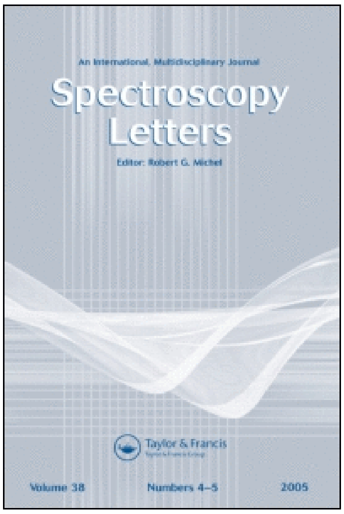

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Synthesis, Thermal Behavior, and Antimicrobial Activity of a Novel Macrocycle and its Transition Metal Complexes Derived from Thiosemicarbazide

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Synthesis, Thermal Behavior, and Antimicrobial Activity of a Novel Macrocycle and its Transition Metal Complexes Derived from Thiosemicarbazide

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ABSTRACT The present study reports the synthesis of Co(II), Ni(II), Mn(II), Cu(II), and Zn(II) complexes with a new macrocyclic ligand (L_2)-1,2,8,9,11,14-hexaazacyclopentadeca-12,13-dioxo-10,15-dithione-2,7-diene. The macrocycle was derived from thiosemicabazone (L_1) and diethyloxalate that were prepared by the reaction of thiosemicarbazide and glutaraldehyde in the ratio of 2:1. The synthesized complexes and ligands were characterized by elemental analysis and molar conductance, magnetic susceptibility, ^{1}HNMR, IR, electronic, and thermogravimetric analyses. The molar conductance values confirmed that the Ni(II), Cu(II), Zn(II), Mn(II) and Co(II) complexes were 1:2 electrolytes. On the basis of electronic spectral studies and molar conductance measurements, the authors proposed an octahedral structure for Ni(II), Mn(II), and Co(II) complexes, tetrahedral geometry for Zn(II) complex, and square planar geometry for Cu(II) complex. The thermal behavior of the compounds was studied by TGA in a nitrogen atmosphere up to 750°C at the rate of 20°C/min. The TGA results revealed that the complexes had higher thermal stability than the macrocycle. All the synthesized compounds were screened against 4 bacteria (i.e., *Streptococcus aureus, Escherichia coli, Bacillus subtillis, Salmonella typhimurium*) and 2 fungi (i.e., *Fusarium oryzae, Candida albicans*). The results showed that the metal complexes inhibited the growth of bacteria to a greater extent as compared to the ligand.

KEYWORDS antibacterial and antifungal activity, macrocyclic complexes, thiosemicabazones

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INTRODUCTION

A large number of natural macrocycles like porphyrin and cobalamine display remarkable properties, and their coordination chemistry has been intensely investigated.[1] Macrocyclic complexes have attracted research interest due to their analytical, biological, and catalytic applications.[2,3] The macrocyclic ligands play an important role in transition metal complexes due to kinetic and thermodynamic stabilities.[4,5] Interest in synthetic macrocycles derived from Schiff base is growing due to their wide applications in catalysts, radiopharmaceuticals, and magnetic-imaging reagents.[6] They provide an environment of controlled geometry and ligand field strength to the metal ions. The formation of macrocyclic complexes mainly depends on the internal cavity and the rigidity of the macrocycle formed. The macrocyclic ligand based on thiosemicarbazone and their metal complexes have shown themselves to be pharmacologically active against several viruses, bacteria, and fungi and certain kinds of tumors.[7–9] The importance of these compounds is mainly the result of their antimicrobial activities.[10,11] It has been observed that the pharmacological activities are enhanced in the presence of transition metal ion.[12] The fungicidal activity of these compounds is due to their ability to form stable chelates with metal ions that fungi need for metabolism.[13] Keeping the above views in mind, we synthesized a series of transition metal complexes having macrocyclic ligand based on thiosemicarbazone. They were characterized by elemental analysis, molar conductance measurements, magnetic susceptibility measurements, ^{1}HNMR spectra, IR spectra, electronic spectra, and thermogravimetric studies.

MATERIALS AND METHODS

Glutaraldehyde, transition metal chloride (S.D. Fine-Chemicals, India), thiosemicarbazide (BDH) and diethyl oxalate (Merck) were used as received. Solvents were distilled before use. Microorganisms were isolated in suitable environment.

Synthesis of L_1

An ethanolic solution of thiosemicarbazide (20 mmol, 1.82 g) was added to ethanolic solution of glutaraldehyde (10 mmol, 0.942 ml) with constant stirring in the presence of a few drops of hydrochloric acid. After addition of all the reagents, the mixture was heated at 60°C with constant stirring for 7 hr. On keeping it overnight at room temperature, a red colored amorphous solid was formed. It was filtered, washed with acetone and diethyl ether, and dried in vacuum over $CaCl_2$. The synthesis is represented in Fig. 1.

Synthesis of L_2

An ethanolic solution of L_1 (10 mmol, 2.47 g) was added to ethanolic solution of diethyl oxalate (10 mmol, 1.36 ml). The diethyl oxalate solution was taken in burette and added drop-wise to the solution of L_1 in such a manner that the addition

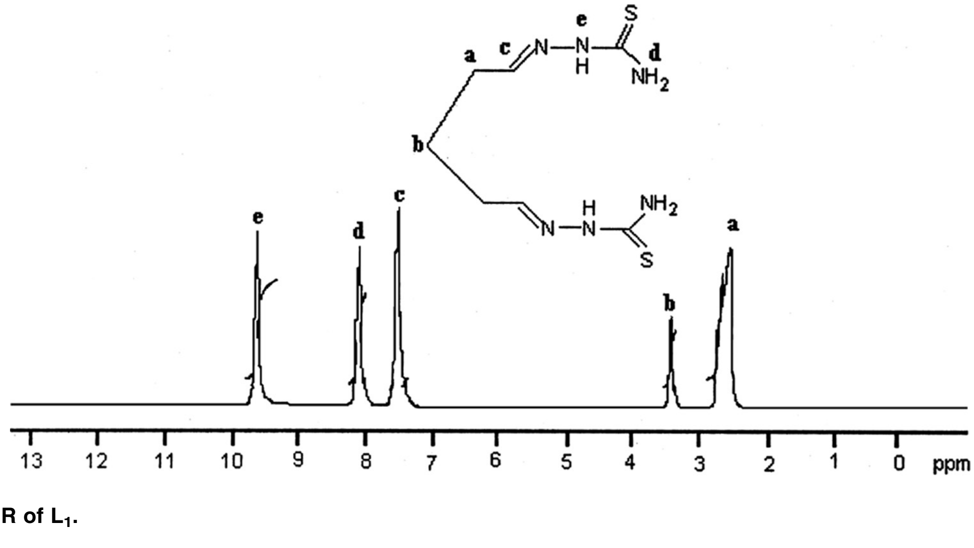


FIGURE 1 ^{1}H NMR of L_1.

would take at least 1 hr. Then, the mixture was heated at 60°C with stirring for 10 hr. After that period, the mixture was reduced by more than half of its volume by rotatory evaporator. After that, we left the mixture at room temperature till all the solvent vaporized. The obtained product was washed with acetone and diethyl ether in vacuum over $CaCl_2$. The synthesis is represented in Fig. 1.

Synthesis of ML_2

An ethanolic solution of L_2 (10 mmol, 3.01 g) was added to ethanolic solution of Ni(II) chloride (10 mmol, 2.37 g) in 1:1 ratio with constant stirring at 50°C. The green precipitate of nickel complex was obtained. This precipitate was washed several times with acetone and diethyl ether and dried in vacuum over $CaCl_2$. The complexes from Co(II), Mn(II), Zn(II), and Cu(II) chlorides were prepared by the same method. Template synthesis also gave the same products as obtained by the above described method. Template synthesis was followed by the addition of ethanolic solution of diethyloxalate to the ethanolic solution of L_1 at 60°C and stirred for 10 hr. Instant precipitate was obtained by adding metal chlorides to the above solution. All the properties of L_2 and metal complexes prepared from both the methods were found to be similar.

Physical Measurements

The IR spectra of the compounds were recorded on PerkinElmer FTIR spectrometer, model 983 (PerkinElmer; United States), using KBr disc in the range of 4000–200 cm^{-1}. The percentages of carbon, hydrogen, and nitrogen of the ligands and the complexes were determined by Elemental Analyzer System GmBH varion, ELIII. The conductivity measurements were carried out on a CM-82T Elico conductivity bridge, and magnetic measurements were done with a model 155 Allied Research vibration sample magnetometer at room temperature. UV-visible spectra of the complexes were done on a Lambda EZ201 spectrometer (PerkinElmer; United States) in DMSO. The ^{1}HNMR spectra of L_1, macrocyclic ligands, and the complexes were run in DMSO-d_6 on a Bruker Spectrospin DPX-300 MHz Spectrometer (Bruker; United States). The thermogravimetric analysis (TGA) of the compounds was done by Perkin Elmer at 200-ml/min–flowing nitrogen atmosphere. Chlorine was estimated gravimetrically, and metals were determined by EDTA complexometric titration followed by decomposition of their complexes with fuming nitric acid. The antibacterial and antifungal activity was performed by agar disc diffusion method. The samples were prepared by using DMSO as solvent at a concentration of 50 μg/ml. The test was performed at 37°C, and bacteria were incubated for 24 hr, while fungi were incubated for 48 hr.

RESULTS AND DISCUSSION

The proposed analytical data of the complexes with their colors are summarized in Table 1. The thiosemicarbazone (L_1) was obtained by the reaction of glutraldehyde with thiosemicarbazide in the ratio of 2:1. The L_1 was refluxed and stirred with diethyloxalate (1:1 molar ratio), which yielded orange-colored macrocyclic ligand (L_2). The ligands L_1 and L_2 were found to be soluble in ethanol and DMSO, whereas all the synthesized metal complexes were insoluble in common organic solvents except DMSO. On heating of all the metal complexes, they underwent decomposition and did not give a sharp melting point. The L_2 and its metal complexes were found to be stable in air. The molar conductance of the metal complexes of Mn(II), Co(II), and Ni(II) fell into the expected range in DMSO for nonelectrolytes, and that circumstance indicated the absence of chloride ions, while the higher values of molar conductance of Cu(II) and Zn(II) complexes showed their electrolytic nature and confirmed the presence of chloride ions outside the coordination sphere.

IR Spectral Studies

The most relevant bands of the ligands and of their metal complexes are tabulated in Table 2 with their assignments. L_1 and L_2 exhibited strong IR bands at 1625 and 1629 cm^{-1} (C=N), respectively, which were higher than those of metal complexes (1610–1619 cm^{-1}). That is, on coordination, $\nu_{C=N}$ shifts to lower wavelength. The band of NH_2 stretching was found to be absent from L_2 and all metal complexes, but the band appeared in the L_1 at 3280 cm^{-1}. The L_1, L_2, and metal complexes exhibited a band in the range of 3162–3150 cm^{-1} assigned to ν_{NH} for secondary amine. The band's appearance in range of

TABLE 1 Analytical Data, Color, Melting Point, Percentage Yield, and Molar Conductance of Ligands and the Metal Complexes

Compounds (formula weight)	Color	M.p. (°C)	Yield % (gm)	Molar Conductance · (Ω^{-1}cm^2 mole^{-1})	Analysis % found (calcd.)					
					C	H	S	N	Cl	M
$C_7H_{14}N_6S_2$, (L_1) (247.056)	Red	230	68 (3.80)	—	34.24 (34.31) ±0.002	5.68 (5.71) ±0.005	25.79 (25.95) ±0.006	33.95 (34.02) ±0.002	—	—
$C_9H_{12}N_6O_2S_2$, (L_2) (301.258)	Orange	280	55 (2.16)	—	36.10 (36.18) ±0.002	4.10 (4.01) ±0.02	21.11 (21.29) ±0.008	27.72 (27.89) ±0.006	—	—
$[MnL_2Cl_2]$ (427.102)	Pale yellow	320	73 (3.63)	12	25.70 (25.51) ±0.007	2.80 (2.83) ±0.010	14.98 (15.01) ±0.003	19.52 (19.68) ±0.008	16.49 (16.60) ±0.006	12.76 (12.86) ±0.007
$[CoL_2Cl_2]$ (431.097)	Dark green	320	82 (4.41)	32	25.30 (25.28) ±0.000	2.96 (2.80) ±0.057	14.68 (14.87) ±0.012	19.28 (19.49) ±0.010	16.42 (16.45) ±0.002	13.76 (13.67) ±0.006
$[NiL_2Cl_2]$ (430.857)	Light green	333	75 (4.03)	28	26.01 (25.29) ±0.028	2.74 (2.80) ±0.021	14.62 (14.88) ±0.017	19.42 (19.50) ±0.004	16.38 (16.45) ±0.004	13.54 (13.62) ±0.006
$[CuL_2]Cl_2$ (435.710)	Green	328	70 (3.29)	132	24.98 (25.01) ±0.001	2.72 (2.77) ±0.018	14.68 (14.71) ±0.002	19.21 (19.29) ±0.004	16.32 (16.27) ±0.003	14.55 (14.58) ±0.002
$[ZnL_2]Cl_2$ (437.554)	White	330	64 (2.79)	140	24.88 (24.90) ±0.000	2.68 (2.76) ±0.028	14.60 (14.65) ±0.003	19.14 (19.20) ±0.003	16.12 (16.20) ±0.005	14.89 (14.94) ±0.003

1655–1665 cm^{-1} in L_2 and metal complexes shows the formation of oxamide group (NH-CO) from the diethyloxalate.[14] The absence of NH_2 group and the presence of oxamide group in L_2 are some of the evidence for the formation of macrocycle. The band observed at 1148 and 1153 cm^{-1} in L_1 and L_2, respectively, is attributed to ν_{N-N}. This band is shifted to higher frequency in metal complexes, that is, in the range of 1160–1163 cm^{-1}. This increase in the frequency is due to the increase in the bond strength and also confirms the coordination via azomethine nitrogen.[15] The IR spectra of L_1, L_2, and all the metal complexes showed a band in the region 2920–2929 cm^{-1} due to the CH_2 stretching frequency. The frequency of $\nu_{C=S}$ band lies in the range of 848–855 cm^{-1} in L_2 and metal complexes. The band observed in the spectra of L_1, L_2, and metal complexes in the range of 1313–1328 cm^{-1} is attributed to $\delta_{C=S}$, that is, deformation of C=S group. The bands in the ranges of 440–457 cm^{-1} and 328–350 cm^{-1} are assigned to M-N and M-Cl, respectively.[16]

TABLE 2 Characteristic IR Bands (cm^{-1}) of the Ligands and the Complexes

Compounds	ν(N-H)	ν/δ(C=S)	ν(C=O) (oxalate group)	ν(C–H)	ν(C=N)	ν(N-N)	ν(M–N)	ν(M–Cl)
Ligand (L_1)	—	1328, 868	—	2929 s	1629 s	1148	—	—
Macrocycle (L_2)	3162 m	1326, 855	—	2923	1625 s	1153	—	—
$[MnL_2Cl_2]$	3155 m	1314, 851	1654	2921 s	1615 s	1160	447 s	350 s
$[CoL_2Cl_2]$	3150 m	1316, 849	1662	2920 s	1619 s	1160	457 s	335 s
$[NiL_2Cl_2]$	3152 m	1316, 849	1657	2920 s	1619 s	1161	455 s	330 s
$[CuL_2]Cl_2$	3158 m	1314, 850	1665	2920 s	1611 s	1163	442 s	—
$[ZnL_2]Cl_2$	3154 m	1315, 848	1657	2921 s	1610 s	1162	450 s	—

Note. m, medium; s, strong.

TABLE 3 ^{1}H NMR Spectra of the Ligands (L_1 and L_2) and the Zn Complex of L_2 δ (ppm)

Compound	N=CH–(4H)	–$(CH_2)_2$–(2H)	–(CH_2)–(4H)	–$CSNH_2$ (2H)	–CONH–(2H)	N-NH (2H)
L_1	(2.55)t	(3.57)m	(8.14)s	—	(9.64)s	(7.58)d
L_2	(2.54)t	(3.57)m	—	(8.80)s	(9.81)s	(7.62)d
$[ZnL_2]Cl_2$	(2.55)t	(3.58)m	—	(8.87)s	(9.94)s	(7.90)d

Note. s, singlet; d, doublet; t, triplet; m, multiplet.

^{1}HNMR Spectra

The ^{1}HNMR spectrum of L_1, L_2, and Zn complex is described in Table 3. The ^{1}HNMR spectra of L_1 and L_2 gave a CH=N signal at 7.58 and 7.62 ppm, which shifted downfield in the Zn complex at 7.90 ppm due to the complexation of nitrogen with metal ions.[17] The spectra of L_1 showed the $–NH_2$ protons at 8.14 ppm,[18] which shifted downfield in the spectra of L_2 (i.e., 8.80 ppm due to the formation of oxamide group).[12] In Zn complex, this peak placed at 8.87 ppm due to the complexation of –NH with metal. The peak of N-NH for L_1, L_2, and the Zn complex appeared in the range of 9.64–9.94 ppm.[19] This peak was found to shift downfield in case of Zn complex due to the complexation of nitrogen with metal. The spectra of L_1, L_2, and Zn complex displayed a quadrate in the range of 2.55–2.56 ppm, which we attributed to $–CH_2$ protons. A multiplet also appeared in all the spectra in the range of 3.57–3.58 ppm due to the presence of $-CH_2$, having different environment from the former.

Electronic Spectra

The magnetic moment and the significant electronic absorption bands with various ligand field parameters of Co, Ni, Mn, Zn, and Cu complexes are given in Table 4. The magnetic moment for the Co(II) complex (4.53 B.M.) was found to lie in the range of octahedral complexes. The cobalt complex displayed two bands at 8855 and 20219 cm^{-1} and a shoulder at 14814 cm^{-1}, which may be assigned to $^4T_2g(F) \leftarrow {}^4T_1g$ (υ_1),$^4T_1g(P) \leftarrow {}^4T_1g$ (υ_3), and $^4A_2g \leftarrow {}^4T_1g$ (υ_2) transitions, respectively,[20] corresponding to six-coordinated octahedral geometry. The β value indicated that the complex exhibited 61%-covalent character. The electronic spectra of Ni(II) complex showed two bands at 12036 and 16000 cm^{-1} and a charge transfer band at 24390 cm^{-1}. The bands indicated that the complex revealed an octahedral geometry.[21] The ground state of Ni (II) in an octahedral coordination was found to be ^3A_2g. Thus, three spin-allowed transitions are $^3T_{2g}(F) \leftarrow {}^3A_{2g}(F)$ (υ_1),$^3T_{1g}(F) \leftarrow {}^3A_{2g}(F)$ (υ_2), and $^3T_{1g}(P) \leftarrow {}^3A_{2g}(F)$ (υ_3). The magnetic moment of

TABLE 4 Electronic Spectral Bands and Magnetic Moments of the Macrocyclic Complexes

Compound	Magnetic moment (B.M.)	Electronic bands (cm^{-1})	Possible assignment	ε^a	10 Dq (cm^{-1})	(B) (cm^{-1})	β
$[MnL_2Cl_2]$	5.88	28655	$^4E_g(4D) \leftarrow {}^6A_{1g}$	12	1754	582	0.60
		24572	$^4Eg(4G) \leftarrow {}^6A_{1g}$	15			
		17610	$^4T_{1g}(4G) \leftarrow {}^6A_{1g}$	10			
$[CoL_2Cl_2]$	4.53	20219	$^4T_{1g}(P) \leftarrow {}^4T_{1g}(F)$	15	1067	689	0.71
		14814	$^4A_{2g}(F) \leftarrow {}^4T_{1g}(F)$	11			
		8855	$^4T_{2g}(F) \leftarrow {}^4T_{1g}(F)$	13			
$[NiL_2Cl_2]$	2.98	24390	$^3T_{1g}(P) \leftarrow {}^3A_{2g}(F)$	18	12011	751	0.69
		16000	$^3T_{1g}(F) \leftarrow {}^3A_{2g}(F)$	14			
		12036	$^3T_{2g}(F) \leftarrow {}^3A_{2g}(F)$	15			
$[CuL_2]Cl_2$	1.73	23980	Charge transfer	14	—	—	—
		17500	$^2A_{1g} \leftarrow {}^2B_{1g}$	12			
		11110	$^2E_g \leftarrow {}^2B_{1g}$	10			
$[ZnL_2]Cl_2$	Diamagnetic	—	—	—	—	—	—

$^a\varepsilon = dm^3\,mol^{-1}\,cm^{-1}$.

TABLE 5 **Thermal Properties of Ligands (L_1 and L_2) and Their Metal Complexes**

	Weight loss (%) at given temperature (°C)							
Compounds	100	200	300	400	500	600	700	% wt at 800°C
L_1	7	14	40	55	68	75	78	20
L_2	5	11	38	55	63	70	76	23
$[NiL_2Cl_2]$	3	9	35	55	57	65	70	27

nickel complex was 2.95 B.M., which showed the presence of two unpaired electrons.

The Cu(II) complex exhibited bands at 11110, 17500, and 23980 cm^{-1}, corresponding to square planar geometry.[22] The first two bands were assigned to $^2E_g \leftarrow {}^2B_{1g}$ and $^2A_{1g} \leftarrow {}^2B_{1g}$ transitions, respectively. The third band was probably enveloped into a strong charge transfer band. The band at 22220–26040 cm^{-1} in the spectra of complexes was observed due to ligand metal charge transfer (LMCT).[23] The Mn(II) complex showed a magnetic moment corresponding to five unpaired electrons (5.88 B.M.), which indicated the presence of high spin in case of Mn(II). The electronic spectral bands of the complex possessed weak absorption bands at 17610, 24572, and 28655 cm^{-1}. These bands were assigned to $^4T_{1g}(4G) \leftarrow {}^6A_{1g}$, $^4E_g(4G) \leftarrow {}^6A_{1g}$, and $^4E_g(4D) \leftarrow {}^6A_{1g}$, respectively.[24] This result corresponded to octahedral geometry of Mn(II) complex. The calculated value of β indicated that the complex had appreciable covalent character. The Zn(II) complex was diamagnetic as expected for a d^{10} electronic configuration and was found to be tetrahedral as indicated by elemental analysis and spectral data.

Mass Spectra

The FAB mass spectrum of Cu(II) complex showed a molecular ion peak m\z at 437.34 amu, which confirms the stoichiometry of metal complex as $[ML_2]Cl_2$ type. It also showed a peak at 72.01 amu, which probably corresponding to free chlorine. The mass spectra of other metal complexes support the described stoichiometry. This stoichiometry was further supported by the elemental analysis of the complexes. The mass spectrum of macrocyclic ligand (L_2) confirmed the probable formula by showing a peak at 302.588 amu corresponding to the molecular ion ($M^+ + 1$).

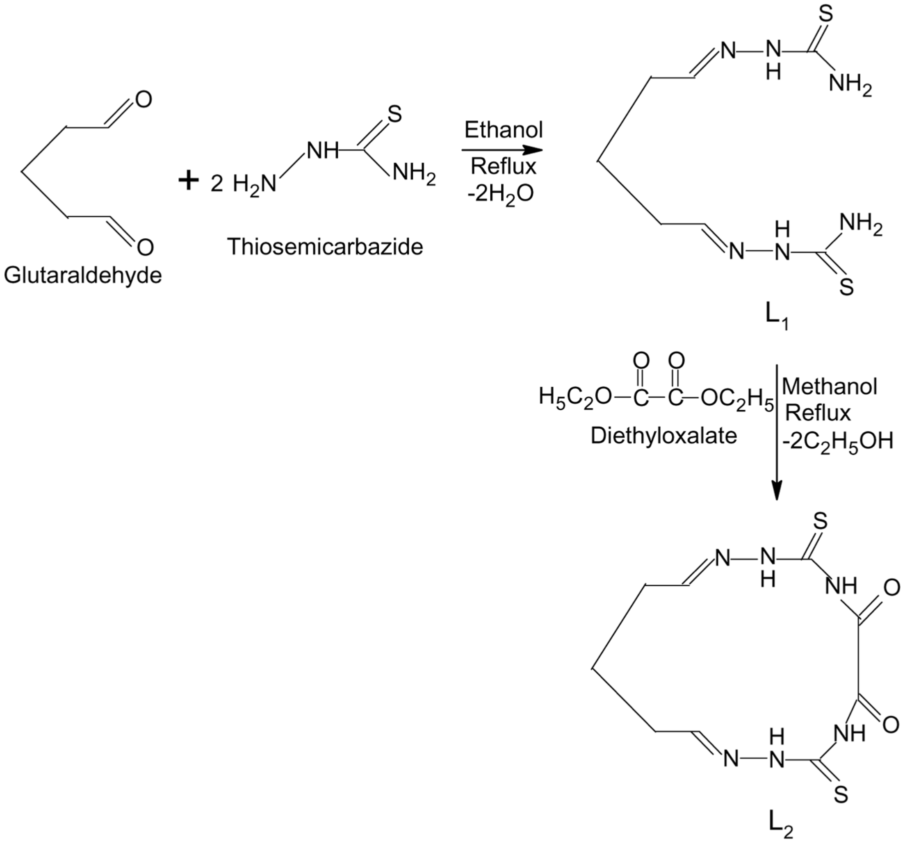
Thermal Studies

The thermogravitric results are given in Table 5. The thermogravimetric studies of L_1, L_2, and metal complexes showed weight loss in the temperature range of 100–200°C due to the elimination of entrapped moisture. L_1 showed 7% weight loss in this region, while L_2 as well as all metal complexes showed about 6 wt% loss in the same range. The coordinated and noncoordinated chlorine in all the metal complexes were eliminated in the

TABLE 6 **Antibacterial and Antifungal Activity of Macrocyclic Ligand and Complexes: Zone of Inhibition[a] (in mm) at 50 μg/ml Concentration**

Compounds	*S. aureus*	*E. coli*	*B. subtillis*	*S. typhimurium*	*F. oryzae*	*C. albicans*
Ligand (L_2)	10 ± 3	—	9 ± 2	10 ± 2	—	11 ± 2
$[MnL_2Cl_2]$	11 ± 2	15 ± 3	18 ± 2	14 ± 2	15 ± 2	19 ± 2
$[CoL_2Cl_2]$	18 ± 2	20 ± 2	14 ± 3	16 ± 2	12 ± 2	12 ± 2
$[NiL_2Cl_2]$	15 ± 3	18 ± 3	20 ± 2	16 ± 3	24 ± 2	11 ± 2
$[CuL_2]Cl_2$	18 ± 2	15 ± 2	22 ± 2	20 ± 2	15 ± 3	19 ± 2
$[ZnL_2]Cl_2$	10 ± 2	12 ± 2	24 ± 2	11 ± 2	20 ± 2	12 ± 2
Kanamycin	29	32	31	31	—	—
Miconazole	—	—	—	—	31	28

[a] Including disc diameter.



SCHEME 1 Synthesis of ligands (L_1 and L_2).

temperature range of 250–350°C, which showed approximately 16.80 wt% loss. The organic and inorganic parts of the L_2 and metal complexes decomposed up to 700°C, and after this temperature, negligible weight loss was observed. The metal complexes decomposed to their metal oxides in the temperature range of 780–800°C. During the study of thermogravimetric curves, we found that L_1 and L_2 showed high weight loss in almost every step in comparison to all metal complexes and that the metal complexes were more thermally stable than L_1 and L_2.

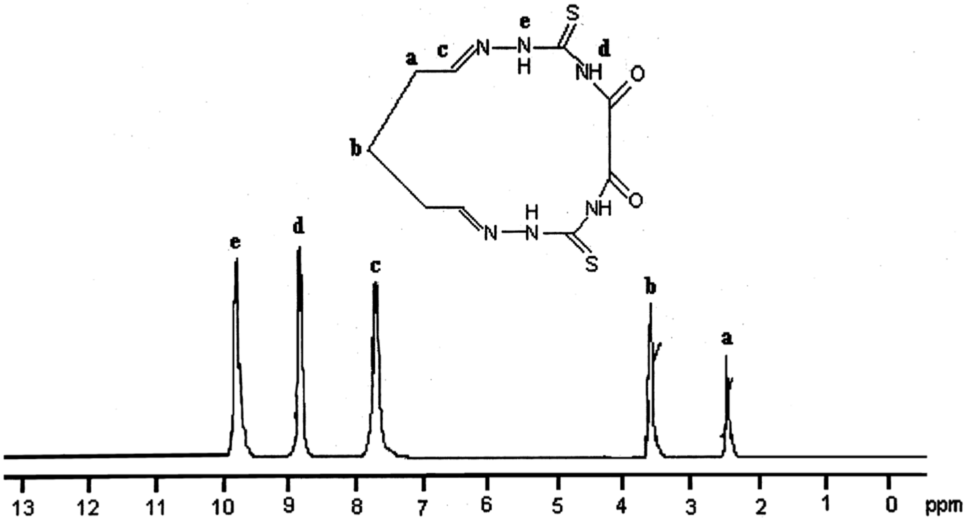


FIGURE 2 ^{1}HNMR of L_2.

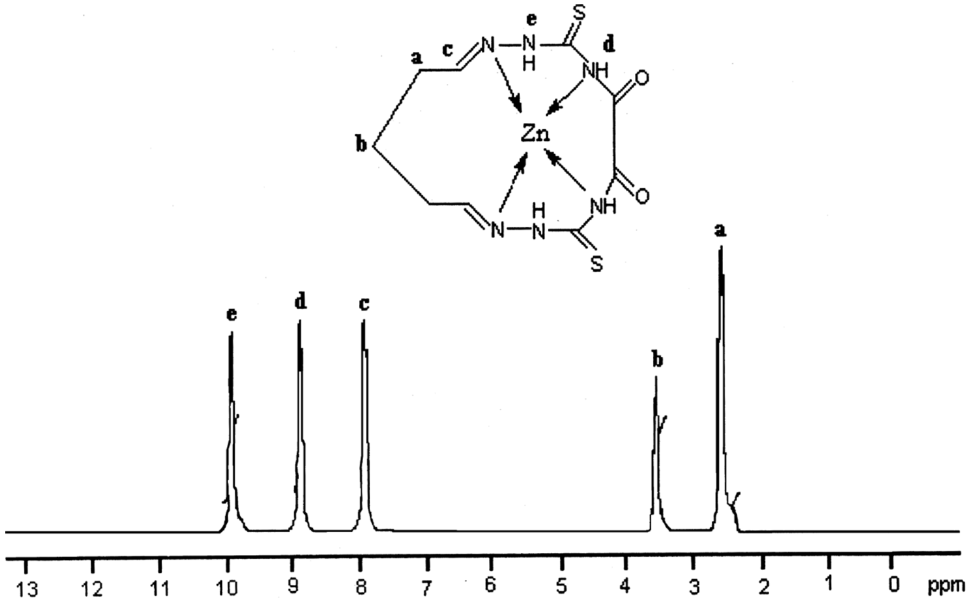


FIGURE 3 ^{1}HNMR of Zn Complex.

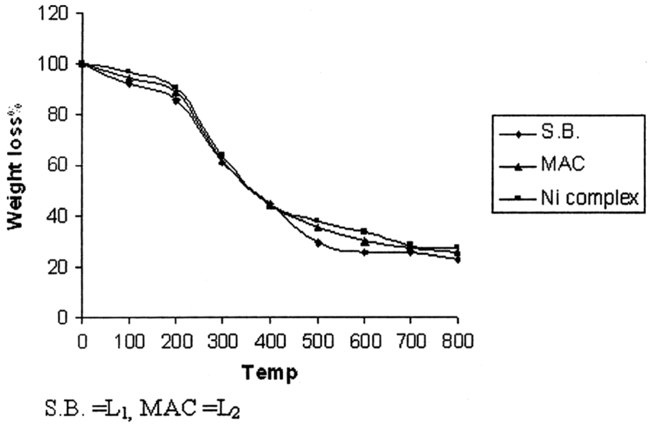


FIGURE 4 TGA of L_1, L_2 and its Nickel complex.

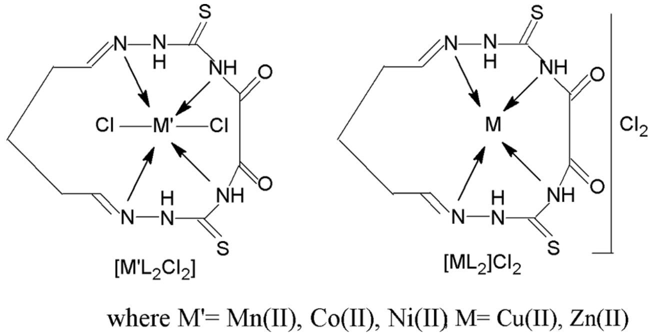


FIGURE 5 Suggested structures of the metal complexes with ligand [L_2].

Antimicrobial Activity

The macrocyclic ligands and its transition metal complexes were screened against four bacteria and two fungi with respect to kanamycin (antibacterial) and miconazole (antifungal) as standard drug. The antifungal and antibacterial activity was carried out by agar disc diffusion method. The results shown in Table 6 revealed that the metal complexes exhibited higher activity as compared with the macrocyclic ligand due to the chelation of the metal ion in the complexes. The chelation was found to enhance the lipophillic character of central metal ion, which subsequently favored its permeation through the lipid layer of all membrane. The maximum bacterial and fungal inhibition was exhibited by Zn(II) complex.

CONCLUSION

A novel macrocycle derived from thiosemicabazone (L1) and diethyloxalate that was prepared by the reaction of thiosemicarbazide and glutaraldehyde in the ratio of 2:1. The Co(II), Ni(II), Mn(II), Cu(II), and Zn(II) complexes with a new macrocyclic ligand (L2) – 1,2,8,9,11,14-hexaazacyclopentadeca-12,13-dioxo-10,15-dithione-2,7-diene were characterized by elemental analysis, molar conductance measurements, magnetic susceptibility measurements, ^{1}HNMR spectra, IR spectra, electronic spectra, and thermogravimetric studies. The complexes were found to be thermally more stable than the parent ligand. The maximum bacterial and fungal inhibition was exhibited by Zn(II) complex, which can be used for pharmaceutical application. Further testing of these complexes has been undertaken.

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REFERENCES

1. Jasat, A.; Dolphin, D. Expanded porphyrins and their heterologs. *Chem. Rev.* **1997**, *97*, 2267–2340.
2. Trommel, J.; Warncke, K.; Marzilli, L. Assessment of the existence of hyper-long axial Co(II)-N bonds in cobalamine B(12) models by using electron paramagnetic resonance spectroscopy. *J. Am. Chem. Soc.* **2001**, *123*, 3358–3366.
3. Salavati, M.; Niasari. Host (nanocage of zeolite-Y)/guest (manganese(II), cobalt(II), nickel(II) and copper(II) complexes of 12 membered macrocyclic Schiff base ligand derived from thiosemicarbazide and glyoxal) nanocomposite materials: Synthesis, characterization and catalytic oxidation of cyclohexene. *J. Mol. Catal. A: Chem.* **2008**, *283*, 120–128.
4. Chandra, S.; Gupta, L. K.; Sangeetika. Spectroscopic, cyclic voltammetric and biological studies of transition metal complexes with mixed nitrogen-sulphur (NS) donor macrocyclic ligand derived from thiosemicarbazide. *Spectrochim. Acta 62A* **2005**, 453–463.
5. Al-Bari, M. M. A.; Chowdhury, M. K. B.; Hossen, M. F.; Hossain, M. M.; Zakaria, C. M.; Ul Islam, M. A. Novel nickel cyclam complexes with potent antimicrobial and cytotoxic properties. *J. Appl. Sci. Res.* **2007**, *3*(11), 1251–1261.
6. Herrea, A. M.; Kalayda, G. V.; Disch, J. S.; Wikstrom, J. P.; Kerendovych, I. V.; Staples, R. J.; Campana, C. F.; Nazarenko, A. Y.; Hass, T. E.; Rybak-Akimova, E. V. Reaction at azomethine C=N complexes of pyridine containing Schiff base macrocyclic ligand. *Dalton Trans.* **2003**, 4482–4492.
7. West, D. X.; Liberta, E.; Padhye, S. B.; Chikate, R. C.; Sonawane, B. P.; Kumbar, A. S.; Yeranda, R. S. Thiosemicabazone complexes of copper(II): Structural and biological studies. *Coord. Chem. Rev.* **1993**, *123*, 49–71.
8. West, D. X.; Padhye, S. B.; Sonawane, B. P. Structural and physical correlations in the biological properties of transition metal heterocyclic thiosemicarbazone and s-alkyl dithiocarbazate complexes. *Struct. Bonding* **1991**, *76*, 1–50.
9. Haidue, Y.; Silvestru, A. Metal complexes in cancer chemotherapy. *Coord. Chem. Rev.* **1990**, *99*, 253–296.
10. Abram, M.; Lang, E.; Bonfada, E. Electrochemical and spectroscopic behavior of Bis(2-mercaptopyridine-N-oxide)oxovanadium(IV). *Z. Anorg. Allg. Chem.* **2002**, *628*, 1419–1424.
11. Ferrari, M. B.; Bisceglie, F.; Pelosi, G.; Sassi, M.; Tarasconi, P.; Cornia, M.; Capacchi, S.; Albertini, R.; Pinneli, S. Synthesis, characterization and X-ray structures of new antiproliferative and proapoptotic natural aldehyde thiosemicabazones and their nickel(II) and copper(II) complexes. *J. Inorg. Biochem.* **2002**, *90*, 113–126.
12. Chandra, S.; Gupta, L. K.; Agrawal, S. Synthesis, spectroscopic and biological approach in the characterization of novel [N_4] macrocyclic ligand and its transition metal complexes. *Trans. Met. Chem.* **2007**, *32*, 558–563.
13. Dhumwad, S. D.; Gudasi, K. B.; Goudar, T. R. Synthesis and structural characterization of biologically active metal-complexes of N(1)-(N-morpholinoacetyl)-N(4)-phenyl thiosemicarbazide and 3,4-methylenedioxybenzaldehyde thiosemicarbazone with oxovanadium(IV), chromium(III), magnesium(II), iron(III), cobalt(II), nickel(II), copper(II), cadmium(II), uranium(VI), thorium(IV) and silicon(IV). *Ind. J. Chem.* **1994**, *33A*, 320–342.
14. Cronin, L.; McGregor, P. A.; Parsons, S.; Teat, S.; Gould, R. O.; White, V. A.; Long, N. J.; Robertson, N. Synthesis, structure and complexation of a large 28-mer macrocycle containing two binding sites for either anions or metal ions. *Inorg. Chem.* **2004**, *43*, 8023–8029.
15. Garg, B. S.; Kurup, M. R. P.; Jain, S. K.; Bhoon, Y. K. Spectroscopic studies on copper(II) complexes derived from a substituted 2-acetylpyridine thiosemicarbazone. *Trans. Met. Chem.* **1988**, *13*, 309–312.
16. Franco, E.; Lopez-Torros, E.; Mendiola, M. A.; Sevilla, M. T. Synthesis, spectroscopic and cyclic avoltametry studies of copper(II) complexes with open chain, cyclic and new macrocyclic thiosemicabazones. *Polyhedron.* **2000**, *19*, 441–451.
17. Habibi, D.; Izadkhah, V. Synthesis of the new schiff base polyaza macrocycles and their complexes with Cu^{2+} and Ni^{2+}. *Phosphorus, Sulphur and Silicon* **2004**, *179*, 1197–1202.
18. Abou-Hussen, A. A.; El-Metwally, N. M.; Saad, E. M.; El-Asmy. Spectral, magnetic, thermal and electrochemical studies on phthaloyl bis(thiosemicarbazide) complexes. *J. Coord. Chem.* **2005**, *58*, 1735–1749.
19. Chandra, S.; Sangeetika, X. EPR, magnetic and spectral studies of copper(II) and nickel(II) complexes of schiff base macrocyclic ligand derived from thiosemicarbazide and glyoxal. *Spectrochim. Acta, Part A* **2004**, *60*, 147–153.
20. Lever, A. B. P. *Inorganic Electronic Spectroscopy*, 1st ed.; Elsevier: Amsterdam, 1968.
21. Mishra, L.; Pandey, A. K. Coordination behavior of 1-(1-phenyl-3-p-chlorophenyl)-pyrazolylcarboxaldehyde thiosemicarbazone with cobalt(II), nickel(II), copper(II) and zinc(II). *Synth. React. Inorg. Met.-Org. Chem.* **1991**, *21*, 1–16.
22. Lever, A. B. P. *Inorganic Electronic Spectroscopy*, 2nd ed.; Elsevier: Amsterdam, 1984.
23. Mandal, S.; Das, G.; Singh, R.; Shukla, R.; Bhardwaz, P. Synthesis and studies of Cu(II)-thiolate complex bioinorganic perspectives. *Coord. Chem. Rev.* **1997**, *160*, 191–235.
24. Chandra, S.; Kumar, R. Synthesis, electrochemistry and spectral studies on cobalt(II) and manganese(II) complexes with 12-, 14-, 15-, and 18-membered N_4, N_2O_2S, N_6 donor macrocyclic ligands. *Synth. React. Inorg. Met. Org. and Nano-Met. Chem.* **2005**, *35*, 161–170.