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Antibacterial Co(II), Ni(II), Cu(II) and Zn(II) complexes with biacetyl-derived Schiff bases

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Abstract: The condensation reactions of biacetyl with *ortho*-hydroxyaniline and 2-aminobenzoic acid to form bidendate NO donor Schiff bases were studied. The prepared Schiff base ligands were further utilized for the formation of metal chelates having the general formula $[ML_2(H_2O)_2]$ where M = Co(II), Ni(II), Cu(II) and Zn(II) and L = HL^1 and HL^2. These new compounds were characterized by conductance measurements, magnetic susceptibility measurements, elemental analysis, and IR, ^{1}H-NMR, ^{13}C-NMR and electronic spectroscopy. Both Schiff base ligands were found to have a mono-anionic bidentate nature and octahedral geometry was assigned to all metal complexes. All the complexes contained coordinated water which was lost at 141–160 °C. These compounds were also screened for their *in vitro* antibacterial activity against four bacterial species, namely: *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi* and *Bacillus subtilis*. The metal complexes were found to have greater antibacterial activity than the uncomplexed Schiff base ligands.

Keywords: Schiff base; biacetyl; metal ion; antibacterial activity.

INTRODUCTION

The promising bacterial resistance to the currently available antibiotics has forced the exploration for new prokaryotic targets as well as novel molecules to inhibit their activity. Among such novel derivatives, metal complexes of biologically active ligands may represent an attractive approach for designing new antimicrobial compounds, due to the dual possibility of both ligands and metal ions interacting with different steps in the life cycle of pathogens.[1–3] Much work has been realized by bioinorganic as well as medicinal chemists to launch the relationship between the metal ions and their complexes as antitumor and antibacterial agents.[4–8] It is however noteworthy that some biologically active com-

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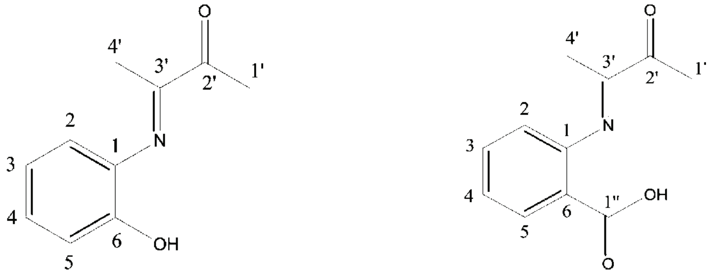
pounds may become more carcinostatic and bacteriostatic upon chelation.[9] Ketones and amines are versatile reactive organic compounds due to presence of C=O and NH_2 groups, respectively. The nucleophilic addition reactions of these compounds result in an important class of compounds known as Schiff bases, which are considered to be the best candidates for coordination with metal ions. A number of studies have reported the ligational aspects and biological role of Schiff bases and their metal complexes.[10–23] A comprehensive search through the literature revealed that no work has been realized on the preparation and characterization of metal complexes of Schiff bases derived from biacetyl, *ortho*-hydroxyaniline and 2-aminobenzoic acid. Consequently, an attempt has been made to synthesize and characterize some novel metal complexes of these Schiff base ligands. The prepared ligands as well as their metal complexes were also investigated for their *in vitro* activity against some bacterial species. The purpose of the work was to understand the coordination as well as the biological chemistry of these novel synthesized compounds.

EXPERIMENTAL

Analytical reagent grade ethanol was used after distillation. All other chemicals and solvents were of reagent grade and procured from Sigma Aldrich or Merck. Metal chlorides were used as the metal(II) salts for synthetic purposes. The IR spectra were recorded on Philips Analytical PU 9800 FT-IR spectrometer. The UV/Vis spectra were obtained on a Specord-200 spectrometer using Software Acuta710, while the ^{1}H-NMR spectra were recorded on a Bruker 250 MHz NMR spectrometer in DMSO-d_6. The conductance of the metal complexes was determined in DMF on a Hitachi YSI-32 model conductometer. The magnetic measurements were realized on solid complexes using the Gouy method. Melting points were determined using a Gallenkamp apparatus.

Preparation of the Schiff bases

An ethanolic solution of biacetyl (0.010 mol, 20 ml) was mixed with an ethanolic solution of 2-aminobenzoic acid (0.010 mol, 20 ml) and *o*-hydroxyaniline (0.010 mol, 20 ml) separately, then 2–3 drops of glacial acetic acid were added and the mixture was refluxed for four hours. The resulting solution was concentrated and cooled. The obtained colored products were filtered off, washed with ethanol and dried. Recrystallization with warm ethanol gave the desired products HL^1 and HL^2 (Scheme 1).



(a) (b)

Scheme 1. Numbering of the C atoms in the a) HL^1 and b) HL^2 ligands.

Preparation of metal complexes

Metal chloride (0.0010 mol) was dissolved in distilled water (30 ml) and the resulting solution was stirred magnetically. To this magnetically stirred solution was added 0.0020 mol of each Schiff base ligand in an ethanolic solution (25 ml). The mixture was refluxed for 2–3 h and cooled to room temperature. After cooling, the formed precipitates were filtered, washed with water, ethanol and dried.

Antibacterial studies

All the synthesized metal complexes were tested for their *in vitro* antibacterial activity against some bacterial strains using the spot on Mueller–Hinton agar by following the reported method.[24] Four test pathogenic bacterial strains, *viz*. *Staphylococcus aureus* (MTCC 1144), *Bacillus subtilis* (MTCC 2423), *Salmonella typhi* (MTCC 733) and *Escherichia coli* (MTCC 739), were considered for the determination of the minimum inhibitory concentration (*MIC*). The minimum inhibitory concentrations were determined by the microbroth dilution technique using Mueller–Hinton broth. Serial two-fold dilutions ranging from 5000 to 4.8 μg ml^{-1} were prepared in Mueller–Hinton broth. The inoculum was prepared with a 4–6 h broth culture of each strain adjusted to a turbidity equivalent to 0.5 McFarland standard, diluted in Mueller–Hinton broth to give a concentration of 50 CFU L^{-1} in the test tray. The trays were covered and placed in plastic bags to prevent drying; incubation was at 37 °C for 18–20 h. The MIC was defined as the lowest concentration of a compound giving complete inhibition of visible growth.

RESULTS AND DISCUSSION

The physico-analytical data for the Schiff base ligands HL^1 and HL^2 are given in Table I. These Schiff bases were prepared by refluxing an appropriate amount of *o*-hydroxyaniline and 2-aminobenzoic acid with biacetyl in absolute ethanol. The prepared Schiff base ligands were further reacted with Co(II), Ni(II), Cu(II) and Zn(II) ions to form the respective metal complexes. These metal complexes were soluble in polar organic solvents, such as MeOH, $CHCl_3$, DMF and EtOH, but less soluble in non-polar solvents, such as 1-hexane, 1-heptane and toluene. These air-stable complexes were obtained in excellent yields (Table I).

TABLE I. Physico-analytical data of the ligands and their metal complexes

S. No.	Compound[a]	Color	M.p. °C	μ_{eff} / μ_B	Λ_m[b] Ω^{-1} cm^2 mol^{-1}	Yield %
1	HL^1	Yellowish brown	180	–	–	75
2	HL^2	Pale Yellow	176	–	–	67
3	$[Cu(L^1)_2(H_2O)_2]$	Sky blue	≈290	1.86	11	70
4	$[Cu(L^2)_2(H_2O)_2]$	Light blue	≈291	1.78	13	56
5	$[Co(L^1)_2(H_2O)_2]$	Tea pink	≈285	4.18	8	62
6	$[Co(L^2)_2(H_2O)_2]$	Brown	≈267	4.21	14	43
7	$[Ni(L^1)_2(H_2O)_2]$	Greenish blue	≈218	3.42	12	55
8	$[Ni(L^2)_2(H_2O)_2]$	Dirt green	≈212	3.26	18	44
9	$[Zn(L^1)_2(H_2O)_2]$	Colorless	≈255	Diamagnetic	17	65
10	$[Zn(L^2)_2(H_2O)_2]$	Colorless	≈243	Diamagnetic	15	54

[a] HL^1, HL^2 = Schiff base ligands; [b] 10^{-3} M solution in DMF

All the metal complexes **3**–**10** (Table I) of these Schiff bases were prepared at a mole ratio of the appropriate metal to ligand of 1:2. The low values of the molar conductivity (8–18 Ω^{-1} cm^2 mol^{-1}) of the resulting complexes in DMF showed that they were non-electrolytic in nature.[25] The elemental analysis data (Table II) support the proposed structures of the synthesized compounds (Figs. 1 and 2).

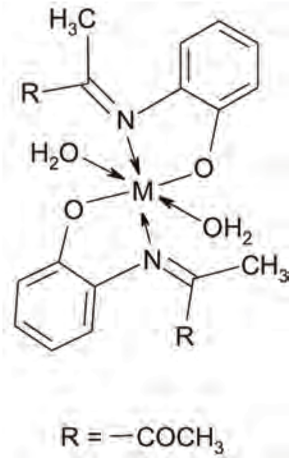


Fig. 1. Proposed structures of metal complexes with HL[1]; M = Co(II), Ni(II), Cu(II) and Zn(II).

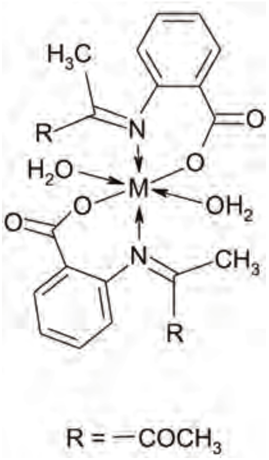


Fig. 2. Proposed structures of metal complexes with HL[2]; M = Co(II), Ni(II), Cu(II) and Zn(II).

TABLE II. Elemental analysis data (Calcd. (Found) %) of the ligands and their metal complexes

S. No.	Compound	C	H	N	M
1	HL^1	64.12 (64.39)	5.02 (5.37)	6.55 (6.82)	–
2	HL^2	67.22 (67.42)	6.26 (6.74)	7.68 (7.87)	–
3	$[Cu(L^1)_2(H_2O)_2]$	51.78 (52.02)	4.60 (4.73)	5.50 (5.52)	12.12 (12.52)
4	$[Cu(L^2)_2(H_2O)_2]$	52.90 (53.15)	5.12 (5.32)	6.02 (6.20)	13.79 (14.07)
5	$[Co(L^1)_2(H_2O)_2]$	52.17 (52.49)	4.12 (4.77)	5.43 (5.56)	11.45 (11.72)
6	$[Co(L^2)_2(H_2O)_2]$	53.55 (53.70)	5.13 (5.37)	6.12 (6.27)	13.01 (13.19)
7	$[Ni(L^1)_2(H_2O)_2]$	52.09 (52.52)	4.56 (4.76)	5.23 (5.58)	11.55 (11.66)
8	$[Ni(L^2)_2(H_2O)_2]$	53.56 (53.74)	5.10 (5.37)	6.12 (6.30)	13.01 (13.13)
9	$[Zn(L^1)_2(H_2O)_2]$	51.59 (51.82)	4.44 (4.71)	5.34 (5.50)	12.65 (12.84)
10	$[Zn(L^2)_2(H_2O)_2]$	52.78 (52.93)	5.15 (5.29)	6.11 (6.18)	14.09 (14.43)

IR Spectroscopy

The assignment of the characteristic IR frequencies for the Schiff base ligands and their resulting complexes are tabulated in Table III and can be discussed as follows. The IR spectra of the Schiff base ligands do not show any band in the region 3400–3150 cm^{-1} which could be assigned to –NH_2 vibrations; instead, new bands at 1638 and 1631 cm^{-1} appeared that can be assigned to (>C=N) lin-

TABLE III. Selected IR data (cm^{-1}) of the ligands and their metal complexes

S. No.	Compound	COO$^-$ $\nu_{C–O}$	COO$^-$ $\nu_{C=O}$	ν_{OH}	ν_{H_2O}	ν_{aCOO^-}	ν_{sCOO^-}	$\Delta\nu^a$	$\nu_{C=N}$	$\nu_{M–O}$	$\nu_{M–N}$
1	HL^1	–	–	3415	–	–	–	–	1638	–	–
2	HL^2	1242	1724	–	–	–	–	–	1631	–	–
3	$[Cu(L^1)_2(H_2O)_2]$	–	–	–	3456	1607	1388	219	1619	438	349
4	$[Cu(L^2)_2(H_2O)_2]$	–	–	–	3478	1594	1377	217	1607	453	363
5	$[Co(L^1)_2(H_2O)_2]$	–	–	–	3488	1591	1367	224	1622	459	370
6	$[Co(L^2)_2(H_2O)_2]$	–	–	–	3508	1582	1375	207	1609	434	378
7	$[Ni(L^1)_2(H_2O)_2]$	–	–	–	3567	1588	1379	209	1634	456	359
8	$[Ni(L^2)_2(H_2O)_2]$	–	–	–	3477	1590	1389	201	1623	450	377
9	$[Zn(L^1)_2(H_2O)_2]$	–	–	–	3456	1567	1295	272	1610	427	345
10	$[Zn(L^2)_2(H_2O)_2]$	–	–	–	3523	1578	1344	234	1608	478	367

[a] $\Delta\nu = \nu_{acoo^-} - \nu_{scoo^-}$

kages.[26] In addition to this characteristic (>C=N) absorption, the Schiff base ligand HL^1 also exhibited bands at 3415 cm^{-1}, which can be assigned to phenolic (O–H) group vibrations, while Schiff base ligand HL^2 showed two characterristic bands at 1724 and 1242 cm^{-1}, assigned to asymmetric and symmetric vibrations of the carboxylic acid group.[26] A comparison of the IR spectra of Schiff base ligands with their metal complexes reveals that they are coordinated mainly in two ways with the metal ions, thus representing their bidentate nature. Both the Schiff base ligands showed a lower shift (1634–1607 cm^{-1}) in the >C=N stretching frequency (Table III), indicating their coordination with metal ions through the nitrogen atom. In the metal complexes of the Schiff base ligand HL^1, the bands at 3415 cm^{-1} assigned to (O–H) vibrations are absent, thus indicating chelating of oxygen to the metal atoms after deprotonation. Similarly, in HL^2 complexes, the absence of bands at 1724 and 1242 cm^{-1} showed that the –COOH group was deprotonated on complexation. It is well recognized by some authors[27] that ionic carboxylato groups do not have any peak around 1700 cm^{-1} due to the C=O group but show two peaks in the region 1610–1550 cm^{-1} and 1400–1280 cm^{-1}, assigned to asymmetric and symmetric vibrations of the COO$^-$ group, respectively. It is also well recognized in the literature[28,29] that this group can act as monodentate, bidentate or as a bridging ligand and differentiation of these binding states can be made from the frequency separation ($\Delta\nu = \nu_a(COO) - \nu_s(COO)$) between the symmetric and the asymmetric stretching of this group. By probing the symmetric and the asymmetric stretching vibrations of large number of carboxylato complexes with known crystal structure, a criteria was established by Deacon and Phillips[29] that can be used to discriminate between these three binding states of carboxylate complexes. These criteria are: a) monodentate carboxylato complexes display $\Delta\nu$ values which are much larger than those of the ionic salts ($\Delta\nu > 200$ cm^{-1}), b) bidentate carboxylato complexes demonstrate $\Delta\nu$ values significantly smaller than the ionic values ($\Delta\nu < 100$ cm^{-1}) and c) bridging complexes demonstrate $\Delta\nu$ values comparable to the ionic values ($\Delta\nu \approx 150$ cm^{-1}). The $\Delta\nu$ values for the prepared complexes (**3**–**10**) were in the range 201––272 cm^{-1}, which suggests that the carboxylato group is acting as monodentate. Furthermore, the presence of peak at 1702 cm^{-1} in the IR spectra of the ligands with no change in the spectra of complexes rejects the possibility for coordination of the second, uncondensed carbonyl group. In all metal complexes some new low frequency bands in the region 478–427, 378–345 and > 3450 and 893––878 cm^{-1} were also observed and can be assigned to ν(M–O), ν(M–N) and coordinated water modes, respectively.[26]

^{1}H- and ^{13}C-NMR spectroscopy

The assignments of the ^{1}H- and ^{13}C-NMR chemical shifts are tabulated in Table IV. In the ^{1}H-NMR spectrum of the Zn-complex of HL^2, a signal assignable to carboxylic group proton was absent, indicating that deprotonation of carboxylic group occurred and that coordination through this group took place.

TABLE IV. NMR data (δ / ppm) of ligands and their Zn complexes

S. No.	Compound	^{1}H-NMR	^{13}C-NMR
1	HL^1	10.9 (1H, *s*, OH), 6.7–7.1 (4H, *m*, H^2-H^5), 2.20 (3H, *s*, H-1’), 1.90 (3H, *s*, H-4’)	197.5 (C-2’), 164 (C-3’),137 (C-1), 122.7 (C-3), 117.2 (C-5), 128.7 (C-4), 123.7 (C-2), 151.5 (C-6), 24.1 (C-1’), 10.1 (C-4’)
2	HL^2	11.1 (1H, *s*, OH), 7.5–8.1 (4H, *m*, H^2-H^5), 2.30 (3H, *s*, H-1’), 1.92 (3H, *s*, H-4’)	197.5 (C-2’), 164 (C-3’),149 (C-1), 135.3 (C-3), 131.6 (C-5), 127.2 (C-4), 122.2 (C-2), 116.4 (C-6), 24.1 (C-1’), 10.1 (C-4’), 169.4 (C-1’’)
9	Zn-complex (HL^1)	6.6–7.4 (4H, *m*, H^2-H^5), 2.22 (3H, *s*, H-1’), 1.91 (3H, *s*, H-4’)	197.5 (C-2’),164 (C-3’),137.9(C-1), 122.7 (C-3), 118.5 (C-5), 128.7 (C-4), 123.7 (C-2), 152.3 (C-6), 24.1 (C-1’), 10.1 (C-4’)
10	Zn-complex (HL^2)	7.4–8.0 (4H, m, H^2-H^5), 2.32 (3H, *s*, H-1’), 1.92 (3H, *s*, H-4’)	197.5 (C-2’), 164 (C-3’), 150 (C-1), 135.3 (C-3), 132.2 (C-5), 127.2 (C-4), 122.2 (C-2), 117.7 (C-6), 24.1 (C-1’), 10.1 (C-4’), 173.2 (C-1’’)

The Zn-complex of this ligand was also characterized by means of ^{13}C--NMR spectroscopy. The higher values of the chemical shift of C-1”, C-1, C-6 and C-5 atom signals in the Zn-complex in comparison with those of the signals in the respective non-coordinated ligand[30] strongly suggest that coordination through the carboxylate groups had occurred. On the other hand, the absence of a change of the chemical shift of the uncondensed carbonyl moiety C-2’ indicates that this group did not participate in the coordination. A similar pattern of the change in the chemical shift was found with ligand HL^1. Thus, both the ^{1}H- and

^{13}C-NMR spectroscopic data support the proposed structures of the ligands and their coordination behavior as well.

Electronic absorption spectra

In the electronic spectra, the Co(II) complexes exhibited two low energy peaks at 7275, 7260 cm^{-1}; 17234, 17224 cm^{-1} and a strong high energy peak at 20482, 20172 cm^{-1}, which can be assigned[31] to the transitions $^4T_{1g}$(F) → $^4T_{2g}$(F), $^4T_{1g}$(F) → $^4A_{2g}$(F) and $^4T_{1g}$ (F) → $^4T_{2g}$ (P) for a high spin octahedral geometry, respectively. The final high intensity band at 27145, 27123 cm^{-1} is assigned to charge transfer (Table V). The electronic spectra of the Ni(II) complexes showed d–d transition at 10213, 10110; 15597, 15654 and 26360, 26197 cm^{-1}. These are assigned[31] to $^3A_{2g}$(F) → $^3T_{2g}$(F), $^3A_{2g}$(F) → $^3T_{1g}$(F) and $^3A_{2g}$ (F) → $^3T_{2g}$(P) transitions, respectively. These are consistent with a well-defined octahedral geometry. The Zn(II) complexes exhibited only a high intensity band at 28251, 28231 cm^{-1}, which is assigned to ligand–metal charge transfer. In case of the Cu(II) complexes, a broad band at 16644, 16612 cm^{-1} was observed that is assigned to the ^2E_g → $^2T_{2g}$ transition, which confirms its octahedral geometry.

TABLE V. Electronic spectroscopic data of the metal complexes

S. No.	Complex	λ_{max} / cm^{-1}	Assignments
3	$[Cu(L^1)\,(H_2O)_2]$	16644	$^2E_g \rightarrow {}^2T_{2g}$
4	$[Cu(L^2)_2(H_2O)_2]$	16612	$^2E_g \rightarrow {}^2T_{2g}$
5	$[Co(L^1)_2(H_2O)_2]$	7260	$^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$
		17234	$^4T_{1g}(F) \rightarrow {}^4A_{2g}(F)$
		20482	$^4T_{1g}(F\ ) \rightarrow {}^4T_{2g}(P)$
		27123	Charge transfer
6	$[Co(L^2)_2(H_2O)_2]$	7275	$^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$
		17224	$^4T_{1g}(F) \rightarrow {}^4A_{2g}(F)$
		20172	$^4T_{1g}(F) \rightarrow {}^4T_{2g}(P)$
		27145	Charge transfer
7	$[Ni(L^1)_2(H_2O)_2]$	10213	$^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)$
		15654	$^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$
		26360	$^3A_{2g}(F) \rightarrow {}^3T_{2g}(P)$
8	$[Ni(L^2)_2(H_2O)_2]$	10110	$^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)$
		15597	$^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)$
		26197	$^3A_{2g}(F) \rightarrow {}^3T_{2g}(P)$
9	$[Zn(L^1)_2(H_2O)_2]$	28251	Charge transfer
10	$[Zn(L^2)_2(H_2O)_2]$	28231	Charge transfer

Magnetic susceptibility measurement

The magnetic moment value 4.18; 4.21 μ_B (Table I) for the solid Co(II) complexes suggests[32] an octahedral environment, indicating three unpaired electrons. The magnetic moment value of the Cu(II) complexes 1.86; 1.78 μ_B suggests distorted octahedral geometry.[33] The magnetic moment value of the Ni(II) complexes 3.42; 3.26 μ_B, showing two unpaired electrons, suggests[33] an octahedral geometry for the Ni(II) complexes. The Zn(II) complexes were found to be diamagnetic, as expected for d^{10} configuration.

Antibacterial activity

The antimicrobial activity (*MIC*, μg ml^{-1}) of the metal complexes/ligands are given in Table VI, from which it can be seen that the complexes had variable antimicrobial activities. The Cu(II)L^1 complex showed an *MIC* of 4 μg ml^{-1} against the bacterial strain *B. subtilis* which is equal to the *MIC* shown by the standard antibiotic cefaclor against the same bacterial strain. The Cu(II)L^2 complex exhibited an *MIC* of 9 μg ml^{-1} against the bacterial strain *S. aureus* which is the same as the *MIC* shown by standard antibiotic cefaclor against the same bacterial strain. Furthermore, complexes of Co(II)L^1 and Co(II)L^2 showed a minimum inhibitory concentration of 5 μg ml^{-1} against the bacterial strain *B. subtilis*, which is the same as the *MIC* shown by the standard antibiotic linezolid against the same bacterial strain. The *MIC* of the complex Ni(II)L^2 against *S. typhi* was found to be 18 μg ml^{-1}, which is equal to the *MIC* shown by the standard antibiotic linezolid against the same bacterial strain. Similarly, the complex Zn(II)L^2 registered an *MIC* of 5 μg ml^{-1} against the bacterial strain *B. subtilis*, which is the same as the *MIC* shown by the standard antibiotic linezolid against the same bacterial strain.

TABLE VI. Minimum inhibitory concentration (*MIC*) exhibited by the ligands and their metal complexes against test bacteria

S. No.	Compound	*MIC* / μg ml^{-1}			
		S. aureus	*B. subtilis*	*S. typhi*	*E. coli*
–	Cefaclor	9	4	7	15
–	Linezolid	6	5	18	12
1	HL^1	–	–	110	118
2	HL^2	–	–	–	149
3	$[Cu(L^1)_2(H_2O)_2]$	18	4	15	10
4	$[Cu(L^2)_2(H_2O)_2]$	9	9	7	14
5	$[Co(L^1)_2(H_2O)_2]$	23	5	11	15
6	$[Co(L^2)_2(H_2O)_2]$	11	5	16	12
7	$[Ni(L^1)_2(H_2O)_2]$	15	24	22	13
8	$[Ni(L^2)_2(H_2O)_2]$	56	33	18	19
9	$[Zn(L^1)_2(H_2O)_2]$	11	7	22	12
10	$[Zn(L^2)_2(H_2O)_2]$	13	5	7	16

Among the series under test for the determination of the *MIC*, complexes **1** and **3** were found to be the most potent as compared to the other complexes. This effect can be logically explained by the fact that the Schiff base derivatives must be activated by the metal ions in some way. This enhancement in antibacterial activity of these metal complexes can be explained based on the chelation theory.[34]

When a metal ion is chelated with a ligand, its polarity will be reduced to a greater extent due to the overlap of ligand orbital and the partial sharing of the positive charge of the metal ion with donor groups. Furthermore, the chelation process increases the delocalization of the π-electrons over the whole chelate ring, which results in an increase in the lipophilicity of the metal complexes. Consequently, the metal complexes can easily penetrate into the lipid membranes and block the metal binding sites of enzymes of the microorganisms. These metal complexes also affect the respiration process of the cell and thus block the synthesis of proteins, which restrict further growth of the organism.

CONCLUSIONS

The complexes of Co(II), Ni(II), Cu(II) and Zn(II) with biacetyl-derived Schiff bases have been described. They were characterized by their physico–analytical and spectral data. The Schiff base ligands were found to have mono-anionic bidentate nature and octahedral geometry was assigned to all the metal complexes. All the metal complexes were found to have appreciable antimicrobial activity against some bacterial strains.

ИЗВОД

АНТИБАКЕТРИЈСКА АКТИВНОСТ КОМПЛЕКСА Co(II), Ni(II), Cu(II) И Zn(II) КОЈИ КАО ЛИГАНДЕ САДРЖЕ ДЕРИВАТЕ ШИФОВИХ БАЗА

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Испитивана је кондензациона реакција биацетила са *o*-хидроксианилином и 2-аминобензоевом киселином, у којој настају бидентатни лиганди типа Шифових база које као доноре садрже атоме азота и кисеоника. Ови лиганди су употребљени за грађење хелатних комплекса опште формуле $[ML_2(H_2O)_2]$ (M = Co(II), Ni(II), Cu(II) и Zn(II); L = HL^1, HL^2). За карактеризацију комплекса употребљена су кондуктометријска и магнетна мерења, као и резултати елементарне микроанализе, IR, ^{1}H-NMR, ^{13}C-NMR и електронске спектроскопије. На основу ових мерења нађено је да ови лиганди граде моноанјонске комплексе октаедарске геометрије. Добијени комплекси садрже координовани молекул воде, који се губи из координационе сфере при температури од 140–160 °C. Испитивана је *in vitro* антибактеријска активност изолованих комплекса на следећим врстама бактерија: *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi* и *Bacillus subtilis*. Добивени резултати ових испитивања су показали да је активност комплекса метала већа од активности некоординованих лиганада.

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REFERENCES

1. A. Scozzafava, C. T. Supuran, *J. Med. Chem.* **43** (2000) 3677
2. D. H. Brown, W. E. Smith, J. W. Teape, A. J. Lewis, *J. Med. Chem.* **23** (1980) 729

3. A. Scozzafava, L. Menabuoni, F. Mincione, G. Mincione, C. T. Supuran, *Bioorg. Med. Chem. Lett*. **11** (2001) 575
4. R. J. P. William, *Quart. Rev*. **24** (1970) 331
5. B. Rosenberg, L. Van Camp, *Cancer. Res.* **30** (1970) 1799
6. M. J. Clare, J. D. Heeschele, *Bioinorg. Chem*. **2** (1973) 187
7. V. L. Narayanan, M. Nasr, K. O. Paull, *Tin Based Antitumour Drugs*, NATO ASI Series, Springer, Berlin, 1990, p. 200
8. A. J. Crowe, *Metal-Based Antitumor Drugs,* Vol. 1, Freund, London, 1989, p. 103
9. R. S. Srivastava, *Indian J. Chem.* **29 A** (1990) 1024
10. S. Kiran, S. B. Manjeet, T. Parikshit, *Eur. J. Med. Chem*. **41** (2006) 147
11. P. Mishra, H. Rajak, A. Mehta, *J. Gen. Appl. Microbiol.* (2005) 133
12. S. Gandhe, M. D. Gautam, *Asian J. Chem.* **16** (2004) 261
13. M. Sonmez, A. Levent, M. Sekerci, *Russ. J. Coord. Chem.* **30** (2004) 655
14. X. Tai, X. Yin, Q. Chen, M. Tan, *Molecules* **8** (2003) 439
15. W. T. Gao, Z. Zheng, *Molecules* **8** (2003) 788
16. Z. H. Chohan, M. F. Jaffery, C. T. Supuran, *Metal Based Drugs* **8** (2001) 95
17. Z. H. Chohan, A. Munawar, C. T. Supuran, *Metal Based Drugs* **8** (2001) 137
18. V. K. Sharma, S. Srivastava, A. Srivastava, *Pol. J. Chem.* **80** (2006) 387
19. R. V. Singh, N. Fahmi, M. K. Biyala, *J. Iran. Chem. Soc.* **2** (2005) 40
20. M. Tümer, C. Celik, H. Köksal, S. Serin, *Transition Met. Chem.* **24** (1999) 525
21. J. A. Gutierrez, J. A. Lopez-Jimenez, R. Gavino, H. Noth, *Monatsh. Chem.* **126** (1995) 505
22. Z. H. Chohan, H. Pervez, A. Rauf, C. T. Supuran, *Metal Based Drugs* **8** (2002) 263
23. F. A. Adam, M. T. El-Haty, A. A. Ibrahem, *J. Chin. Chem. Soc.* **31** (1984) 345
24. D. P. Singh, V. Malik, R. Kumar, *Res. Lett. Inorg. Chem.* (2009) 1
25. D. J. Finney, *Probit analysis*, Cambridge University Press, Cambridge, 1971
26. J. Iqbal, M. Imran, S. Iqbal, S. Latif, *J. Chem. Soc. Pak.* **29** (2007) 151
27. F. Gao, P. Yang, J. Xie, H. Wang, *J. Inorg. Biochem*. **60** (1995) 61
28. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and Coordination Compounds*, Wiley, New York, 1986
29. G. B. Deacon, R. J. Phillips, *Coord. Chem. Rev*. **33** (1980) 227
30. H-Y. Zhang, D-L. Chen, P-K.Chen, D-J. Che, G-X.Cheng,H-Q. Zhang, *Polyhedron* **11** (1992) 2313
31. L. J. Bellamy, *The Infrared Spectra of Complex Molecules*, Methuen, London, 1966, p. 13
32. M. U. Hassan, Z. H. Chohan, C. T. Supuran, *Main Group Metal Chem*. **25** (2002) 291
33. C. J. Balhausen, *An Introduction to Ligand Field Theory*, McGraw-Hill, New York, 1962, p. 134
34. L. Mishra, V. K. Singh, *Indian J. Chem*. **32 A** (1997) 446.