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Synthesis, characterization and biological studies of Co(II), Ni(II), Cu(II) and Zn(II) complexes of Schiff bases derived from 3-formyl-2-mercaptoquinolines

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ABSTRACT

Co(II), Ni(II), Cu(II) and Zn(II) complexes have been synthesized by the Schiff bases derived from 3-formyl-2-mercaptoquinoline with 4-nitro-ortho-phenylinediamine. The synthesized Schiff bases and chelates were characterized by elemental analysis, molar conductance, magnetic susceptibilities, UV-Fluorescence, IR, ^{1}H-NMR, Fabmass, ESR and thermal studies. The results indicate that, the ligand acts as a octahedral geometry. The ligands and their metal complexes have been screened in vitro for antibacterial and antifungal studies. The results showed that the biological activity of the ligands get increased on complexation. The Cu(II) and Ni(II) complexes are found to be potent in DNA cleavage studies.

Keywords: Quinoline; coordination; metal complexes; NMR; antibacterial; antifungal.

INTRODUCTION

Quinolines are a class of nitrogen heterocycles, which are an integral part of a large number of natural and synthetic compounds which play important roles in many biological systems [1,2]. As a structural subunit in many natural products, the quinoline ring system is one of the most commonly encountered heterocycles in medicinal chemistry. A literature survey revealed that substituted quinolines possess diverse chemotherapeutic activities including antibacterial [3, 4], antifungal [5, 6], anti-amoebic [7,8], antileishmanial [9,10], antimalarial [11,12], and antitumor [13-15], immunosuppressive [16], analgesic, vasorelaxing [17], antiplasmodial [18], anticonvulsant, and antihypertensive [19].

Schiff bases are important class of ligands due to their synthetic flexibility, their selectivity and sensitivity towards the central metal ion, structural similarities with natural biological substances and also due to the presence of imine group (-N=CH-) which imports in elucidating the mechanism of transformation and rasemination reaction in biological system [20-22].

2-Mercapto-3-formylquinoline [23] is an interesting starting material for synthesis of heterocycles. In our laboratory, extensive work is being carried out on the synthetic utility of 2-mercapto-3-formylquinoline for the synthesis of metal complexes and their physical and biological properties associated [24]. Herein we report the synthesis of Schiff bases derived from 2-mercapto-3-formyl quinoline and 4-nitro-*ortho*-phenylenediamine (NOPDA) and their corresponding 3d series Co(II), Ni(II), Cu(II) and Zn(II) metal complexes. The newly synthesized ligands and their metal complexes are characterized by elemental analysis, spectral (IR, ^{1}H-NMR, mass, UV-Vis, ESR and fluorescence), thermal, magnetic and molar conductivities. Further, ligands and metal complexes have been screened for biological activity against various pathogenic bacterial and fungal strains, DNA cleavage ability; and their redox behaviour is established electronically.

EXPERIMENTAL SECTION

2.1 *Physical measurements*

Elemental Analyses (C, H and N) were performed on a Perkin- Elmer 2400 CHN elemental Analyzer Model 1106, Carloerba Strumentazione. The IR spectra of the ligands and their Co(II), Ni(II), Cu(II) and Zn(II) complexes were recorded on a HITACHI-270 IR spectrophotometer in the 4000-250 cm^{-1} region in KBr disks. Molar conductivity measurements were recorded on an ELICO-CM-82 T conductivity bridge with a cell having cell constant 0.51. The electronic spectra of the complexes were recorded in DMF on a VARIAN CARY 50-BIO UV-spectrophotometer in the region of 200-1100 nm. The ^{1}H-NMR spectra of ligands were recorded in $CDCl_3$ on BRUKER 300 MHz spectrometer at room temperature using TMS as an internal reference. FAB mass spectra were recorded on a JEOL SX 102/DA-6000 mass spectrometer/data system using Argon/Xenon (6 KV, 10Am) as the FAB gas. The accelerating voltage was 10 KV and the spectra were recorded at room temperature m-Nitrobenzyl alcohol was used as the matrix. The mass spectrometer was operated in the +ve ion mode. Thermogravimetric analysis data were measured from room temperature to 1000°C at a heating rate of 10°C/min. The data were obtained by using a PERKIN-ELMER DIAMOND TG/DTA instrument.

2.2 Materials

All the chemicals used were of reagent grade and used without further purification.

2.2.1 *Synthesis of 2-chloro-3-formyl-quinoline (N1)*

This compound was synthesized by the reaction of acetanilide with Vilsmier reaction at 80 ^{0}C as per the procedure given in the literature [25].

2.2.2 *Synthesis of 2-mercapto-3-formyl-quinoline (N2)*

One mole of 2-chloro-3-formyl-quinoline is mixed with 1.5 mole of sodium sulfide dissolved in 5 mL of DMF. The mixture is stirred for 1-2 hours at room temperature. This mixture was

poured in crushed ice followed by acidification with acetic acid to obtain yellow coloured solid melting point 245 ^{o}C [26].

2.2.3 ***Synthesis of Schiff base (L)***

A mixture of 2-mercapto-3-formyl-quinoline and 4-nitro-*ortho*-phenylinediamine in the 2:1 ratio in ethanol-acetic acid mixture (20 mL) was stirred at room temperature for 6 hours. After the completion of the reaction (7 hours), the solid separated was filtered, washed with excess of cold ethanol, dried and crystallized from ethanol or methanol.

2.2.4 ***Synthesis of Co(II), Ni(II) Cu(II) and Zn(II) complexes***

For the preparation of the metal chelates, hot ethanolic solutions of the respective metal chlorides (0.01 mol) and the Schiff base (0.01 mol) were refluxed for about 4 h on a water bath and the pH of the reaction mixture was adjusted *ca.* 7.0- 7.5. During the refluxation the metal chelates were separated out. The metal chelates thus separated were filtered, washed successively with ethanol and ether and finally dried over fused $CaCl_2$ in vacuum. Yield of all the metal complexes lie in the range of 65-72 % (Scheme 1).

2.3 ***Pharmacology***

2.3.1 ***Antibacterial and antifungal activities***

The antibacterial activity of the ligands and their Co(II), Ni(II), Cu(II) and Zn(II) metal complexes were assayed against two bacterial stain namely, *Escherichia coli* and *Bacillus cirroglagellous* by Minimum Inhibitory Concentration (MIC) [27-28] method with three different concentrations of 100 µg, 50 µg and 25 µg Similar procedure was followed for the antifungal activity of the above said ligands and metal complexes against two fungi namely, *Aspergillus niger and Candida albicans.* The activity was also assayed for the pure solvent DMF and the standard Gentamycine for each of antibacterial and Flucanazole for antifungal cultures. Final adjustments were made using optical density measurement for bacteria (absorbance 0.05 at a wavelength of 580 nm).

The zone of inhibition in mm for the ligands and their Co(II), Ni(II), Cu(II) and Zn(II) complexes are presented in (table 1). From the data of metal complexes it is clear that the metal chelates exhibit higher antimicrobial activity than that of the free ligand molecules. In the present case compared to other metal complexes Ni(II) and Cu(II) complexes were good antifungal agents.

The activity of any compound is a complex combination of steric, electronic and pharmacokinetic factors. A possible explanation for the toxicity of the complexes has been postulated in the light of chelation theory. It was suggested that the chelation considerably reduces the charge of the metal ion mainly because of partial sharing of its positive charge with the donor groups and possible π- electron delocalization over the whole chelate ring. This increases the lipophilic character of the metal chelate which favors its permeation through lipoid layers of cell membranes. Further more, the mode of action of the compounds may involve the formation of a hydrogen bond through the –N=C group of the chelate or the ligand with the active centers of the cell constituents resulting in interference with the normal cell process. The higher fungicidal activities experienced by the compounds may be ascribed to the fact that the ligand and metal ions are more susceptible towards the fungicidal cells than bacterial cells. Thus

it can be concluded that although these compounds are not good bactericides yet they may serve as better fungicides.

2.3.2 DNA cleavage experiment

2.3.2.1. *Preparation of culture media*

DNA cleavage experiments were carried out according to the literature *(29, 30).* Nutrient broth (peptone, 10 g l^{-1}; yeast extract, 5 g l^{-1}; NaCl, 10 g l^{-1}) was used for the culturing of *E. coli*. The 50mL medium was prepared and autoclaved for 15 min at 121 ^{o}C under 15-lb pressure. The autoclaved medium was inoculated with the seed culture. The *E. coli* was incubated for 24 h.

2.3.2.2. *Isolation of DNA*

The fresh bacterial culture (1.5 mL) was centrifuged to obtain the pellet, which was then dissolved in 0.5 mL of lysis buffer (100 mM Tris pH 8.0, 50 mM EDTA, 10 % sodium dodecyl sulphate (SDS)). To this, 0.5 mL of saturated phenol was added and incubated at 55 ^{o}C for 10 min. It was then centrifuged at 10,000 rpm for 10 min, and to the supernatant, an equal volume of chloroform: isoamyl alcohol (24:1) and 1/20th volume of 3 M sodium acetate (pH 4.8) were added. Then, this solution was centrifuged at 10,000 rpm for 10 min and to the supernatant, 3 vol of chilled absolute alcohol was added. The precipitated DNA was separated by centrifugation and the pellet was dried and dissolved in a TAE buffer (10 mM Tris pH 8.0, 1 mM EDTA) and stored in cold conditions.

2.3.2.3. Agarose gel electrophoresis

Cleavage products were analyzed by the agarose gel electrophoresis method [29, 30].Test samples (1 mg mL^{-1}) were prepared in DMF. The samples (25 μg) were added to the isolated DNA of *E. coli*. The samples were incubated for 2 h at 37 ^{o}C. Then 20 μL of DNA sample (mixed with bromophenol blue dye at a 1:1 ratio) was loaded carefully into the electrophoresis chamber wells along with a standard DNA marker containing TAE buffer (4.84 g Tris base, pH 8.0, 0.5 MEDTA per 1 L) and finally loaded on agarose gel and a constant electricity of 50 V was passed for around 30 min. The gel was removed and stained with 10.0 μg mL^{-1} ethidium bromide for 10–15 min and the bands observed under Vilberlourmate Gel documentation system and photographed to determine the extent of DNA cleavage. Then, the results were compared with that of a standard DNA marker.

RESULTS AND DISCUSSION

The synthesized complexes are colored and are insoluble in water, methanol and ethanol, totally soluble in DMF and DMSO. The elemental analyses (table 2) are consistent with the type $ML2H_2O$. The conductivity measurement in DMF/DMSO at the 10^{-3}M concentrations is too low to account for any dissociation of the complex in DMF/DMSO. Hence, the complexes may be regarded as non-electrolytes. In order to establish whether the water molecule present in the synthesized complexes coordinated to the metal ion, weighed complexes were dried over P_4O_{10} in vacuum for 1 h and weighed again. No loss in weight was observed. This was confirmed by heating the complex for 2 h at 105 ^{0}C and no weight loss was considered for the water of hydration. These observations suggest that, water molecules in the Co(II), Ni(II), Cu(II) and Zn(II) complexes are coordinated to the metal ion.

3.1 *Infrared spectra*

The infrared spectral data of the ligands and their metal complexes are listed in (table 3). A high intensity band observed *ca.* 1620 cm^{-1} is attributed to the ν(C=N) vibration [31]. This fact renders the proof for the formation of Schiff base. The low intensity bands arriving in the region of 700-600 cm^{-1} are assignable to the fact of the formation of C-S bonds and further the absorption bands between 2000 and 2600 cm^{-1} indicating the S-H bonding [32]. Medium intensity bands in the 1645 – 1601 cm^{-1} region are regarded as a combination of C=N and C=C stretching vibrations of aromatic ring. The frequencies *ca* 1550 and 1350 cm^{-1} were observed for symmetric and asymmetric nitro group.

In the case of Co(II), Ni(II), Cu(II) and Zn(II) complexes we observed the following changes. The medium intensity band appeared around 1620 cm^{-1} due to ν(C=N) in Schiff bases shifted to 1613-1601 cm^{-1} in the complexes. The low shift indicated that, the azomethine group of the ligands has coordinated to the metal ion through nitrogen. The position of low intensity band due to C-S appeared in the region 700–600 cm^{-1} is unaltered. The absorption bands around 2620 cm^{-1} indicating the S-H bonding in the Schiff bases have appeared as a medium to high intensity band in the 350-380 cm^{-1} region in the complexes. These observations support the formation of M-S bonds *via* deprotonation [33]. So the H-atom of –SH groups have been replaced by the metal ion. In addition the Co(II), Ni(II), Cu(II) and Zn(II) complexes exhibit a broad band at 3440-3461 cm^{-1}; which was attributed to the symmetric and antisymmetric –OH stretching modes. There was also a medium to high intensity band around 817-832 cm^{-1} and each of these bands was assigned to the coordinated water molecule. The important features of the infrared spectra of all the complexes are the appearance of two strong bands at 350-380 cm^{-1} region are assignable ν(M-S) and those in the region 420-470 cm^{-1} to ν(M-N) vibrations, supporting the coordination of the ligands as tetradentate NS chelating agents [33-35].

3.2 *^{1}H-NMR spectra*

The Schiff bases exhibit the characteristic resonance at 8.06 ppm due to the azomethine proton. A singlet corresponding to one proton observed at 12.84 ppm is probably due to SH group. Hydrogen bonding leads to deshielding and to an increase in the frequency of the PMR signal of the hydrogen bonded proton. This may explain the observed increase in the chemical shift. The sharp multiplet signals of the phenyl protons are found in the region 7.54-9.38 ppm. Co(II), Ni(II) and Cu(II) complexes being paramagnetic in nature were ^{1}H-NMR inactive. The peak due to SH group appeared at 7.4 ppm in the ligands was not observed in the Zn(II) complexes. This confirmed the involvement of thiolate sulphur in coordination with the metal via de protonation. The downfield shift of the methine proton from 8.06 ppm in the ligand spectrum to 9.11 ppm in the complexes indicated the participation of azomethine nitrogen in the coordination [36].

3.3 *Electronic spectra*

The electronic spectra of Co(II) complexes exhibited absorption bands in the regions 8000–10,000 cm^{-1} and 18,000–20,000 cm^{-1} corresponding to ν_1 and ν_3 transitions, respectively, which are attributed to the transitions $^4T_{1g}$ (F)→$^4T_{2g}$ (F) (ν_1); $^4T_{1g}$ (F)→ T_{1g} (P) (ν_3). In the present investigation, Co(II) complexes show the absorption bands at 8936–8952 and 19,153–19,171 cm^{-1} are corresponding to ν_1 and ν_3 transitions, respectively. These bands are the characteristic of high spin octahedral Co(II) complex [37]. However, ν_2 band is not observed because of its proximity to strong ν_3 transition.

The Ni(II) complex exhibited three bands at 10,330, 15,801 and 26,336 cm^{-1} and attributed to the $^3A_{2g} \rightarrow {}^3T_{2g}$ (v_1); $^3A_{2g} \rightarrow {}^3T_{1g}$ (F) (v_2) and $^3A_{2g} \rightarrow {}^3T_{1g}$ (P) (v_3) transitions, respectively, which indicate an octahedral geometry around Ni(II) ion [38]. The ligand field parameters are given in table 4. The value of v_2/v_1 is found to be around 1.53, and the μ_{eff} value is around 3.18, which is within the range of 2.8–3.5 BM, suggesting the octahedral environment. The values of the nephelauxetic parameter, β, indicate the low covalent character of the metal-ligand σ bonds [39]. Hence the ligand field parameters correlate the electronic spectral and magnetic properties.

The electronic spectra of Cu(II) complexes display two prominent bands. A low-intensity broad band of around 14,392 cm^{-1} is assignable to $^2E_g \rightarrow {}^2T_{2g}$ transition and another high-intensity band at 25,548 cm^{-1} is due to symmetry forbidden ligand → metal charge transfer. On the basis of electronic spectra distorted octahedral geometry around Cu(II) ion is suggested [40].

3.4 *Magnetic data*

The magnetic moments obtained at room temperature are listed in Table 2. The magnetic measurement for Co(II) complexes exhibit magnetic moment values of 4.80–4.90, which are in agreement with the octahedral range of 4.3–5.2 BM. Ni(II) complexes showed the magnetic moment values of 2.90–3.01 within the range of 2.8–3.5 BM, suggesting [41] consistency with their octahedral environment. The Cu(II) complexes showed a magnetic moment of 1.75–1.78 BM, slightly higher than the spin-only value 1.73 BM expected for one unpaired electron, which offers the possibility of an octahedral geometry [42].

3.5 *FAB-Mass spectral studies*

The FAB-mass spectra of Co(II), Ni(II), Cu(II) and Zn(II) complexes of Schiff base **N4** showed a molecular ion peak M+ at m/z 591, 591, 595 and 597 respectively, equivalent to their molecular weights. All the fragments of the species $[ML.2H_2O]^+$ undergo demetallation to form the species $[L+H]^+$ giving a fragmentation at *m/z* 485. The fragmentation peak observed in the case of Co (II) complex at 554 correspond to the loss of two water molecules. Also, the species $[ML.2H_2O]^+$ undergoes demetallation to form the species $[L+H]^+$ giving a fragment ion at *m/z* 485. Similar features are evident for other complexes. All these fragmentation patterns were well observed in the FAB-mass spectra.

3.6 *ESR spectra*

The ESR spectrum of one representative Cu(II) complex was recorded at room temperature (300 K) and at liquid nitrogen temperature(77 K) which has exhibited unresolved broad signals giving only one g value, i.e., g_{iso} (g_{iso} at 300 K is 2.066 respectively). The shape of ESR indicates that the present complexes may have distorted octahedral geometry [43].

3.7 *Thermogravimetric study*

The thermal behavior of Co(II), Ni(II), Cu(II) and Zn(II) complexes have been studied as a function of temperature. The thermal behavior of all the complexes is almost same. Hence, only the representative $[Co(N4)(H_2O)_2]$, $[Ni(N4)(H_2O)_2]$, $[Cu(N4)(H_2O)_2]$ and $[Zn(N4)(H_2O)_2]$complexes have been discussed here.

The $[Co(N4)(H_2O)_2]$, $[Ni(N4)(H_2O)_2]$, $[Cu(N4)(H_2O)_2]$ and $[Zn(N4)(H_2O)_2]$ complexes takes place in four step as indicated by DTG peaks around 160-165 ^oC, 260-270 ^oC and 390-395 ^oC

corresponding to mass loss of coordinated water molecules, quinoline moiety and 4-nitro-*ortho*-phenylenediamine. Finally, the metal complexes decompose gradually with the formation of metal oxide above 500 ºC. The nature of proposed chemical change with the temperature range and the percentage of metal oxide are presented in Table 5.

Table 1.Antibacterial and antifungal activity of Quinoline derivatives and their metal complexes (zone of inhibition in mm)

Complex Code	Compound	Conc. µg/L	Antifungal		Antibacterial	
			A.niger	*C. albicans*	*E. coli*	*B. cirroglagellous*
		100	17	16	24	25
N4	-	50	14	12	15	17
		25	07	06	09	10
		100	20	19	22	24
1	$[Co(N4)(H_2O)_2]$	50	12	10	10	14
		25	04	02	03	06
		100	17	16	20	19
2	$[Ni(N4)(H_2O)_2]$	50	06	07	11	10
		25	--	--	01	--
		100	20	21	24	26
3	$[Cu(N4)(H_2O)_2]$	50	10	12	16	18
		25	04	05	07	08
		100	16	15	19	20
4	$[Zn(N4)(H_2O)_2]$	50	07	06	08	10
		25	--	--	02	--
		100	--	--	28	28
Gentamycine		50	--	--	21	21
		25	--	--	13	13
		100	22	22	--	--
Flucanazole		50	14	14	--	--
		25	07	07	--	--
		100	12	12	12	12
DMF		50	06	06	06	06
		25	02	02	02	02

Key to interpretation (for 100 µg/L); Less than 10mm----------Inactive; Less than 10-15mm------Weakly active Less than 15-20mm------Moderately active; More than 20mm---------Highly active

3.8 *UV-Fluorescence Spectra*

The UV-Vis and fluorescence spectra of ligands and their complexes were determined in 200–800 nm region in DMSO and DMF.

For ligand (N4) and its complexes: In UV-Visible spectra two absorption maxima were observed in the range 250-290 and 304-424 nm due to $\pi-\pi^*$ and $n-\pi^*$ transitions, respectively. In fluorescence spectra emission were observed in the range 413-467 nm, the highest emission was observed for ligand 467 nm which decreases on complexation with metals in DMSO solvent.

Similarly in DMF solvent, UV-Visible spectra two absorption maxima were observed in the range 250-290 and 302-422 nm due to π– π* and n– π* transitions, respectively. In fluorescence spectra emission were observed in the range 439-472 nm, the highest emission was observed for Cu-complex 472 nm (table 6) [44, 45].

Table 2. Analytical, magnetic and conductance data of the Quinoline derivatives and their transition metal complexes

Code	Empirical Formula	C % Calc. (Found)	H % Calc. (Found)	N % Calc. (Found)	S % Calc. (Found)	M % Calc. (Found)	Molar condt. Ohm^{-1} cm^{-2} $mole^{-1}$	μ_{eff} (BM)
N4	$C_{26}H_{18}N_5O_2S_2$	62.90 (62.88)	3.62 (3.58)	14.10 (14.02)	12.90 (12.85)	--	--	--
1	$[Co(N4)(H_2O)_2]$	53.17 (53.11)	2.89 (2.85)	11.93 (11.89)	10.90 (10.87)	10.9 (10.98)	10.30	4.80
2	$[Ni(N4)(H_2O)_2]$	53.16 (53.10)	2.87 (2.85)	11.92 (11.87)	10.89 (10.86)	10.01 (9.98)	9.20	3.01
3	$[Cu(N4)(H_2O)_2]$	52.74 (52.63)	2.86 (2.82)	11.83 (11.79)	10.81 (10.75)	11.73 (11.67)	12.30	1.78
4	$[Zn(N4)(H_2O)_2]$	52.58 (52.50)	2.86 (2.81)	11.79 (11.72)	10.78 (10.73)	11.01 (11.00)	13.40	Dia

Table 3. Infrared spectral data of Schiff bases and their metal complexes in cm^{-1}

Code	Empirical Formula	$\nu_{(OH)}$ cm^{-1}	$\nu_{(C-S)}$ cm^{-1}	$\nu_{(C=N)}$ cm^{-1}	$\nu_{(C-N-C)}$ cm^{-1}	$^{\nu}(H_2O)$ cm^{-1}	$\nu_{(M-N)}$ cm^{-1}	$\nu_{(M-S)}$ cm^{-1}	$\nu_{(NO2)}$ Asym cm^{-1}	$\nu_{(NO2)}$ Sym cm^{-1}
N4	$C_{26}H_{18}N_5O_2S_2$	-	692	1620 (s)	939 (m)	-	-	-	1520	1310
1	$[Co(N4)(H_2O)_2]$	3440 (b)	619	1601 (s)	1051 (m)	817 (s)	523 (w)	354 (w)	1544	1343
2	$[Ni(N4)(H_2O)_2]$	3460 (b)	652	1606 (s)	1017 (m)	820 (s)	512 (m)	375 (w)	1545	1349
3	$[Cu(N4)(H_2O)_2]$	3415 (b)	612	1616 (s)	1081 (m)	828 (s)	514 (w)	390 (w)	1542	1342
4	$[Zn(N4)(H_2O)_2]$	3461 (b)	613	1613 (s)	1072 (m)	832 (s)	521 (w)	351 (w)	1541	1344

Table 4. Electronic spectral data of octahedral Co(II) complexes (in DMF solution)

Code	Complex	ν_1 cm^{-1}	ν_2	ν_3 cm^{-1}	ν_2 (cal) cm^{-1}	Dq cm^{-1}	B' cm^{-1}	Distortion (%)	$\nu_{2/}\nu_1$	LFSE Kcal/mol	μ_{eff} Cald. BM	β	β (%)
1	$[Co(N4)(H_2O)_2]$	8952	--	19171	11920	895	282	1.45	1.33	30.69	3.22	0.267	73.26
2	$[Ni(N4)(H_2O)_2]$	10274	15796	26324	16336	1027	789	3.30	1.54	35.22	3.17	0.747	25.26

Table 5. Thermal data of complexes

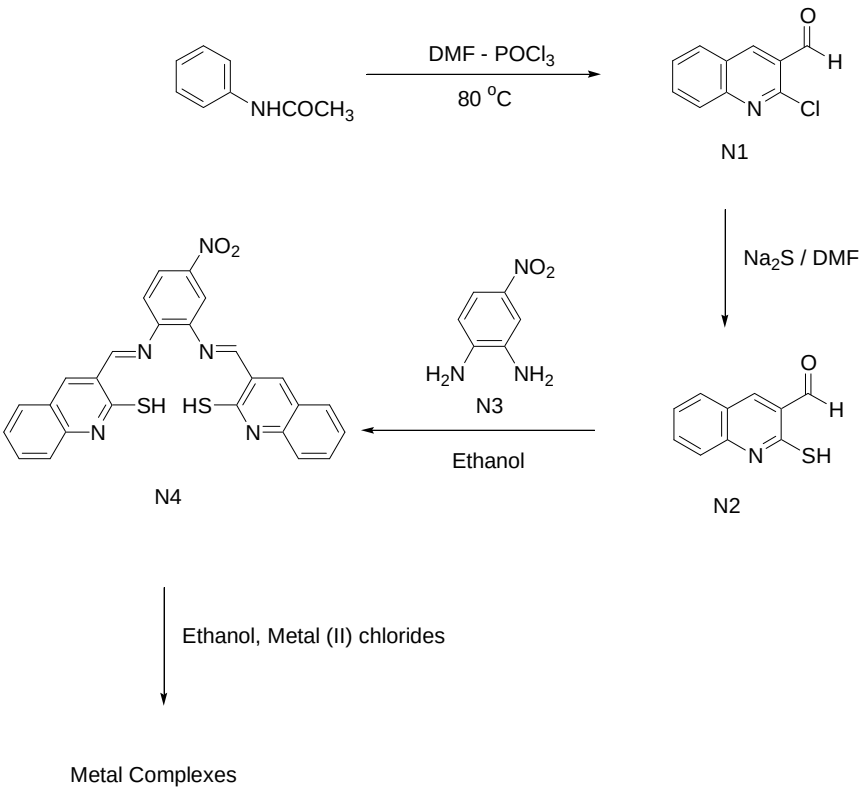
Complex code	Complex	Temp (^oC)	% weight loss	Proposed chemical change	Metal %
1	$[Co(N4)(H_2O)_2]$	199	6.09 (6.22)	Water molecules	
		242	26.39 (26.65)	Phenyl moiety	12.07 (12.12)
		485	31.95 (31.50)	Quinoline Moiety	
2	$[Ni(N4)(H_2O)_2]$	213	6.09 (6.22)	Water molecules	
		256	26.15 (26.25)	Phenyl moiety	12.07 (12.12)
		409	31.45 (31.50)	Quinoline Moiety	
3	$[Cu(N4)(H_2O)_2]$	213	6.12 (6.22)	Water molecules	
		256	26.39 (26.65)	Phenyl moiety	13.15 (312)
		409	31.95 (31.50)	Quinoline Moiety	
4	$[Zn(N4)(H_2O)_2]$	213 610	(6.22)	Water molecules	
		256	26.39 (26.65)	Phenyl moiety	13.01 (13.11)
		409	31.95 (31.50)	Quinoline Moiety	

3.9 DNA Cleavage study

The gel containing *E. coli* DNA treated with compounds shows that after treatment, the intensity of all the treated DNA samples has diminished, possibly because of the cleavage of the DNA. The complete cleavage was observed with **1** $[Co(N4)(H_2O)_2]$ and **2** $[Ni(N4)(H_2O)_2]$. All other compounds have shown partial cleavage (figure 1). The results show that the biological activity of the ligands get increased on complexation. The Co(II) and Ni(II) complexes are found to be potent in DNA cleavage studies.

The gel containing *Bacillus cirroglagellous* DNA treated with compounds shows that after treatment, the intensity of all the treated DNA samples has diminished, possibly because of the cleavage of the DNA. The complete cleavage was observed with **1** $[Co(N4)(H_2O)_2]$ and **2** $[Ni(N4)(H_2O)_2]$. All other compounds have shown partial cleavage.

The gel containing *A. niger* DNA treated with compounds showed the complete cleavage was observed with all the samples.



Scheme 1. Synthesis of Schiff base N4 and its complexes

Table 6. Emission spectral data of Schiff bases (N3 and N4) and its Co (II), Ni(II), Cu(II) and Zn(II) complexes in DMSO and DMF.

Compound	In DMSO			In DMF		
	UV	Fluorescence*	Stokes Shift	UV	Fluorescence*	Stokes Shift
N4	290/424	467	43	290/424	439	15
1 [Co(N4)(H_2O)$_2$]	270/374	462	88	288/374	444	70
2 [Ni(N4)(H_2O)$_2$]	250/304	413	109	250/304	456	152
3 [Cu(N4)(H_2O)$_2$]	275/376	428	52	275/384	472	88
4 [Zn(N4)(H_2O)$_2$]	286/402	436	34	272/399	452	53

** Higher wavelength is used for excitation for emission (fluorescence) studies.*

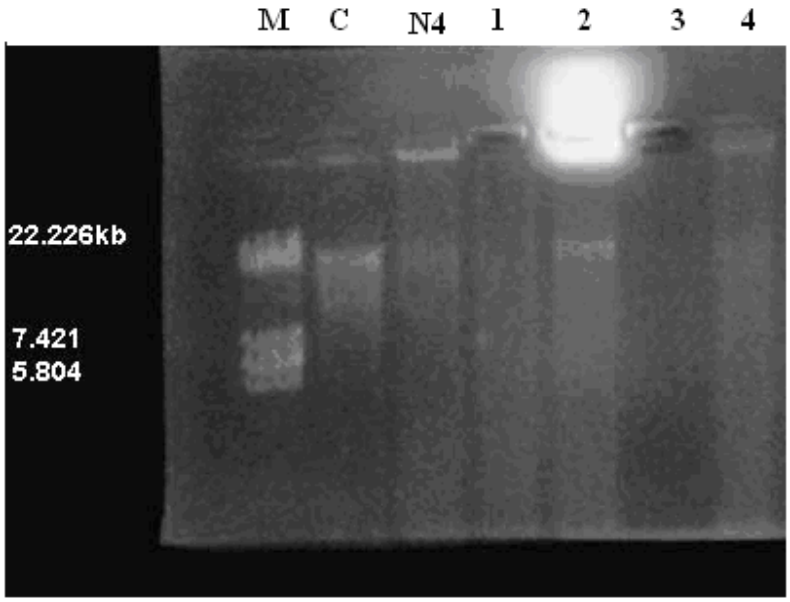
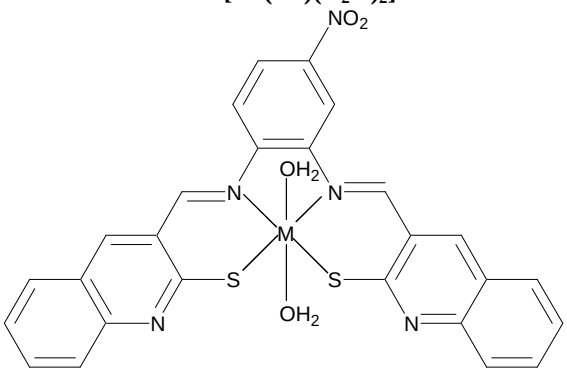


Figure 1. DNA cleavage on genomic DNA of *E. coli*. M, standard molecular weight marker; Control, control DNA of *E. coli*; lane N4, *E. coli* DNA treated with $C_{26}H_{17}N_5O_2S_2$; lane 1, *E. coli* DNA treated with $[Co(N4)(H_2O)_2]$; lane 2, *E. coli* DNA treated with $[Ni(N4)(H_2O)_2]$; lane 3, *E. coli* DNA treated with $[Cu(N4)(H_2O)_2]$; lane 4, *E. coli* DNA treated with $[Zn(N4)(H_2O)_2]$.



M = Co(II), Ni(II), Cu(II) and Zn(II)

Figure 2. Proposed structure of the complexes

CONCLUSION

With the help of various physico-chemical techniques, geometries of the newly synthesized compounds have been proposed (figure 2). The tentative structures of all the complexes are based on elemental analysis, IR, ^{1}H NMR, electronic, magnetic measurements, thermal studies and mass spectra.

Copper and Nickel complexes were found most active towards the fungicidal activity at lower MIC concentrations. Cobalt and Nickel complexes were found to be potent in DNA cleavage studies. Efforts are under continuous progress to synthesize, characterize and fluorescently

evaluate the inner-transition complexes with the above ligands and find their applicability into various analytical and spectroscopical techniques.

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Research Highlights

- *The synthesized ligands and their corresponding complexes of 3d transition metal ions such as Co(II), Ni(II), Cu(II) and Zn(II) are characterized by various physico-chemical properties like elemental analysis, molar conductance, magnetic susceptibilities, UV-Fluorescence, IR, ^{1}H-NMR, ESR and thermal studies.*
- *From the above observations, we proved the ligand acts as a tetradentate fashion to the metal ion and all complexes show octahedral geometry by coordination with water molecules, which are confirmed their FAB Mass spectral studies.*

- *The ligands and their metal complexes have been screened in vitro for antibacterial and antifungal studies. The results show that the biological activity of the ligands get increased on complexation.*
- *The Cu(II) and Ni(II) complexes are found to be potent in DNA cleavage studies.*