

SYNTHESIS, CHARACTERIZATION AND ANTIMICROBIAL STUDIES OF METAL COMPLEXES WITH SCHIFF BASES DERIVED FROM 2-THIENYL GLYOXAL

Prashant Singh* and Rajesh K.S. Dhakarey

Department of Chemistry, Institute of Basic Sciences, Dr. B. R. A. University,
Khandari, Agra (India).

*E-mail: prashantsingh_11@rediffmail.com

ABSTRACT

A series of new metal chelates of Co(II), Ni(II) & Cu(II) with a Schiff base ligands derived from condensation of 2-Thienyl glyoxal and 2-Aminopyridine derivatives and characterized via elemental analysis, IR, Mass, NMR, magnetic and electronic spectral data. The antimicrobial activity of the Schiff base and their complexes have been also studied, showing that the complexes were of more antifungal and antibacterial activity than the free ligands.

Key Words: Schiff base, NMR, Infrared studies, Mass spectra, chemical shift & Antimicrobial studies.

INTRODUCTION

Recently, there has been considerable interest in chemistry of the metal complexes of Schiff bases containing O, N, and S donors¹⁻⁵. The increased activity in this field may be attributed to the striking structural features and reported antimicrobial activity of these donor ligands and the complexes derived from them⁶⁻⁷. Chelating ligands containing O, N, and S donor atoms show broad biological activity and are of special interest because of the variety of ways in which they are bonded to metal ions. It is known that the existence of metal ions bonded to biologically active compounds may enhance their activities⁸. Oxo(thiophen-2-yl)acetaldehyde or 2-Thienyl glyoxal (2TG)⁹ and some 2-aminopyridine derivatives are capable to form complexes with transition metal ions in the form of Schiff bases. The complexes of Co(II), Ni(II) & Cu(II) ions with a Schiff bases derived from 2TG with 6-aminopyridin-3-ol, 2-amino-5-nitropyridine and 2-amino-5-bromopyridine have been prepared and investigated using different chemical techniques, such as; elemental analysis, Mass, ¹HNMR, infrared, electronic spectra and magnetic studies. The obtained chemical analysis data showed the formation of 1:2 [M: L] ratio and an octahedral geometry was suggested for metal complexes. The structure of the Schiff Base is shown below:

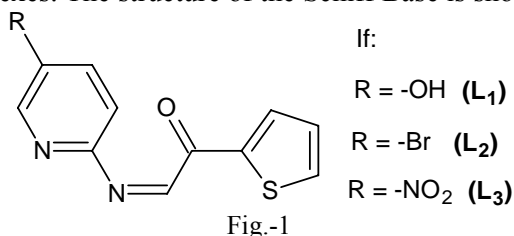
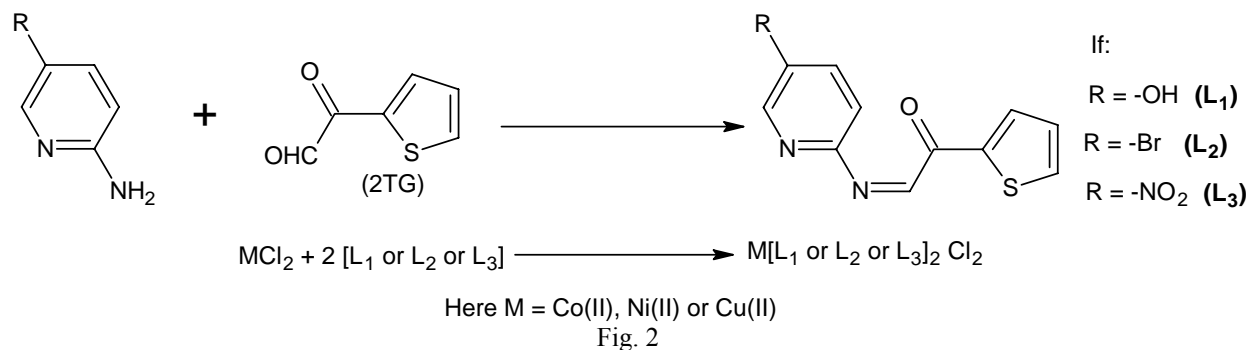


Fig.-1

The present research relates to the synthesis of Schiff bases (L₁, L₂ & L₃) and their metal ion chelates with Co(II), Ni(II) & Cu(II) ions. The Schiff bases and its metal chelates were also screened for their antifungal and antibacterial activities against some species of pathogenic fungi and bacteria. The synthesis of Schiff bases and its metal chelates is shown below:



EXPERIMENTAL

2TG was synthesized as per the reported method⁹. All the other chemicals used were of AR grade. All reactions were carried out using LR grade solvents after purifying by routine procedures. Double distilled water was used.

Synthesis of Schiff bases

Same preparation method was used for Schiff bases; A mixture of 2-thienyl glyoxal (14 g, 10 m mol) dissolved in 45 ml acetone and [6-aminopyridin-3-ol (11.0 g, 10 m mol) or 2-amino-5-bromopyridine (17.3 g, 10 m mol) or 2-amino-5-nitropyridine (13.9 g, 10 m mol)] dissolved in 25 ml ethanol was refluxed on water bath for 6 h under stirring. On cooling to room temperature, chocolate brown crystals were obtained. The crystals were filtered and washed with ethanol, recrystallized from acetone and dried at ambient temperature and purity was confirmed by TLC technique. The yield varied from 75-80%. IUPAC names of the resulting Schiff bases are:

2-[(5-Hydroxypyridin-2-yl)imino]-1-(thiophen-2-yl)ethanone (**L₁**)

2-[(5-Bromopyridin-2-yl)imino]-1-(thiophen-2-yl)ethanone (**L₂**)

2-[(5-Nitropyridin-2-yl)imino]-1-(thiophen-2-yl)ethanone (**L₃**)

Synthesis of complexes

A common preparation method was used for complexes; A solution of chloride salt of Co(II), Ni(II) or Cu(II) ions (10 mmol) in 25ml ethanol was directly mixed to the solution of the Schiff bases (**L₁**, **L₂** or **L₃**) in the same solvent. The molar ratio of metal: ligand was 1:2 for all Schiff bases. Reflux the above mixture for 3-4 h. On cooling, filter the product and the material was dried in air to get the crystals of metal chelates. The yield varied from 40-60% and the purity of the complexes was confirmed by the elemental analysis. The elemental analyses shows that, the Co(II), Ni(II) and Cu(II) complexes have 1:2 stoichiometry of the type $ML_2 \cdot 2Cl$.

Antimicrobial Studies

The *in vitro* antimicrobial activity was performed by the "Paper disc diffusion plate method"¹⁰. The complexes and ligands were tested against phytopathogenic bacteria viz. *Escherichia coli* and *Proteus vulgaris*, and fungi viz. *Aspergillus niger* and *Aspergillus flavus*. For the determination of antifungal activity; about 20 ml of sterilized PDA (Potato Dextrose Agar)¹¹ and in case of antibacterial screening, NA (Nutrient Agar) medium was poured in each sterilized petridish and before gelation of the media, about 2 ml of homogeneous mixture of fungi/bacteria in cool sterilize broth of PDA and NA respectively was mixed in each petridish. After half an hour, when the media was gelatinized, discs of 5 mm size prepared from Whatman filter paper (No.1) thoroughly moistened with the solution of 250, 500 & 1000ppm concentration of complexes and ligands were placed over the seeded media and incubated at $32 \pm 1^\circ C$ and $28 \pm 1^\circ C$ for 72 hours in case of fungi and 24 hours in case of bacteria respectively. Zones of inhibition in mm (including the size of the discs) have been recorded and tabulated in Table III. It is clear from the microbiocidal screening data that the metal complexes are more toxic in comparison to their

parent ligand itself. Hence complexation increases the antimicrobial activity. Such increased activity of the metal complexes can also be explained on the basis of 'Chelation theory'¹².

Physical measurements

Melting points of the synthesized compounds were determined in open glass capillaries using melting point apparatus. Percentage of C, N and H were determined on a Perkin Elmer 2400 CHN analyser at RSIC, Punjab Univ. Chandigarh. IR spectra were recorded using KBr pellets on 'Perkin Elmer-Spectrum BX FTIR' spectrometer in the region $\sim 4000-200\text{cm}^{-1}$ at RSIC, Punjab Univ. The NMR spectra were recorded on Bruker Avance-II Ultrashield-400 MHz FT-NMR spectrometer at Punjab Univ. Chemical shifts (δ) were determined using TMS as internal standard, and multiplicity (s, singlet; d, doublet; t, triplet; m, multiplet) is indicated for every signal. Mass spectra were recorded on Waters Micromass Q-Tof micro spectrometer at Punjab Univ. Magnetic susceptibility measurements were determined at room temperature on 'EG&G model-155' by VSM (vibrating sample magnetometer) method at RSIC, IIT-Madras. Electronic spectra of complexes were carried out on 'Elico SL-171' spectrometer at 25°C using ethanol/acetone as solvent at Department of Chemistry, R.B.S. College, Agra.

RESULTS AND DISCUSSION

Mass spectral studies

On the basis of the "bar graph" presentation of the Schiff bases, we can observe that the peaks at m/z 156, m/z 150 and m/z 149 are the parent ion peaks of the Schiff bases L_1 , L_2 & L_3 respectively and peak at m/z 231, m/z 294 and m/z 260 is corresponding to the molecular weight (M^+) of L_1 , L_2 & L_3 respectively. In the case of L_1 other peaks at m/z 108 and 149 supports the fragmentation of azomethine linkage and thiophene ring respectively. In the case of L_2 peaks at m/z 171 and 212 supports the fragmentation of azomethine linkage and thiophene ring respectively. In the case of L_3 peaks at m/z 137 and 178 supports the fragmentation of azomethine linkage and thiophene ring respectively.

¹H NMR Spectra

¹H NMR spectrum of Schiff bases [L_1 , L_2 & L_3] were recorded in CDCl_3 . In all the spectra of Schiff bases, a sharp singlet in range $\delta 7.3-7.5$ assigned as azomethine proton. In the spectra of L_1 a broad singlet found in the chemical shift range of $\delta 10.3-10.9$, due to hydroxylic proton. Peaks due to thienyl protons present at position 3, 4 & 5 found in the range of (s, δ 8.5-8.8), (m, δ 5.6-5.9) and (t, δ 8.1-8.3) respectively in all the ligands spectra. Peaks due to protons present in pyridine ring at position 3, 4 & 6 found in the range of (d, δ 6.3-6.6), (d, δ 6.9-7.1) and (d, δ 7.7-7.9) respectively in all the ligands spectra.

Table-1: Analytical, magnetic and physical properties of ligands and their complexes

Compound (Code)	Formula	Color	m.p. (°C)	Elemental analysis: % Found (% Calcd.)			μ_{eff} [B.M.]
				C	H	N	
Ligand 1 (L1)	$\text{C}_{11}\text{H}_8\text{N}_2\text{O}_2\text{S}$	Light Brown	124-126° (decom.)	56.3 (56.8)	3.3 (3.4)	12.1 (12.0)	-
Co[L1]2 Cl2 (a)	$\text{Co}[\text{C}_{11}\text{H}_8\text{N}_2\text{O}_2\text{S}]_2 \text{Cl}_2$	Brown	136-139°	44.5 (44.4)	2.7 (2.7)	9.2 (9.4)	4.3
Ni[L1]2 Cl2 (b)	$\text{Ni}[\text{C}_{11}\text{H}_8\text{N}_2\text{O}_2\text{S}]_2 \text{Cl}_2$	Greenish Brown	132-135°	44.2 (44.4)	2.8 (2.7)	9.5 (9.4)	3.21
Cu[L1]2 Cl2 (c)	$\text{Cu}[\text{C}_{11}\text{H}_8\text{N}_2\text{O}_2\text{S}]_2 \text{Cl}_2$	Dark Brown	210-214°	43.9 (44.1)	2.5 (2.6)	9.3 (9.3)	1.83
Ligand 2 (L2)	$\text{C}_{11}\text{H}_7\text{N}_2\text{OSBr}$	Brown	124-125° (decom.)	44.3 (44.7)	2.3 (2.3)	9.4 (9.4)	-
Co[L2]2 Cl2 (d)	$\text{Co}[\text{C}_{11}\text{H}_7\text{N}_2\text{OSBr}]_2 \text{Cl}_2$	Brown	150-153°	36.2 (36.6)	2.0 (1.9)	7.5 (7.7)	4.2
Ni[L2]2 Cl2 (e)	$\text{Ni}[\text{C}_{11}\text{H}_7\text{N}_2\text{OSBr}]_2 \text{Cl}_2$	Greenish Brown	140-145°	36.8 (36.7)	2.1 (1.9)	7.9 (7.7)	3.11

Cu[L2]2 Cl ₂ (f)	Cu[C ₁₁ H ₇ N ₂ OSBr] ₂ Cl ₂	Brown	220-224°	36.7 (36.4)	1.8 (1.9)	7.5 (7.7)	1.85
Ligand 3 (L3)	C ₁₁ H ₇ N ₃ O ₃ S	Brown	120-123° (decom.)	49.9 (50.5)	2.4 (2.7)	15.8 (16.0)	-
Co[L3]2 Cl ₂ (g)	Co[C ₁₁ H ₇ N ₃ O ₃ S] ₂ Cl ₂	Brown	125-128°	40.7 (40.5)	1.9 (2.1)	12.7 (12.8)	4.6
Ni[L3]2 Cl ₂ (h)	Ni[C ₁₁ H ₇ N ₃ O ₃ S] ₂ Cl ₂	Greenish Brown	142-146°	40.4 (40.52)	2.1 (2.1)	12.8 (12.8)	3.26
Cu[L3]2 Cl ₂ (i)	Cu[C ₁₁ H ₇ N ₃ O ₃ S] ₂ Cl ₂	Dark Brown	214-217°	40.0 (40.22)	2.1 (2.1)	12.5 (12.7)	1.88

Electronic and Magnetic Studies

The effective magnetic moment values of all the Co(II) complexes lie in the range of 4.2-4.6 BM, which suggested a distorted octahedral geometry (Table-I). These values are much higher than the spin only value of 3.87BM. These μ_{eff} values in all the complexes may arise due to electron pairing in the formation of strong covalent bond involving the use of 3d electron of Co(II) ion or spin-spin interaction¹³.

The electronic spectra of Co(II) complexes exhibited absorption bands in the region 8000-10000 cm⁻¹ and 18500-19500 cm⁻¹ corresponding to ν_1 and ν_3 transitions respectively, which are attributed to the transitions ${}^4T_{1g}(F) \rightarrow {}^4T_{2g}(F)$ (ν_1); ${}^4T_{1g}(F) \rightarrow {}^4T_{1g}(P)$ (ν_3). In the present investigation, brownish Co(II) complexes show the absorption bands at 9345 and 19300 cm⁻¹ for complex (a), 9452 and 18930 cm⁻¹ for complex (d) and 8737 and 19030 cm⁻¹ for complex (g) corresponding to ν_1 and ν_3 transitions respectively. These bands are the characteristic of high spin octahedral Co(II) complex¹⁴. However, ν_2 band is not observed because of its proximity to strong ν_3 transition.

The greenish brown Ni(II) complexes exhibited three bands at 10346, 15350 and 26272 cm⁻¹ for complex (b), 10562, 15684 and 25370 cm⁻¹ for complex (e) and 10444, 15359 and 26546 cm⁻¹ for complex (h), which are attributed to the ${}^3A_{2g} \rightarrow {}^3T_{2g}$ (ν_1); ${}^3A_{2g} \rightarrow {}^3T_{1g}(F)$ (ν_2) and ${}^3A_{2g} \rightarrow {}^3T_{1g}(P)$ (ν_3) transitions respectively indicating octahedral geometry around Ni(II) ion¹⁵. Ni(II) complexes showed the magnetic moment value in the range of 3.11- 3.26 BM, which is within the range of 2.8-3.5 BM suggesting¹⁶ consistency with their octahedral environment.

The Electronic spectra of Cu(II) complex display two prominent bands. A low intensity broad band around 13996 cm⁻¹ for complex (c), 13856 cm⁻¹ for complex (f) and 14103 cm⁻¹ for complex (i) is assignable to ${}^2T_{2g} \rightarrow {}^2E_g$ transition. Another high intensity band at 25620 cm⁻¹ for complex (c), 25588 cm⁻¹ for complex (f) and 25954 cm⁻¹ for complex (i) is due to symmetry forbidden ligand \rightarrow metal charge transfer. On the basis of electronic spectra distorted octahedral geometry around Cu(II) ion is suggested^{14,17}. The Cu(II) complexes showed magnetic moment in the range of 1.83-1.88 BM, is slightly higher than the spin-only value 1.73 BM expected for one unpaired electron, which offers possibility of an octahedral geometry¹⁸. (Table-I)

Infrared spectral Studies

In order study the binding mode of the Schiff bases¹⁹ to metal in the complexes, IR spectra of the free ligands are compared to metal complexes. In the IR spectra of L₁, four sharp bands found at ~1617, ~ 1272, ~ 1740 and ~ 1650 cm⁻¹ are due to $\nu\text{C}=\text{N}$, $\nu\text{C}-\text{S}-\text{C}$, $\nu\text{C}=\text{O}$ and $\nu\text{C}-\text{N}-\text{C}$ bending vibrations respectively. In the IR spectra of L₂, these four sharp bands found at ~1625, ~ 1298, ~ 1732 and ~ 1655 cm⁻¹ and in L₃, these four sharp bands found at ~1618, ~ 1310, ~ 1736 and ~ 1648 cm⁻¹ respectively. In all the metal complexes with L₁, L₂ or L₃, above bands shift to downwards, confirms the atom-metal coordination through azomethine nitrogen²⁰, thienyl sulphur²¹, carbonyl oxygen²² and pyridinyl nitrogen²³ respectively.

In all the complexes additional bands are also appear in the region $\sim 320-340$, $380-420$, $430-500$ and $530-570 \text{ cm}^{-1}$. These vibrations have been ascribed to $\nu\text{M-Cl}$, $\nu\text{M-S}$, $\nu\text{M-O}$ and $\nu\text{M-N}$ respectively²⁴ indicating coordination. (Table-II)

Table-2: IR Spectral data of ligands and their complexes

Compound	$\nu\text{C=O}$	$\nu\text{C=N}$	$\nu\text{C-N-C}$	$\nu\text{C-S-C}$	$\nu\text{M-N}$	$\nu\text{M-O}$	$\nu\text{M-S}$	$\nu\text{M-Cl}$
L1	1740s	1617s	1650s	1272s	-	-	-	-
(a)	1710s	1596s	1642s	1250m	531w	494s	392m	320m
(b)	1695s	1598s	1630s	1253m	548s	465m	401m	325m
(c)	1683s	1600m	1645s	1253s	560w	430w	385w	330m
L2	1732s	1625s	1655s	1298s	-	-	-	-
(d)	1700s	1602s	1646s	1277m	541w	484s	400m	324m
(e)	1689s	1608s	1620s	1276m	551s	468s	410m	328m
(f)	1688s	1610m	1631s	1260s	565w	434w	388w	333m
L3	1736s	1618s	1648s	1310s	-	-	-	-
(g)	1704s	1600s	1627s	1288m	562w	473m	390m	320m
(h)	1695s	1602s	1628s	1271m	545s	451s	406m	326m
(i)	1685s	1598m	1633s	1291s	563w	440w	381w	335m

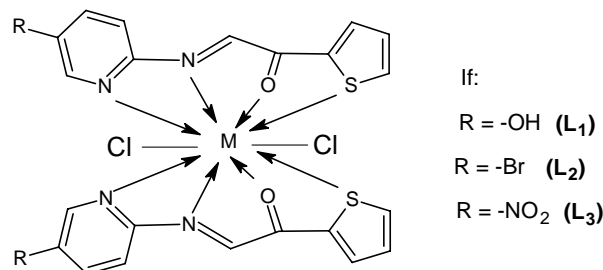
Table-3: Antimicrobial data of synthesized compounds

Compound	Conc. (in ppm)	Inhibition Zone, in mm			
		<i>E. coli</i>	<i>P. vulgaris</i>	<i>A. niger</i>	<i>A. flavus</i>
L1	250 / 500 / 1000	7 / 6 / 8	6 / 7 / 8	6 / - / -	- / 6 / 7
(a)	250 / 500 / 1000	8 / 8 / 10	7 / 12 / 9	6 / 7 / 8	6 / 7 / 8
(b)	250 / 500 / 1000	- / 9 / 10	7 / 11 / 9	6 / 8 / 8	- / 11 / 10
(c)	250 / 500 / 1000	8 / 8 / 8	8 / 8 / 10	6 / 6 / 8	7 / 9 / 10
L2	250 / 500 / 1000	6 / 7 / 7	6 / 7 / 8	6 / 6 / 6	7 / 8 / 6
(d)	250 / 500 / 1000	6 / 9 / 12	7 / 12 / 11	6 / 7 / 9	8 / 10 / 8
(e)	250 / 500 / 1000	7 / 8 / 11	- / 10 / 9	7 / 7 / 11	9 / 10 / 8
(f)	250 / 500 / 1000	6 / 10 / 13	7 / 12 / 12	6 / 8 / 12	9 / 12 / 8
L3	250 / 500 / 1000	6 / 6 / 8	- / 8 / 7	- / 5 / 6	6 / 7 / 7
(g)	250 / 500 / 1000	7 / 7 / 7	9 / 9 / 9	6 / 9 / 6	8 / 8 / 7
(h)	250 / 500 / 1000	7 / - / 9	10 / 8 / 9	6 / 7 / 8	8 / 8 / 9
(i)	250 / 500 / 1000	7 / 7 / 12	9 / 8 / 9	8 / 9 / 9	6 / 7 / 8

Note: ('-' = Not Measurable)

CONCLUSION

All the spectral studies suggest that the Schiff bases are tetradentate in nature having O, N and S donor atoms with octahedral geometry. All the compounds are bioactive showing good antimicrobial property. The suggested structure of the complexes are:



Here M = Co(II), Ni(II) or Cu(II)

Fig.- 3

REFERENCES

1. R. Dhakarey and G.C. Saxena, *J. Chin. Chem. Soc.*, **32**, 35 (1985).
2. P. Singh, S. Das and R. Dhakarey; *E-Jour. Chem.*, **6(1)**, 99-105 (2009).
3. S. Yamada, *Coord Chem Rev.*, **537**, 190-192 (1999).
4. S.K. Sridhar and A. Ramesh, *Indian J. Chem.*, **44B(3)**, 668 (2002).
5. Z.H. Chohan and S. Kausar, *Met. Based Drugs*, **7(1)**, 17 (2000).
6. K.A.Melha, *J. Enzyme Inhib. Med. Chem.*, **23(2)**, 285-95 (2008).
7. V.B. Badwaik, R.D. Deshmukh and A.S. Aswar, *J. Coord. Chem.*, **62(12)**, 2037-2047 (2009).
8. N.H. Al-Shaalan, *Molecules*, **12(5)**, 1080-91(2007).
9. F. Kippnis and J. Ornfeldt, *J. Am. Chem. Soc.*, **68(12)**, 2734 (1946). ; H.A. Riley and A.R. Gray, *Org. Synth.*, **2**, 509 (1943); **15**, 67 (1935).
10. A.W. Baur, W.M. Kirby, J.C. Sherris and M. Turk, *Am. J. Clin. Path.*, **45**, 493 (1966).
11. C.J. Alexopoulos and E.S. Beneke, 'Laboratory Manual for Introductory Mycology', Burgess Pub. Co., Minneapolis, (1962).
12. K.N. Thimmaiah, W.D. Lloyd and G.T. Chandrappa, *Inorg. Chim. Acta*, **81**, 106 (1985).
13. S. Yamada, K. Yamanouchi, W. Mori and M. Kishita., *Bull.Chem. Soc. Japan*, **49(8)**, 2111-2114 (1976).
14. A.B.P Lever, 'Inorganic Electronic Spectroscopy', Elsevier, Amsterdam, (1984).; S. Yamada, *Coord. Chem. Rev.*, **2**, 83 (1967).
15. F.M. Morad, M.M.Elajaily and S.B. Gweirif, *J. Sci. and Appl.*, **1(1)**, 72-78 (2007).
16. M. Sonmez and M. Sekerci, *J. Serb. Chem. Soc.*, **72(3)**, 259-264 (2007).
17. N. Raman, S. Ravichandran and C. Thangaraja, *J. Chem. Sci.*, **116(4)**, 215-219 (2004).
18. B.N. Figgis and J. Lewis, *J. Prog. Inorg. Chem.*, **6**, 87 (1964).
19. G.C. Basseler and R.M. Silverstein, 'Spectrometric Identification of Organic Compounds', Wiley Interscience, New York, (1992).
20. K. Nakamoto, 'Infrared and Raman Spectra of Inorganic and Coordination Compounds', John Wiley & Sons, New York, (1997).
21. C. Spinu, M. Pleniceanu and C. Tigae, *Turk. J. Chem.*, **32**, 487-493 (2008).
22. A.P. Mishra and M. Soni, *Metal-Based Drugs*, Article ID 875410 (2008).
23. N.M. Hosny, *J. Coord. Chem.*, **60(24)**, 2755-2764 (2007).
24. M.A.S. Monshi and N.M.A. Salam, *J.King Saud. Univ.*, **8(2)**, 197-206 (1996).

(Received: 25 September 2009

Accepted: 25 October 2009

RJC-460)

RJC will widely cover all branches of **CHEMISTRY** including: Organic, Inorganic, Physical, Analytical, Biological, Pharmaceutical, Industrial, Environmental, Agricultural & Soil, Petroleum, Polymers, Nanotechnology, Green Chemistry, Forensic, Phytochemistry, Synthetic Drugs, Computational, as well as Chemical Physics and Chemical Engineering.

Manuscript Categories: Full-length paper, Review Articles, Short/Rapid Communications.

Manuscripts should be addressed to:

Prof. (Dr.) Sanjay K. Sharma

Editor-in-Chief

23, 'Anukampa', Janakpuri, Opp. Heerapura Power Station,
Ajmer Road, Jaipur-302024 (India)

E-mail: rasayanjournal@gmail.com, drsanjay1973@gmail.com

Mobile: 09414202678, 09887050628