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Biologically Active Complexes of Nickel(II), Copper(II) and Zinc(II) with Schiff-Base Ligand Derived from the Reaction of 2-Aminopyridine and Pyrrol-2-carboxaldehyde—Their Synthesis and Characterisation

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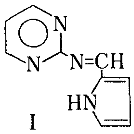
A new Schiff-base ligand *N*-(2′-pyrrylmethylidene)2-aminopyrimidine derived from the reaction of 2-amino pyrimidine and pyrrol-2-carboxaldehyde and its nickel(II), copper(II) and zinc(II) complexes have been synthesised and characterised on the basis of elemental analysis, molar conductance, infrared, electronic and proton nuclear magnetic resonance (^{1}H-NMR) and magnetic susceptibility data. The ligand and its complexes when screened for antibacterial activity against bacterial species such as, *Escherichia coli*, *Pseudomonas aerutinosa* and *Klebsiella pneumoniae*. In all cases, the activity substantially increased on complexation with metals.

Keywords Schiff-base; potential ligand; metal ion; antibacterial activity

Introduction

Schiff-bases are an important class of organic compounds which are prepared[1—4] by the condensation reaction of carbonyls with amines. The azomethine functional grouping ($>$C$=$N–) in such compounds along with additional potential donor atoms make them important and promising chelates.[5,6] In view of exhibiting their interesting ligating properties, we have synthesised a new biologically important Schiff-base ligand (I) and its nickel(II), copper(II) and zinc(II) complexes.

The ligand (I) and its title complexes **1**—**3** have been characterised on the basis of conductance and magnetic measurements and infrared (IR), proton nuclear magnetic resonance (^{1}H-NMR), elemental analysis and electronic spectral data. These have also been screened for their possible antibacterial activity against bacterial species *Escherichia coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, the results of which show that ligand (I) is biologically active. It is more interesting when it is complexed with metal ions and becomes more potent and active against all testing bacterial species.



I

Experimental

The complexes were analysed for their metal contents by standard methods.[7] Antibacterial activity of the metal complexes in comparison to the ligand was studied on wild type pathogenic bacterial species collected from infected patients admitted to Bahawal Victoria Hospital, Bahawalpur. These studies were carried out in the Microbiology Laboratory, Department of Pathology, Qaid-e-Azam Medical College, Bahawalpur.

Synthesis of *N*-(2-Pyrrylmethylidene)2-aminopyrimidine (I) Pyrrol-2-carboxaldehyde (0.95 g, 0.01 M) in absolute ethanol (15 ml) was added to the stirred ethanolic solution (20 ml) of 2-aminopyrimidine (0.95 g, 0.01 M) at 50 °C. Then 2—3 droups of conc. H_2SO_4 were added and the mixture was refluxed for 1 h during which a solid product was formed which was cooled, filtered, washed with ethanol (1 × 5 cm) first, then with ether (2 × 5 ml) and dried. The product thus obtained was recrystallised in aqueous ethanol to give (I) (53% yield). mp 150—152 °C. IR (Nujol) 3220, 2936, 1942, 1640, 1605, 1544, 1298, 1110, 806 cm^{-1}. ^{1}H-NMR (DMSO-d_6) δ: 6.9 (m, 3H, H-2, 5, 6), 8.3 (m, 5H, H-1, 3, 4, 7, 8). $C_9H_8N_4$ requires %: C, 62.79; H, 4.65; N, 32.55, Found %: C, 62.81; H, 4.63; N, 32.59.

Synthesis of Metal Complexes An ethanolic solution (10 ml) of ligand (I) (0.02 M) was added with stirring to an aquous solution (15 ml) of metal(II) chloride (0.01 M). The mixture was refluxed to the boiling point for 1 h. The precipitated solid product was formed which was cooled, filtered, washed with ethanol (1 × 5 ml) and dried. The crude product thus obtained was recrystallised in aqueous ethanol to give metal complex Table I.

Results and Discussion

The newly synthesised ligand (I) is a crystalline compound, stable at room temperature, and has a sharp melting point. It is soluble in water, ethanol, dimethylformamide (DMF) and dimethylsulphoxide (DMSO) and sparingly soluble in organic solvents such as ether, chloroform, acetone, *etc.*

IR spectrum of ligand (I) shows the absence of a band at 1740 cm^{-1} due to $(-\overset{\displaystyle O}{\overset{\|}{C}}-)$ stretching and the presence of a strong band at 1640 cm^{-1} due to the ($>$C$=$N–) azomethine group indicative of the Schiff base linkage. The band appearing at 3220 cm^{-1} is attributed to ν_{NH} mode. Similarly, ^{1}H-NNR studies of the ligand show all the expected number of protons in support of its structure. Elemental analysis data also confirm the percentage of CHN in the ligand.

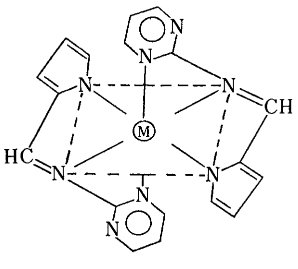
The analytical data and physical properties of the metal complexes are summarised in Table I. All the complexs are crystalline compounds soluble in water, DMF and DMSO. The conductance measurement of the complexes in aqueous solution show their lower value (0.54×10^2—0.35×10^2 siemens/cm^2/mol) suggesting[8] their non-electrolytic nature.

A comparison of IR spectra of the ligand and their metal complexes indicate that vibrations due to azomethine function (at 1640 cm^{-1}) and due to –N$=$C$<$ of the heterocyclic ring (at 1605 cm^{-1}) in the ligand shifted towards the lower side in the metal complexes (at *ca.* 1630—1635 cm^{-1} due to azomethine and at 1600—1595 cm^{-1} due to nitrogen of heterocyclic ring) indicating coordination to the metal atoms through these groups. The band at 3220 cm^{-1} in the ligand due to the ν NH mode also shifted to the lower frequency (at 3210 cm^{-1}) in metal chelates suggesting the participation of pyrrol-NH function in complexation. The conclusive evidence[9] of metal chelation is shown by the observation of the appearance of a new band in the spectra of metal complexes due to (M–N) at *ca.* 485—490 cm^{-1} which confirmed the coordination of metals with the ligand behaving as tridentate NNN donor group.

The room temperature magnetic moment of the nickel(II) complex was found to be 3.41 BM which is indicative of its six coordinated octahedral geometry.[10,11] The μ_{eff} of the

Table I. Physical, Analytical and Spectral Data of Metal Complexes

Complex No./Mol.	Formula	mp (°C)	BM	IR (cm^{-}1)	λ_{max} (cm^{-1})	Analysis (%) Calcd (Found) C	H	N
1	$Ni(L_I)_2\cdot Cl_2$	138—140	3.41	3210, 2965, 2680, 1946, 1698, 1632,	25500, 17200, 9750	45.82	2.96	23.73
				1600, 1134, 1098, 944, 485, 360		(45.81	2.94	23.75)
2	$Cu(L_I)_2\cdot Cl_2$	158—160	1.78	3210, 2950, 2938, 2344, 1635, 1595,	27200, 22100, 13200	45.35	2.93	23.49
				1467, 1383, 1113, 490, 365		(45.37	2.93	23.51)
3	$Zn(L_I)_2\cdot Cl_2$	222—224	Dia	3215, 2932, 2860, 1872, 1683, 1630,	27500, 13200	45.18	2.92	23.40
				1598, 1467, 1134, 505, 490, 370		(45.20	2.91	23.38)



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

Fig. 1. Proposed Structure for $[M(L_I)_2]^{+2}$ Ion

Cu(II) complex around 1.78 BM suggested distorted octahedral geometry[12] of the complex having a d^9 system with one unpaired electron.

The electronic absorption spectra of nickel(II) manifested three bands at 25500, 17200, 9750 cm^{-1} assignable respectively to $^3A_{2g}\rightarrow{}^3T_{1g}(P)$, $^3A_{2g}\rightarrow{}^3T_{1g}(F)$ and $^3A_{2g}\rightarrow{}^3T_{2g}(P)$ transitions which are suggestive of octahedral geometry.[13] Cu(II) complex showed three broad bands in the regions 27200, 22100, 13200 cm^{-1}. The lower energy band may be assigned as the $10\,Dq$ band for distrorted octahedral configuration[14,15] of Cu(II) corresponding to the transition $^2E_g\rightarrow{}^2T_{2g}$. The band in the region 22100 cm^{-1} can be attributed to a symmetry forbidden ligand→metal charge transfer. In some cases it emerges with the high intensity ligand band. The absorption spectra of Zn(II) complex similarly showed a charge transfer band at 27500 cm^{-1} and a band at 13200 cm^{-1} due to transition $^2E_g\rightarrow T_{2g}$ in distorted octahedral environment.[16]

On the basis of the above observations it is proposed that all the complexes show an octahedral geometry (Fig. 1) in which the two ligands acting as tridentate ligand possibly accomodate themselves to bind with the metal atom in such a way that a stable configuration of the metal chelate is formed.

Antibacterial Studies The synthesised ligand (I) and its metal complexes **1**—**3** were tested for their antibacterial activity against bacterial species *Escherichia coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The antibacterial activity of the compounds was tested at a concentration of 30 μg/0.01 ml in DMF using the paper disc diffusion method as described previously.[17,18] The same method was applied for assessing the activity of these compounds, the results of which are reproduced in Table II and show that ligand and all their metal complexes are potent and biologically active against the testing bacterial species. More so, the metal complexes have shown to be more antibacterial than the simple uncomplexed ligand. This inturn proves the idea of our previous studies[19—22] that metal chelation increases the potency/biological activity of such compounds having their antibacterial characteristic properties.

Table II. Antibacterial Activity Data of Complexes

Ligand[a)]/ Complex No.[b)]	Microbial species a	b	c
I	++	+	++
1	+++	++	+++
2	++++	++	+++
3	+++	++	+++

a) Uncomplexed ligand (I). *b*) Same numbering as in Table I. a = *Escherichia coli*, b = *Pseudomonas aeruginosa*, c = *Klebsiella pneumoniae*. Inhibition zone measured in diameter, +, 6—10 mm; ++, 10—16 mm; +++, 16—20 mm; ++++, >20 mm.

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