and asymmetric bending vibrations of lattice water [19]. The presence of water in the coordination zone of Zn (II), Fe(III), and Ni(II) is indicated by the appearance of one to three new bands in 856 -980 cm^{-1} range in their spectra; one new band observed in 251-268 cm^{-1} region due to ν($M-H_2O$) supports the coordination of water molecule (s) with the metals.

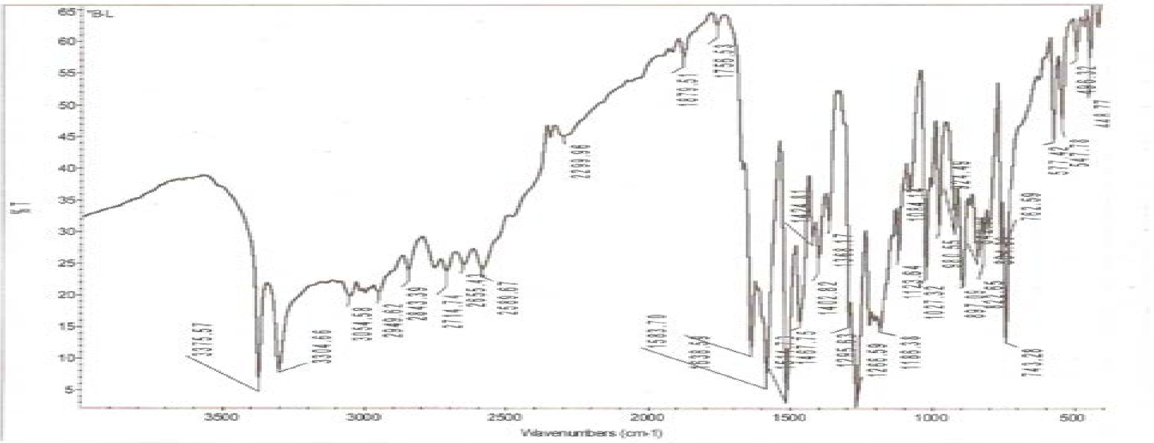

Figure 1: FT-IR spectrum of $C_{14}H_{12}NO_3$

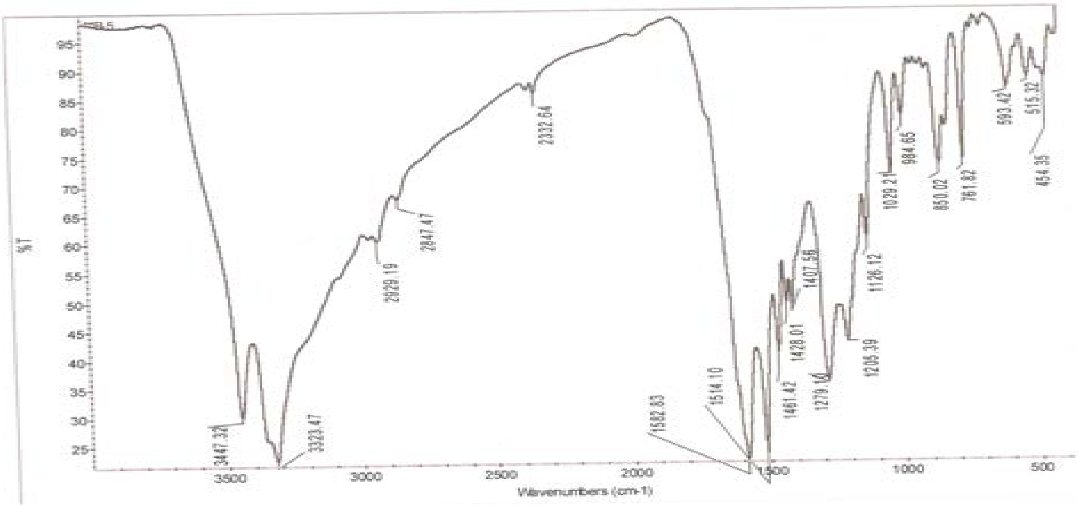

Figure 2: FT-IR spectrum of $[Cu_3(C_{14}H_{12}NO_3)_2Cl_4].2H_2O$

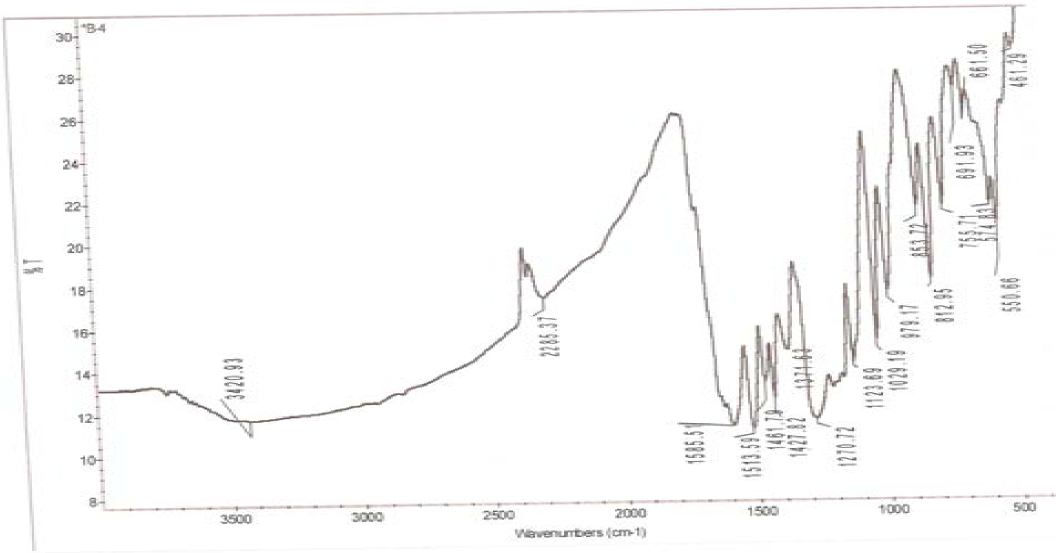

Figure 3: FT-IR spectrum of $[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$

Figure 4: FT-IR spectrum of [Fe($C_{14}H_{12}NO_3$)$_2$(H_2O)Cl].2H_2O

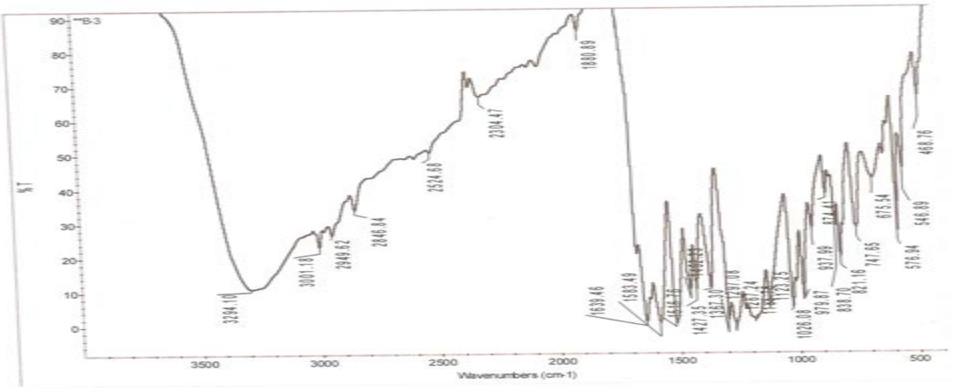

Figure 5: FT-IR spectrum of [Ni($C_{14}H_{12}NO_3$)$_2$(H_2O)$_2$].4H_2O

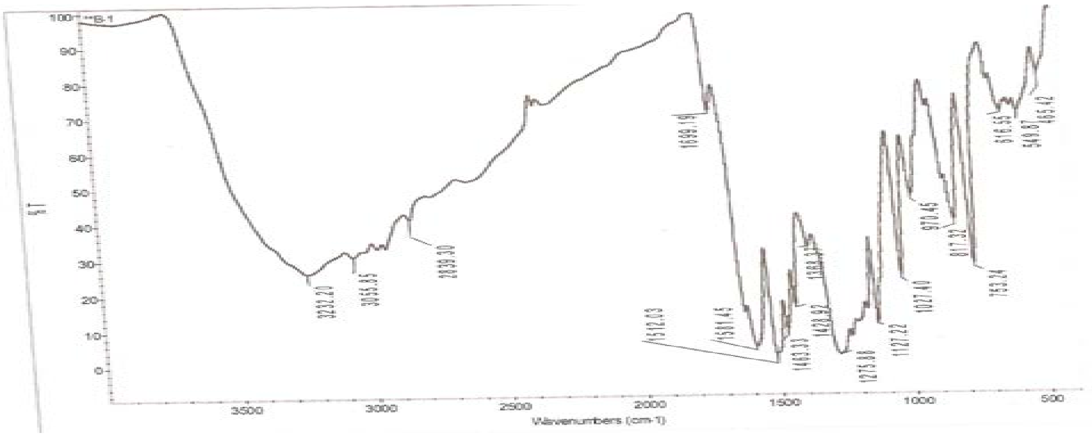

Figure 6: FT-IR spectrum of [Zn($C_{14}H_{12}NO_3$)$_2$ (H_2O)$_2$]

3.2. Electronic (UV- Visible) Spectra and Magnetic moments

The room temperature (295 K) magnetic moment (Table 5) of Cu (II) complex (1.01BM) lower than spin-only value (1.73 BM) which may be due to Cu-Cu antiferromagnetic interactions. Three bands displayed in the electronic spectra at 21739 cm^{-1}, 26315 cm^{-1} and 27778 cm^{-1} are characteristics of D_{4h} symmetry, clearly indicate square planar geometry of the four coordinate complexes. Ligand to metal charge transfer bands of higher energy also appear at 33333 cm^{-1} and 37037 cm^{-1} (Table 7). Iron (III) complex displayed magnetic moment of 3.52 BM which is lower than spin only value of d^5 configuration (5.92 BM). In the absence of antiferromagnetic interactions in the mononuclear complex, the low magnetic moment value obtained indicate high-spin (S=5/2) to low-spin (S=1/2) crossover phenomenon in this complex. UV-visible spectrum (Table 7) of this complex, however, displayed eight bands which are characteristic of electronic transitions from the ground sextet term $^6A_{1g}$ to many spin-forbidden states of a high-spin octahedral stereochemistry. Four absorption bands were observed in high energy region for Ni (II) complex at 27777 cm^{-1}, 32258 cm^{-1}, 34482 cm^{-1} and 37037 cm^{-1}. The magnetic moment of this complex 2.83 BM is consistent with an S=1 ground state in an octahedral field, indicating octahedral geometry of this paramagnetic complex. Infrared and analysis data also support stereochemical inference obtained from magnetic moment study. Based on these results out of the four absorption bands observed, only 27777 cm^{-1} band could be assigned for $^4T_{1g}$ (P) ← $^6A_{1g}$ transition of paramagnetic octahedral Ni (II) complex and other three bands correspond to ligand to metal charge transfer. Infrared, analysis and conductometric studies are suggesting dimeric structure of Cr (III) complex. Magnetic moment of this complex was lower than the spin only value (3.87) in an octahedral stereochemistry. This could be attributed to Cr-Cr antiferromagnetic interaction. Chromium (III) electronic absorption spectrum that displays three bands at 19607 cm^{-1}, 26315 cm^{-1} and 28571 cm^{-1} assigned to $^4T_{2g} \leftarrow {}^4A_{2g}$, $^4T_{1g}$ (F) $\leftarrow {}^4A_{2g}$ and $^4T_{1g}$ (p) $\leftarrow {}^4A_{2g}$ transitions respectively and at 34482 and 38461cm^{-1} for charge transfer transitions. The value of the first spin-allowed transition (ν_1) at 19607 cm^{-1} is directly taken as 10Dq. Zinc (II) complex displayed only one absorption band at 29411 cm^{-1} attributed to LMCT transition and all Zn (II) complexes are diamagnetic in nature and are found to be octahedral geometry [20]. The values of Racah parameters for all complexes were calculated by the Figgis equations [21].

Table 5: Molar susceptibility and magnetic moment measurement data

Compound	MW	GS (χ_gx10^6 cgs)	MS (X_Mx10^6 cgs)	DC (X_Dx10^{6}cgs)	ES (X_M^{corr}x10^6 cgs)	EMM µeff(BM)
CuC	854.0	0.12	101.63	-326.02	427.65	1.01
NiC	651.0	4.65	3027.15	-284.42	3311.57	2.79
FeC	629.5	7.90	4973.05	-268.82	5241.87	3.52
CrC	1215.0	1.45	1761.75	-511.64	2273.39	2.33
ZnC	585.0	-	-	-	-	D

MW; Molecular weight; GS: Gram susceptibility; MS: Molecular susceptibility; DC: Diamagnetic correction; ES: Effective Susceptibility; EMM: Effective magnetic moment; D: diamagnetic

Table 6: Antimicrobial activity of ligand and the corresponding complexes

	Inhibition zone (mm)							
	Fungi				Bacteria			
Compounds	*A. niger*		*Coll.*		*E. coli*		*S. aureus*	
	10 (µL)	20 (µL)	10 (µL)	20 (µL)	10 (µL)	20 (µL)	10 (µL)	20 (µL)
$C_{14}H_{13}NO_3$	28	30	16	24	19	28	20	29
$[Cu_3(C_{14}H_{12}NO_3)_2Cl_4].2H_2O$	17	22	18	19	-	7	-	8
$[Zn(C_{14}H_{12}NO_3)_2\,(H_2O)_2]$	26	28	17	25	20	23	20	21
$[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$	-	5	17	18	4	7	5	8
$[Ni(C_{14}H_{12}NO_3)_2(H_2O)_2].4H_2O$	9	10	17	20	10	19	8	22
$[Fe(C_{14}H_{12}NO_3)_2(H_2O)Cl].2H_2O$	-	-	9	16	-	-	-	-
Bavistin (standard)	28	30	33	35	-	-	-	-
Chloramphenicol (standard)	-	-	-	-	21	29	23	34
DMSO (control)	0	0	0	0	0	0	0	0

Chloraphenicol- used as check Standard for bacteria; Bavistin- fungicide used as check Standard for fungi; A. niger: Aspergillus niger; Coll: Colletotrichum; E. coli: Escherichia coli, S. aureus: Staphylococcus aureus

Table 7: Electronic absorption spectral data of the Schiff base and its complexes

Compounds	Absorpition region(cm^{-1})	Band assignments	Ligand field parameters Racah's parameter			
			B	C	10Dq	β
$C_{14}H_{13}NO_3$	20408	$\pi - \pi^*$				
CuC	21739 sh	$^{2}A_{1g} \leftarrow {}^{2}B_{1g}$				
	26315 sh	$^{2}B_{2g} \leftarrow {}^{2}B_{1g}$				
	27777	$^{2}E_{g} \leftarrow {}^{2}B_{1g}$				
	33333	LMCT				
	37037 sh	LMCT				
NiC	27777sh	$^{3}T_{1g}$				
	32258	$(P) \leftarrow {}^{3}A_{2g}(F)$				
	34482	LMCT				
	37037	LMCT				
FeC	21739sh	$^{4}T_{1g}\,(G) \leftarrow {}^{6}A_{1g}$	905.8	3623	9963.8	0.69
	23255	$^{4}T_{2g}\,(G) \leftarrow {}^{6}A_{1g}$				
	23809sh	$^{4}A_{1g}\,(G) \leftarrow {}^{6}A_{1g}$				
	23890sh	$^{4}E_{g}\,(G) \leftarrow {}^{6}A_{1g}$				
	27777sh	$^{4}T_{2g}\,(D) \leftarrow {}^{6}A_{1g}$				
	30303	$^{4}E_{g}\,(D) \leftarrow {}^{6}A_{1g}$				
	33333	$^{4}T_{1g}\,(P) \leftarrow {}^{6}A_{1g}$				
	35714	LMCT				
CrC	19607	$^{4}T_{2g} \leftarrow {}^{4}A_{2g}$	784	3136	19607	0.76
	26315sh	$^{4}T_{1g}\,(F) \leftarrow {}^{4}A_{2g}$				
	28571	$^{4}T_{1g}\,(p) \leftarrow {}^{4}A_{2g}$				
	34482	LMCT				
	38461	LMCT				
ZnC	29411	LMCT				

ZnC: $Zn(C_{14}H_{12}NO_3)_2\ (H_2O)_2]$**;** **CuC:** $[Cu_3(C_{14}H_{12}NO_3)_2C_{l4}].{}_2H_2O$**;** **CrC:** $[(Cr(C_{14}H_{12}NO_3)_2Cl]_2.4H_2O$**;** **NiC:** $[Ni(C_{14}H_{12}NO_3)_2(H_2O)_2].4H_2O$**;** **FeC:** $[Fe(C_{14}H_{12}NO_3)_2(H_2O)Cl].{}_2H_2O$**;** LMCT- Ligand–metal charge transfer

3.3. Antifungal and antibacterial activities of ligand and complexes

Antifungal and antibacterial activities of ligand against both fungi and bacteria strains (Table 6) in both concentrations are better than all the complexes and almost comparable with the standards drugs, Bavistin and Chloramphenicol. Therefore, ligand can be proposed as potential antifungal as well as antibacterial drug. Among the complexes Zn (II) complex showed highest antifungal and antibacterial activity against both fungi and bacteria but slightly lower than standard drugs. However Cu (II) and Cr (III) complexes are next to Zn (II) complex in exhibiting antibacterial activities but Ni (II) is next to Zn (II) complex in fungicidal actions. Bactericidal properties of all active compounds were dose dependent. Antimicrobial activities of the complexes can be explained on the basis of chelation theory. On chelation, the polarity of the metal ion will be reduced to a great extent due to overlap of the ligand orbital(s) and partial sharing of the positive charge of the metal ion with donor groups. Further, it increases the delocalization of π-electrons over the whole chelate ring and enhances the penetration of the complexes into lipid membranes and blocking of the metal binding sites in enzymes of microorganism. These complexes also disturb the respiration process of the cell and thus block the synthesis of proteins which restricts further growth of microorganisms [22].

4. Conclusion

The data recorded from AAS showed that metal to ligand ratios were found to be 1:2 for Zn (II), Ni (II), Cr (III) and Fe (III) complexes and 3:2 for Cu(II) complex. The electronic spectral data was in favour of octahedral geometry for all complexes except Cu(II) which showed square planar geometry. Electronic spectral and magnetic data indicated the paramagnetic and diamagnetic nature of the five complexes (Cu(II), Ni(II), Cr(III), Fe(III)) and Zn(II) complexes). FT-IR studies revealed the coordination of azomethine nitrogen and phenolic oxygen atoms to the metal ion. Antimicrobial studies reveal that all compounds are effective against both tested bacteria and fungi though their effects are dose dependent. The ligand exhibited highest antifungal and bacterial activities among all the complexes and Zn (II) complex is effective but lower compared to the ligand. Taking the results of this study into consideration, it is recommended that complexes of the ligand with other transition metals need to be investigated for their antimicrobial activities.

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5. Conflict of interest

The authors declare that no conflict of interest.

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