

Effect of 1-(4-chloro-phenylazo)-naphthalen-2-ol and 2-[1-(4-Chloro-phenylimino)-ethyl]-phenol with Cu(II), Ni(II), Zn(II), Co(II) and Mn(II) ions on Bacterial growth

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Abstract: A new Schiff base mixed ligand metal complexes were synthesized with the Schiff base derived from 2-hydroxyacetophenone and 4-Chloroaniline and 1-(4-chloro-phenylazo)-naphthalen-2-ol. The complexes were formulated as mononuclear species on the basis of chemical analysis, molar conductance, IR, Electrochemical, Magnetic studies, electronic spectral and ESR studies. The Schiff base and its metal complexes are soluble in common organic solvent but insoluble in water. The empirical formula calculation of the complex compounds indicated the formula $[ML^1L^2]$ for Cu(II), Ni(II) & Zn(II) and $[ML^1L^2X_2]$ for Co(II) & Mn(II) Schiff base mixed ligand complexes. The conductivity data for all the complexes are consistent with those expected for non electrolyte. The infrared spectral data shows the coordination site that is via -OH, C=N and N=N groups of the mentioned ligands. The electronic and ESR spectra exhibit the expected geometrical structures for the prepared chelates. The 3D molecular modelling and analysis also gives the bond lengths and bond angles for the following representative complex $[CuL_1L_2]$. The free ligand and its metal complexes showed higher antibacterial effects than that of some investigated bacteria.

Keywords: Mixed ligand complexes, mononuclear Schiff base complexes, antibacterial activity, octahedral and square planar geometry.

Introduction

The development in the field of bioinorganic chemistry has increased considerable interest in synthesizing new Schiff base complexes, since it has been recognized that many of these complexes may serve as models for biologically important species [1-4]. Schiff base ligands and their complexes derived from the reaction of derivatives of salicylaldehyde with amines have been studied extensively for their various crystallographic, structural and magnetic properties [5]. The study of mixed ligand complexes formation is relevant in the field of analytical chemistry, where the use of mixed ligand complexes allows the development of methods with increased selectivity, sensitivity and has also great importance in the field of biological and environmental chemistry [6]. The chemical properties of mixed ligand complexes can be tuned to force metal ions to adopt unusual coordination geometry. The azo group possesses excellent donor properties and is important in coordination chemistry, and some azo compounds have been shown to possess good antibacterial activity [7].

Hence in the present investigation we describe the synthesis, characterization, and antimicrobial activity of transition metal complexes with Schiff base ligand (2-[1-(4-chloro-phenylimino)-ethyl]-phenol) and azo dye ligand (1-(4-chloro-phenylazo)-naphthalen-2-ol).

Experimental

All the chemicals were purchased from commercial sources and used without any further purification. Elemental analysis was obtained using Perkin Elmer elemental analyzer. The molar conductance of the complexes in DMF (10^{-3}) solution was measured at $27\pm 3^\circ\text{C}$ with an Elico model conductivity meter. Infrared spectra were recorded on the Perkin Elmer FT-IR 8300 model spectrometer using KBr disc in the range of $4000-400\text{ cm}^{-1}$. Electronic spectra were recorded at 300 K on a Perkin-Elmer Lambda 40(UV-Vis) spectrometer using DMF in the range 200-800 nm. EPR spectra of compounds were recorded on a Bruker model EMX plus, X-band spectrometer (9.86 GHz) with 100 KHZ modulation frequency. The Redox nature of the complex in DMF was measured using CHI-760 Electrochemical Analyzer by employing a glassy carbon electrode as working electrode, Ag/AgCl as a reference electrode and platinum wire as auxiliary electrode.

Synthesis of 1-(4-chloro-phenylazo)-naphthalen-2-ol (L^1)

A (0.054 mol) of 4-chloroaniline was dissolved in 16 ml of conc.HCl and 16 ml of water, it is then cooled in ice bath. Then 20 ml of (0.058 mol) sodium nitrite solution was added to the above solution with constant stirring. A cooled solution (45 ml) 10% NaOH solution of 2-naphthol (0.054 mol) was added drop wise to the resulting solution with stirring and the mixture was left for 1 hr at 0°C . Red precipitate was filtered and recrystallized from acetic acid, then washed with ethanol.

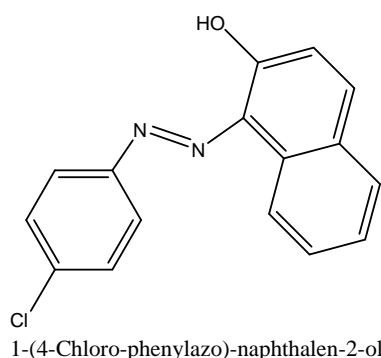


Fig.1: Structure of Azo dye Ligand (L^1)

Synthesis of 2-[1-(4-Chloro-phenylimino)-ethyl]-phenol (L^2)

The Schiff base ligand was prepared by mixing ethanolic solution of 4-chloro-phenylamine (1 mmol) and ethanol solution of salicylaldehyde (1 mmol) with constant stirring. On adding solution of 4-chloro-phenylamine to the solution of salicylaldehyde, the colourless solution turns yellow solution. This mixture was then refluxed for 2 hrs on waterbath. This mixture was then allowed to cool at room temperature. As the volume of the solvent is reduced the yellow crystal separates out and is then dried. The product was recrystallised from ethanol.

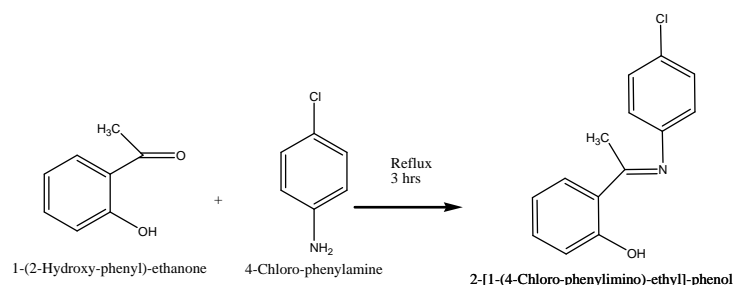


Fig.2: Synthesis and Structure of Schiff base Ligand (L^2)

Synthesis of Schiff base Mixed ligand Complexes

The present mixed ligand complexes were prepared by mixing equal amount of hot ethanolic solutions of first ligand (1-(4-chloro-phenylazo)-naphthalen-2-ol) with the same ratio of metal salts. The mixture was refluxed for one hour and then the second ligand (2-[1-(4-Chloro-phenylimino)-ethyl]-phenol) was added in the

same ratio to the previous mixtures and refluxed for extra 3 hrs. The resulting complex were washed several times with hot ethanol until the filtrate become clear and then dried.

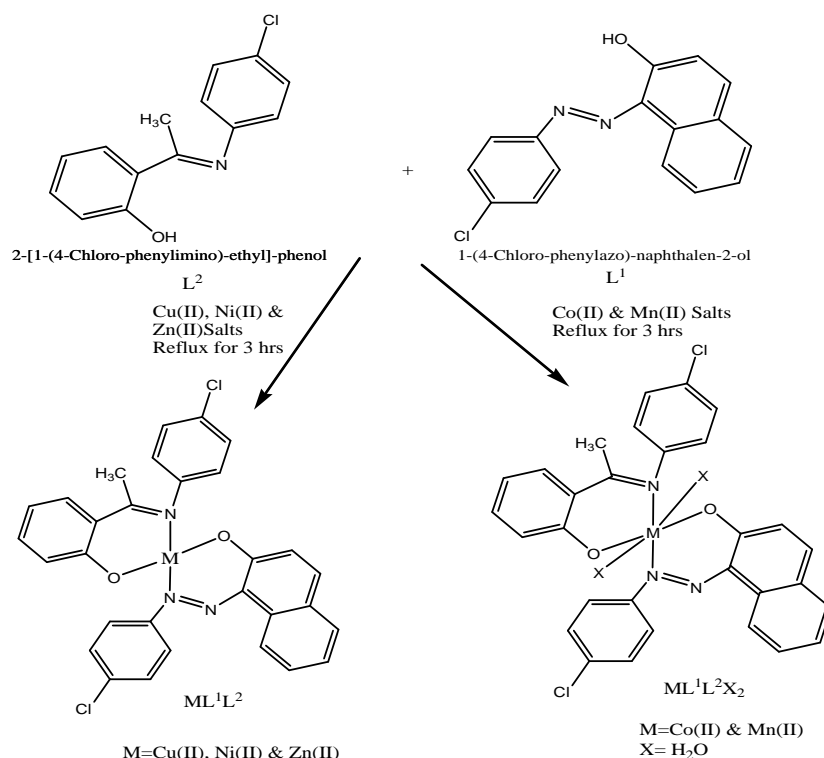


Fig.3: Synthesis and structure of Schiff base mixed ligand Metal complexes

Results and Discussion

Elemental Analysis

The present investigation describes the synthesis, characterization, and antimicrobial activity of the elemental analysis data of the Schiff base mixed ligand metal complexes (Table.1). It has been found that the theoretical values are in good agreement with the found values.

Table-1: Synthesis data of Schiff Base and its Mixed Ligand Complexes

Compounds	Molecular formula	Found (calculated)				⁻¹ cm ² mol ⁻¹
		C%	H%	N%	M%	
L ¹	C ₁₆ H ₁₁ ClN ₂ O	67.96 (67.89)	3.92 (3.91)	9.91 (9.88)	-	-
L ²	C ₁₄ H ₁₂ ClNO	68.43 (68.41)	4.92 (4.89)	5.70 (5.68)	-	-
[Cu L ¹ L ²]	C ₃₀ H ₂₁ Cl ₂ CuN ₃ O ₂	61.07 (61.08)	3.58 (3.57)	7.12 (7.10)	10.77 (10.74)	5.3
[Ni L ¹ L ²]	C ₃₀ H ₂₁ Cl ₂ N ₃ NiO ₂	61.57 (61.49)	3.61 (3.60)	7.18 (7.19)	10.03 (9.98)	7.3
[ZnL ¹ L ²]	C ₃₀ H ₂₁ Cl ₂ N ₃ O ₂ Zn	60.88 (60.89)	3.57 (3.55)	7.10 (7.08)	11.05 (11.01)	12.7
[CoL ¹ L ² X ₂]	C ₃₀ H ₂₅ Cl ₂ CoN ₃ O ₄	57.98 (57.96)	4.05 (4.06)	6.76 (6.69)	9.48 (9.46)	8.9
[MnL ¹ L ² X ₂]	C ₃₀ H ₂₅ Cl ₂ MnN ₃ O ₄	58.35 (58.31)	4.07 (4.04)	6.80 (6.81)	8.89 (8.82)	10.6

Molar conductance Measurements

In the concentration 10^{-3} M DMF, the synthesized Schiff base mixed ligand complexes shows the conductance value ranges from 5-12 $\text{cm}^2\text{mol}^{-1}$. These values suggest the presence of a non-electrolytic nature of Schiff base mixed ligand metal complexes [8].

Infrared Spectra

The coordination site of the ligand moieties was clearly evidenced from the IR spectral data. The most important IR absorption bands corresponding to the ligand and the complexes are presented in table.2. The observed band in the range 1586 cm^{-1} is due to (N=N) group of the 1-(4-chloro-phenylazo)-naphthalen-2-ol ring moiety[9]. These bands are shifted to lower region during the complex formation indicating its participation in coordination with the metal ions. The sharp band in the range $755\text{-}776\text{ cm}^{-1}$ and $1524\text{-}1545\text{ cm}^{-1}$ are due to aromatic (C-H) [10,11] and (C=C) [10,12] respectively. The medium intense band in the range 1622 cm^{-1} are observed due to (C=N) which has been shifted towards lower region at around $1598\text{-}1612\text{ cm}^{-1}$ in the complexes indicating the reduction of double bond character of carbon-nitrogen bond of azomethine group and indicates that C=N of the ligand coordinates to the metal through nitrogen [13,14]. The appearance of these bands support the involvement of -OH, C=N and N=N groups in the formation of new Schiff base mixed ligand complexes. Another bands in the range of $521\text{-}637$ and $438\text{-}472\text{ cm}^{-1}$ which are not present in the free ligands assigned to (M-O) and (M-N) vibrations. In Co(II) and Mn(II) complexes the appearance of a broad band around $3490\text{-}3520\text{ cm}^{-1}$ in the spectra of the complexes suggests the presence of water molecules. A band of weak intensity at $815\text{-}827\text{ cm}^{-1}$ suggests the presence of coordinated water in Co(II) and Mn(II) complexes.

Table-2: Infrared spectroscopic data of the Schiff base ligands and its complexes

Complexes	(C=N)	(O-H)	(N=N)	(M-O)	(M-N)
L ¹	-	3450	1586	-	-
L ²	1622	3457	-	-	-
[Cu L ¹ L ²]	1612	-	1539	521	451
[Ni L ¹ L ²]	1598	-	1548	637	472
[ZnL ¹ L ²]	1615	-	1542	573	465
[CoL ¹ L ² X ₂]	1608	3520	1540	564	438
[MnL ¹ L ² X ₂]	1616	3490	1546	582	469

Electronic Spectra

The electronic absorption spectra of the prepared complexes were recorded over the range 200-800 nm in DMF solvent. The solutions were thoroughly mixed and allowed to stand. The absorbance of the solutions was then measured. Their λ_{max} values together with tentative assignments are summarized in Table.3. The Cu(II) complex shows a d-d band in the region 455 nm due to ${}^2B_{1g} \rightarrow {}^2A_{1g}$ transition which supports square-planar geometry [15]. The spectra of Ni(II) complex consists of two bands in the range between 554 nm and 430 nm and were assigned ${}^3T_1(F) \rightarrow {}^2A_2(F)$ and ${}^3T_1(F) \rightarrow {}^3T_1(P)$ respectively. This is a probable indicative of four coordinated square planar geometry for Ni(II) complex. The brownish yellow color of the complexes, its diamagnetism and the position of electronic absorption bands of medium intensity are characteristics of square planar Ni(II) complex [16]. The Zn(II) complex shows an absorption band at 410 nm attributed to the L → M charge transfer transition, which is compatible with this complex having a square planar geometry d^{10} electronic configuration [17]. The electronic spectrum of the cobalt complex showed a band at 625 nm corresponding to ${}^4T_{1g}(F) \rightarrow {}^4A_{2g}(F)$ transition which is consistent with the octahedral geometry of the complex[18]. The Mn(II) binuclear complex shows bands at 549, 678 nm respectively are corresponding to ${}^6A_{1g} \rightarrow {}^4E_g(4D)$, ${}^6A_{1g} \rightarrow {}^4T_{2g}(4G)$ transitions which are compatible to an octahedral geometry around manganese(II) ion[19].

Table-3: Electronic Spectral data and Cyclic Voltammetric data of Schiff base mixed ligand metal complexes.

Compound	max	Geometry of the complex	CV Data (V)	
			Epc	Epa
L ¹	-	-	1.3	0.5
L ²	-	-	1.5	0.7
[Cu L ¹ L ²]	280,346,455	Square planar	1.6	0.8
[Ni L ¹ L ²]	365,430,554		1.2	0.4
[ZnL ¹ L ²]	350,410		1.7	0.5
[CoL ¹ L ² X ₂]	340,445,625	Octahedral	1.4	0.6
[MnL ¹ L ² X ₂]	354,549,678		1.6	0.9

Magnetic Studies

The magnetic moments of the mixed-ligand complexes were measured at room temperature. The magnetic moment values for Co(II) complexes is 4.31 BM. corresponding to three unpaired electrons which suggests an octahedral geometry [20-21]. The Mn(II) complex show magnetic moments is 5.92 BM at room temperature corresponding to five unpaired electrons which suggest octahedral geometry [22]. The magnetic moment value of Cu(II) complex is found to be 1.82 B.M., which is well within the expected range of square planar complexes. The Zn(II) complex was found to be diamagnetic as expected for d¹⁰ ions and do not show any d-d transitions[23]. Similarly Ni(II) complex was found to be diamagnetic in nature.

Electrochemical Studies

The redox behavior of these complexes has been investigated by cyclic voltammogram in DMF using 0.1 M Tetrabutyl ammonium perchlorate (TBAP) as supporting electrolyte. The electrochemical data obtained at a glassy carbon electrode in DMF solution are recorded.

The cyclic voltammogram of the mixed ligand Schiff base contains two peaks. These are due to oxidative nature of organic molecule and reductive nature of azomethine group.

The Copper complex in DMF shows cathodic peak of 1.6 V indicates the one electron reduction of Cu(II) → Cu(I) process and the anodic peak of 0.8 V indicates the oxidation process of Cu(I) → Cu(II)[24,25]. The non-equivalent current intensity of cathodic and anodic peaks ($i_c/i_a=0.7$ V) indicates a quasi reversible behaviour [26-28]. It has been shown that the formal redox potential of Cu(II)/Cu(I) couple is dependent on factors such as coordination number, hard/soft nature of the ligands and bulkiness of the ligands [29]. The cobalt complexes exhibit one electron quasi reversible transfer process with a peaks at Epa=0.6 V, Epc=1.4 V. This gives evidence for quasi reversible Co(II)/Co(I) couple. The cyclic voltammogram of Nickel complexes shows well defined redox process corresponding to the formation of the quasi-reversible Ni(II)/Ni(I) couple. The anodic peak at Epa=0.4 V and the associated cathodic peak at Epc=1.2 V corresponds to Ni(II)/Ni(I) couple[30]. The one electron cyclic response for Manganese complexes were observed at Epc=1.6 V and Epa=0.9 V. This corresponds to Mn(II)/Mn(I). The Table.3 also show the redox nature of the other Schiff base mixed ligand complexes.

ESR studies

The ESR spectrum of metal complexes provides information about the study of the environment of the metal ion in the complex, *i.e.*, the geometry and nature of the ligating sites of the Schiff base and the metal. The Schiff base mixed ligand Cu(II) complex consist of axial symmetrical signal with g at 2.178 and g at 2.056. Hence the unpaired e⁻ lies in the dx²-y² orbital with g >g >g_e (2.0023 free spin value) [31]. This confirms square planar geometry for Cu(II) complex.

Molecular Modelling and Analysis

The molecular modelling of Mononuclear Schiff base Mixed ligand Cu(II) complex as a representative, is based on its Square planar structure with bi-dentate ligands. This Molecular modeling structure also shows the stereochemistry of the complex. The details of the bond lengths (Å) and bond angles (°) as per the 3D structure (Fig.4) are given in Tables 4 and 5 respectively [32,33]. The actual bond lengths and bond angles are close to the optimal values in most of the cases, and thus the proposed structure of the compound is acceptable. The missing of some values of standard bond lengths/bond angles may be due to the limitations of the

software, which we had already noticed in modeling of other systems[34].

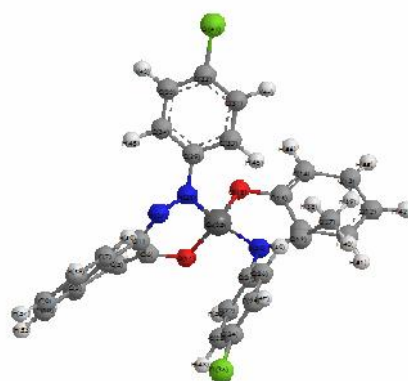


Figure-4. 3D Molecular Structure of the Schiff base mixed ligand copper complex

Table-4 Various bond lengths of Schiff base mixed ligand copper complex [Cu L¹L²]

Atoms	Actual Bond length	Optimal Bond length	Atoms	Actual Bond length	Optimal Bond length
C(1)-C(2)	1.503	1.503	C(19)-C(37)	1.497	1.497
C(1)-C(6)	1.503	1.503	N(20)-C(21)	1.462	1.462
C(1)-N(27)	1.260	1.260	N(20)-Cu(35)	1.846	-
C(2)-C(3)	1.503	1.503	C(21)-C(22)	1.420	1.420
C(2)-C(7)	1.420	1.420	C(21)-C(26)	1.420	1.420
C(3)-C(4)	1.337	1.337	C(22)-C(23)	1.420	1.420
C(3)-C(10)	1.503	1.503	C(22)-H(51)	1.100	1.100
C(4)-C(5)	1.796	1.503	C(23)-C(24)	1.420	1.420
C(4)-H(56)	1.100	1.100	C(23)-H(49)	1.100	1.100
C(5)-C(6)	1.337	1.337	C(24)-C(25)	1.420	1.420
C(5)-H(54)	1.100	1.100	C(24)-Cl(36)	1.719	1.719
C(6)-O(11)	1.665	1.355	C(25)-C(26)	1.420	1.420
C(7)-C(8)	1.420	1.420	C(25)-H(43)	1.100	1.100
C(7)-H(59)	1.100	1.100	C(26)-H(50)	1.100	1.100
C(8)-C(9)	1.610	1.503	N(27)-N(28)	1.426	1.426
C(8)-H(45)	1.100	1.100	N(28)-C(29)	1.462	1.462
C(9)-C(10)	1.337	1.337	N(28)-Cu(35)	1.846	-
C(9)-H(44)	1.100	1.100	C(29)-C(30)	1.420	1.420
C(10)-H(55)	1.100	1.100	C(29)-C(34)	1.420	1.420
O(11)-Cu(35)	1.810	-	C(30)-C(31)	1.420	1.420
C(12)-C(13)	1.903	1.420	C(30)-H(48)	1.100	1.100
C(12)-C(17)	1.420	1.420	C(31)-C(32)	1.420	1.420
C(12)-H(52)	1.100	1.100	C(31)-H(46)	1.100	1.100
C(13)-C(14)	1.503	1.503	C(32)-C(33)	1.420	1.420
C(13)-H(57)	1.100	1.100	C(32)-Cl(41)	1.719	1.719
C(14)-C(15)	1.337	1.337	C(33)-C(34)	1.420	1.420
C(14)-H(58)	1.100	1.100	C(33)-H(42)	1.100	1.100
C(15)-C(16)	1.503	1.503	C(34)-H(47)	1.100	1.100
C(15)-O(18)	1.355	1.355	C(37)-H(38)	1.113	1.113
C(16)-C(17)	1.503	1.503	C(37)-H(39)	1.113	1.113
C(16)-C(19)	1.318	1.337	C(37)-H(40)	1.113	1.113
C(17)-H(53)	1.100	1.100			
O(18)-Cu(35)	1.810	-			
C(19)-N(20)	1.462	1.462			

Table-5 Various bond Angles of Schiff base mixed ligand copper complex

Atoms	Actual Bond Angle	Optimal Bond Angle	Atoms	Actual Bond Angle	Optimal Bond Angle
C(2)-C(1)-C(6)	120.000	120.000	C(6)-O(11)-Cu(35)	91.971	-
C(2)-C(1)-N(27)	120.000	120.000	C(13)-C(12)-C(17)	105.912	120.000
C(6)-C(1)-N(27)	119.998	120.000	C(13)-C(12)-H(52)	135.700	120.000
C(1)-C(2)-C(3)	120.000	120.000	C(17)-C(12)-H(52)	118.386	120.000
C(1)-C(2)-C(7)	119.998	120.000	C(12)-C(13)-C(14)	118.496	120.000
C(3)-C(2)-C(7)	120.000	120.000	C(12)-C(13)-H(57)	134.532	120.000
C(2)-C(3)-C(4)	119.998	120.000	C(14)-C(13)-H(57)	106.968	120.000
C(2)-C(3)-C(10)	119.998	120.000	C(13)-C(14)-C(15)	120.000	120.000
C(4)-C(3)-C(10)	120.000	120.000	C(13)-C(14)-H(58)	120.000	120.000
C(3)-C(4)-C(5)	118.867	120.000	C(15)-C(14)-H(58)	119.998	120.000
C(3)-C(4)-H(56)	137.216	120.000	C(14)-C(15)-C(16)	120.001	120.000
C(5)-C(4)-H(56)	103.915	120.000	C(14)-C(15)-O(18)	115.697	124.300
C(4)-C(5)-C(6)	112.233	120.000	C(16)-C(15)-O(18)	124.299	124.300
C(4)-C(5)-H(54)	137.205	120.000	C(15)-C(16)-C(17)	119.998	120.000
C(6)-C(5)-H(54)	110.559	120.000	C(15)-C(16)-C(19)	132.998	120.000
C(1)-C(6)-C(5)	119.998	120.000	C(17)-C(16)-C(19)	106.999	120.000
C(1)-C(6)-O(11)	142.005	124.300	C(12)-C(17)-C(16)	119.998	120.000
C(5)-C(6)-O(11)	97.996	124.300	C(12)-C(17)-H(53)	119.998	120.000
C(2)-C(7)-C(8)	120.000	120.000	C(16)-C(17)-H(53)	119.998	120.000
C(2)-C(7)-H(59)	119.998	120.000	C(15)-O(18)-Cu(35)	109.470	-
C(8)-C(7)-H(59)	119.998	120.000	C(16)-C(19)-N(20)	114.525	120.000
C(7)-C(8)-C(9)	118.771	120.000	C(16)-C(19)-C(37)	148.590	121.400
C(7)-C(8)-H(45)	120.017	120.000	N(20)-C(19)-C(37)	96.879	125.300
C(9)-C(8)-H(45)	120.015	120.000	C(19)-N(20)-C(21)	121.998	124.000
C(8)-C(9)-C(10)	118.769	120.000	C(19)-N(20)-Cu(35)	119.998	-
C(8)-C(9)-H(44)	120.017	120.000	C(21)-N(20)-Cu(35)	118.001	-
C(10)-C(9)-H(44)	120.019	120.000	N(20)-C(21)-C(22)	119.998	120.000
C(3)-C(10)-C(9)	120.000	120.000	N(20)-C(21)-C(26)	120.000	120.000
C(3)-C(10)-H(55)	120.000	120.000	C(22)-C(21)-C(26)	119.998	120.000
C(9)-C(10)-H(55)	119.998	120.000	C(21)-C(22)-C(23)	120.001	120.000
C(21)-C(22)-H(51)	119.998	120.000	C(31)-C(30)-H(48)	119.998	120.000
C(23)-C(22)-H(51)	119.998	120.000	C(30)-C(31)-C(32)	119.998	120.000
C(22)-C(23)-C(24)	119.998	120.000	C(30)-C(31)-H(46)	119.998	120.000
C(22)-C(23)-H(49)	120.000	120.000	C(32)-C(31)-H(46)	119.998	120.000
C(24)-C(23)-H(49)	119.998	120.000	C(31)-C(32)-C(33)	120.000	120.000
C(23)-C(24)-C(25)	120.001	120.000	C(31)-C(32)-Cl(41)	120.000	118.800
C(23)-C(24)-Cl(36)	119.998	118.800	C(33)-C(32)-Cl(41)	119.998	118.800
C(25)-C(24)-Cl(36)	119.998	118.800	C(32)-C(33)-C(34)	120.001	120.000
C(24)-C(25)-C(26)	120.001	120.000	C(32)-C(33)-H(42)	119.998	120.000
C(24)-C(25)-H(43)	119.998	120.000	C(34)-C(33)-H(42)	119.998	120.000
C(26)-C(25)-H(43)	119.998	120.000	C(29)-C(34)-C(33)	120.000	120.000
C(21)-C(26)-C(25)	120.000	120.000	C(29)-C(34)-H(47)	119.998	120.000
C(21)-C(26)-H(50)	119.998	120.000	C(33)-C(34)-H(47)	119.998	120.000
C(25)-C(26)-H(50)	119.998	120.000	O(11)-Cu(35)-O(18)	109.470	-
C(1)-N(27)-N(28)	115.001	115.000	O(11)-Cu(35)-N(20)	109.472	-
N(27)-N(28)-C(29)	122.000	124.000	O(11)-Cu(35)-N(28)	109.470	-
N(27)-N(28)-Cu(35)	119.998	-	O(18)-Cu(35)-N(20)	109.472	-
C(29)-N(28)-Cu(35)	117.998	-	O(18)-Cu(35)-N(28)	109.470	-
C(29)-N(28)-C(30)	120.000	120.000	N(20)-Cu(35)-N(28)	109.470	-
N(28)-C(29)-C(30)	120.000	120.000	C(19)-C(37)-H(38)	110.000	110.000
			C(19)-C(37)-H(39)	109.998	110.000

N(28)-C(29)-C(34)	120.000	120.000	C(19)-C(37)-H(40)	110.002	110.000
C(30)-C(29)-C(34)	119.998	120.000	H(38)-C(37)-H(39)	109.002	109.000
C(29)-C(30)-C(31)			H(38)-C(37)-H(40)	108.998	109.000
C(29)-C(30)-H(48)			H(39)-C(37)-H(40)	108.813	109.000

Antibacterial Assay

The *in-vitro* antibacterial activity of the ligands and its Schiff base mixed ligand complexes were tested against the bacteria by well diffusion method using nutrient agar as the medium. Stock solution was prepared by dissolving the compound in DMF. In a typical procedure, a well made on the agar medium inoculated with microorganisms in a petri plate. The well was filled with the test solution using a micropipette and the plate was incubated 24 hrs for bacteria at 35°C. During the period, the test solution diffused and the growth of the inoculated microorganisms was affected. A clearing zone around the wells indicates the inhibitory activity of the compound on the organism. The diameter of the zone of inhibition produced by the complexes was compared with standard Streptomycin. Results are shown in **Table.4, clearly** indicate that the inhibition are much larger by metal complexes as compare to the metal free ligand. The effect of L¹ may be due to -Ph, -OH and -N=N groups which are electron releasing. The activity of the ligand becomes more pronounced when combined with metal ions. In Metal complex, the chelation tends to make the ligands act as more powerful and potent bacterial agents, thus killing of the bacteria than the ligand. It is observed that in complexes the positive charge of the metal partially shared with the donor atoms present in the ligand and there may be -electron delocalization over the whole chelate ring. It is suggested that the complexes having antibacterial activity may act either by killing the microbe or by inhibiting multiplication of the microbe by blocking their active sites [35].

Table- 6: Antibacterial activity of ligand and its Schiff base mixed ligand complexes

S.NO	Compounds	<i>Staphylococcus aureus</i>	<i>Bacillus cereus</i>	<i>Escherichia coli</i>	<i>Pseudomonas aeruginosa</i>
1	L ¹	15	12	13	11
2	L ²	11	9	7	10
4	[Cu L ¹ L ²]	15	13	17	12
5	[Ni L ¹ L ²]	13	18	16	19
6	[ZnL ¹ L ²]	15	12	14	16
7	[CoL ¹ L ² X ₂]	18	17	19	16
8	Streptomycin	23	21	25	20

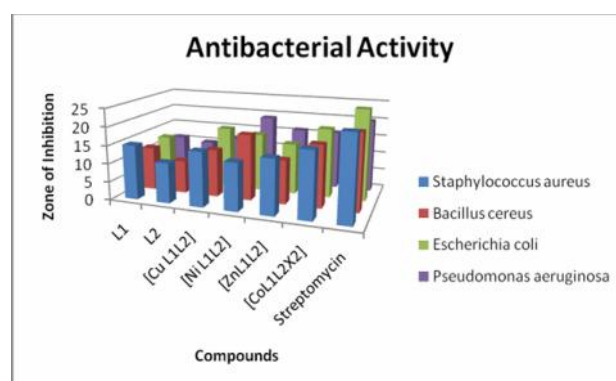


Fig.5: Antibacterial activity of ligand and its Schiff base mixed ligand complexes

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