Synthesis, Characterization and Antifungal Activity of Mn(II), Co(II), Ni(II) and Cu(II) Complexes with 4-Hydroxybenzaldehyde-N-4'-cytidinylazomethine

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Synthesis of Mn(II), Co(II), Ni(II) and Cu(II) complexes of 4-hydroxybenzaldehyde-N-4'-cytidinylazomethine has been described and their structures have been established on the basis of elemental analysis, infrared spectra, ^{1}H NMR spectra and magnetic analysis. The complexes have been screened for their antifungal potential against some fungal strains *viz.*, *Aspergillus niger* and *Aspergillus flavus*. The minimum inhibitory concentrations of the Schiff bases and metal complexes were determined by filter paper disc method. The result reveals that the antifungal activities of metal complexes are higher than that of the free ligand.

Key Words: Cytidinylazomethine, Transition metal complex, Antifungal activity.

INTRODUCTION

The interest in the study of nucleoside and azomethines possessing potential donor sites has been intensively increasing because of their coordination capability, their pharmacological activity and their uses in analytical chemistry as metal extracting agents. It has recently been shown that the metal complexes are more potent and less toxic in many cases as compared to the parent compound. Cytosine is a pyrimidine base, occurring condensed with ribose to form the nucleosides cytidine. Cytidine is considered as modified as nucleosides, important class of non-natural molecules. Cytidine derivatives possess many chemical as well as medicinal importance, antibacterial[1,2]. antifungal[3,4], anticancer[5,6], antiinflammatory[7,8], diuretic[9,10] and many more activities. Among the numerous types of azomethines, the heterocyclic azomethine having oxygen and nitrogen sites and their metal complexes have received considerable attention during the last years, especially for the large number of their applications. Thus, it was found that the azomethines are characterized by the -CH=N- (imino group) which has special importance in elucidating the mechanism of transmination and racemization in biological system[11-13]. Azomethines have high potential chemical permutation possibilities and show diuretic[14], anticancer[15,16], anti-bacterial[17,18] and antifungal activities[19,20]. This class of compounds has also exhibited activity against a wide range of organisms and is known to have medicinal importance and is used in

drug design[21,22]. It has been also reported that when some aldehydes were functionalized by condensation with various amines, the resulting azomethines had anti parasitic activities[23]. These finding prompted us to synthesize the substituted cytidinylazomethine derivatives by the combination of cytidine and 4-benzaldehyde derivative moieties in one frame may lead to compounds with interesting antifungal activity (**Scheme-I**).

EXPERIMENTAL

All the reagents and solvents were generally received form commercial supplier. Reactions were done in dried glassware. Melting points were taken in open capillaries by thermonic melting point apparatus, (Campbell Electronic, Mumbai, India) and are uncorrected. The purity of the newly synthesized compounds was checked by thin layer chromatography (TLC) on silica gel-G coated plates by using different solvent systems. Infrared spectra were determined on Bruker IFS-66 FTIR (Bruker Bioscience, USA) using KBr pallets and wave number (ν) was reported in cm^{-1}. The ^{1}H NMR spectra were taken on Jeol GSX-300 FT NMR (Jeol, Tokyo, Japan) in $CDCl_3$ or DMSO-d_6 and chemical shifts (δ) are given in ppm. Tetramethylsilane (TMS) was used as internal reference standard. Mass spectra were recorded on Spec Finnigan Mat 8230 MS. Magnetic susceptibilities were determined using Sherwood Scientific Magnetic Susceptibility meter (UK), elec-
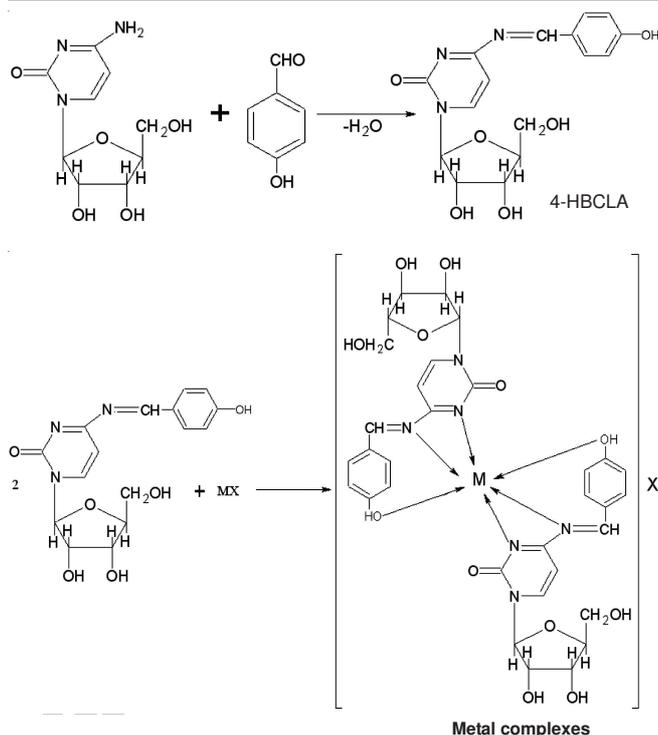
Scheme-I

tronic spectra of complexes in DMF on GBC model UV visible spectrophotometer. The carbon, hydrogen and nitrogen analysis were performed on Carlo Erba-1108 (Carlo Erba, Milan, Italy) and the results were found with in ± 0.4 % of the theoretical values.

General procedure of synthesis of Schiff base, 4-hydroxybenzaldehyde-N-4'-cytidinylazomethine (4-HBCLA): Schiff base was prepared[24,25] by refluxing calculated quantities of cytidine amine (10 mmol, 2.432 g in 25 mL of ethanol and 1 mL of DMF) and 4-hydroxybenzaldehyde (10 mmol, 1.24 g in 20 mL of ethanol) were mixed with clear solution and then stirred for *ca.* 1 h. Then this mixture was refluxed for 12-14 h. The content were cooled precipitate was obtained. It was washed with ethanol and dried in air; a whitish yellow solid was obtained.

General procedure of synthesis of metal complex: The corresponding, metal chloride or metal sulphate (5 mmol, 25 mL) in ethanol or dioxane to a solution of the metal ligand; 4HBCLA (10 mmol, 25 mL) in same solvent. The resulting mixture was stirred for 0.5 h and refluxed for 4-6 h on a water bath. The precipitated complex was filtered and washed with ethanol mixture, ether and dried in air.

Pharmacology evaluation: Synthesized Schiff bases and their corresponding metal complexes were tested for the growth inhibitory activity against fungi *viz.*, *Aspergillus niger* and *Aspergillus flavus* using 'Filter paper disc' method[26] at 250, 500 and 1000 ppm level in acetone/ethanol. For screening anti fungal activity 'Potato Dextrose Agar'[27] was used as a growth medium. Sterilized filter paper discs of 5 mm diameter were soaked in the solutions of different concentrations of synthesized compounds and introduced on sterilized culture media. The plates were incubated for bacteria and 72-96 h at 28 ºC for fungi. The zones of inhibition based upon zone size around the discs were measured.

RESULTS AND DISCUSSION

The analytical data showed the suggested formula for metal complexes as: $[M(C_{16}H_{17}N_3O_6)_2]X_2$, where M = Mn(II), Co(II) and Cu(II), X = Cl$^-$ and Ni(C$_{16}$H$_{17}$N$_3$O$_6$)SO$_4$. All the complexes were sparingly soluble in acetone and DMSO and partially soluble in benzene but completely soluble in solvent like DMF, ethanol and water. The results of the elemental analysis showed that all the complexes have 1:2 (metal:ligand) stoichiometry. These complexes decompose above 250 ºC. However, the analytical, spectroscopic and magnetic data enabled the possible structure of the synthesized complexes to be predicted. All complexes gave satisfactory elemental analyses results, as shown in Table-1.

Infrared spectral studies: The IR spectra of Schiff base derived from 4-hydroxybenzaldehyde and cytidine amine shows a band at 3425 cm^{-1} assigned as ν(-OH) and no absorption bands at 1599 cm^{-1} indicates the persence of (C=O) group. Absence of doublet in the region of 3400-3300 cm^{-1} indicates the absence of CHO group. The complexes show a band at *ca.* 1610 cm^{-1} implying C=N stretching vibration[28], which shows a shift in the spectra of complexes. Hence, the azomethine nitrogen is the first donor site in this case[29]. There is no shift in the position of C=O group and a slight shift indicates the non-involvement of carbonyl 'O' in coordination in complexes. The phenyl ring vibrations are observed in all the cases near 1425 cm^{-1}. Considerable shifts in the ν(C=N) stretching frequencies, which corresponds to the N(3) of cytidine amine of all the metal complexes[30-32], clearly in the metal co-ordination (2nd binding site). Regarding the third chelating site of the ligand, the infrared spectra of complexes shows a shift in the frequency of ν(-OH) group which is at 3495-3450 cm^{-1} in the ligand and gets shifted in the complexes, thus indicating the involvement of phenolic oxygen[33] in coordination with metal. The ring streching (*ca.* 1425 cm^{-1}) ring, C-H bending (*ca.* 1254 cm^{-1}) and C$_{ring}$-C$_{exo}$ stretching (*ca.* 984 cm^{-1}) are also observed in the spectra[34]. Below 600 cm^{-1} are also observed indecating the complex formation with frequencies of ν(M-O) and ν(M-N)[35]. All the complexes gave satisfactory infrared spectra results, as shown in Table-2.

NMR spectral studies: The ^{1}H NMR spectral data are reported along with the possible assignments in Table-3. All the protons were found as to be in their expected region[36]. The NMR spectra of compounds contained multiple signals in the δ 6.90 to 8.08 ppm regions due to aromatic protons and a singlet at 8.40-9.75 ppm from the C-H protons of the CH=N groups. The conclusions drawn from these studies further support to the mode of bonding discussed in their IR spectra. In the spectra of metal(II) complexes, coordination of the ligands *via* azomethine-N, cytidine-N and phenolic-O was established. The number of protons calculated from the integration curves and those obtained from the values of the expected CHN analyses agree with each other. It was observed that DMSO did not have any coordinating effect neither on the spectra of the ligands nor on its metal complexes.

Electronic spectra: The electronic spectra of newly synthesized Mn(II) complex showed four transitions in the range of 19700-26950 cm^{-1}. The first pair of bands were assigned to the ^{4}T$_{1g}$(G) followed by T$_{2g}$(G) terms. The sharpness of the

TABLE-1
ELEMENTAL ANALYSES OF SCHIFF BASE AND ITS METAL COMPLEXES

Empirical formula	m.w.	Colour	m.p. (ºC)	Yield (%)	μ_{eff} (BM)	Elemental analysis (%): Calcd. (found)			
						C	H	N	M
$C_{16}H_{17}N_3O_6$	347.34	Light yellow	190	52	–	55.32 (55.11)	4.89 (4.71)	12.09 (11.87)	–
$Mn(C_{16}H_{17}N_3O_6)_2Cl_2$	820.54	Light pink	280	57	5.75	46.83 (46.62)	4.14 (4.01)	10.23 (10.13)	6.75 (6.51)
$Co(C_{16}H_{17}N_3O_6)_2Cl_2$	825.23	Pink	265	67	4.48	46.57 (46.37)	4.12 (4.27)	10.18 (10.02)	7.14 (7.01)
$Ni(C_{16}H_{17}N_3O_6)_2SO_4$	850.39	Light green	180	54	2.75	45.19 (45.01)	3.99 (3.81)	9.88 (9.97)	6.90 (7.03)
$Cu(C_{16}H_{17}N_3O_6)_2Cl_2$	829.84	Deep blue	165	59	1.76	46.31 (46.51)	4.09 (4.21)	10.12 (10.01)	7.65 (7.43)

TABLE-2
INFRARED FREQUENCIES OF SCHIFF BASE AND ITS METAL COMPLEXES

Compound	IR (KBr, ν_{max}, cm⁻¹)								
	(C=O)	(C=N)	(C-N-C)	(M-O)	(M-N)	(M-Cl)	(OH)	(NH)	(C-O)
$C_{16}H_{17}N_3O_6$	1688	1599	1428	-	-	-	3520	3425	1570
$Mn(C_{16}H_{17}N_3O_6)_2Cl_2$	1680	1590	1443	480	425	370	3540	3434	1545
$Co(C_{16}H_{17}N_3O_6)_2Cl_2$	1667	1595	1453	450	427	352	3510	3415	1565
$Ni(C_{16}H_{17}N_3O_6)_2SO_4$	1666	1610	1443	465	430	345	3525	3435	1540
$Cu(C_{16}H_{17}N_3O_6)_2Cl_2$	1660	1590	1448	450	425	362	3540	3544	1560

TABLE-3
¹H NMR SPECTRA OF SCHIFF BASE AND ITS METAL COMPLEXES

Compound	¹H NMR (DMSO-d_6) δ ppm
$C_{16}H_{17}N_3O_6$	10.11 (s, 1H, OH, exchangeable), 8.59 (s, 2H, N=CH), 7.13 (d, 2H, J = 7.4, =CH), 6.53–7.06 (m, 8H, Ar-H), 5.64 (d, 2H, =CH), 5.44 (d, 2H, $J_{1',2'}$ = 3.1 Hz, H-1'), 4.94-5.54 (m, 4H, H-2',3',OH), 4.67-4.78 (t, 1H, J = 4.7 Hz, OH-5'), 4.12-4.63 (m, 3H, H-2',3',4'), 3.7-3.9 (m, 2H, CH2-5').
$Mn(C_{16}H_{17}N_3O_6)_2Cl_2$	9.99 (s, 2H, OH, exchangeable), 8.49 (s, 2H, N=CH), 7.14 (d, 2H, J = 7.4, =CH), 6.53–7.07 (m, 8H, Ar-H), 5.63 (d, 2H, =CH), 5.44 (d, 2H, $J_{1',2'}$ = 3.1 Hz, H-1'), 4.92-5.37 (m, 4H, H-2',3',OH), 4.68-4.89 (t, 2H, J = 4.7 Hz, OH-5'), 4.23-4.64 (m, 6H, H-2',3',4'), 2.71-2.93 (m, 4H, CH2-5').
$Co(C_{16}H_{17}N_3O_6)_2Cl_2$	9.98 (s, 2H, OH, exchangeable), 8.41 (s, 2H, N=CH), 7.12 (d, 2H, J = 7.4, =CH), 6.54–7.04 (m, 8H, Ar-H), 5.64 (d, 2H, =CH), 5.42 (d, 2H, $J_{1',2'}$ = 3.1 Hz, H-1'), 4.91-5.38 (m, 4H, H-2',3',OH), 4.64-4.85 (t, 2H, J = 4.7 Hz, OH-5'), 4.23-4.65 (m, 6H, H-2',3',4'), 2.72-2.91 (m, 4H, CH2-5').
$Ni(C_{16}H_{17}N_3O_6)_2SO_4$	9.93 (s, 2H, OH, exchangeable), 8.43 (s, 2H, N=CH), 7.13 (d, 2H, J = 7.4, =CH), 6.56–7.06 (m, 8H, Ar-H), 5.64 (d, 2H, =CH), 5.42 (d, 2H, $J_{1',2'}$ = 3.1 Hz, H-1'), 4.94-5.38 (m, 4H, H-2',3',OH), 4.65-4.89 (t, 2H, J = 4.7 Hz, OH-5'), 4.22-4.63 (m, 6H, H-2',3',4'), 2.74-2.93 (m, 4H, CH2-5').
$Cu(C_{16}H_{17}N_3O_6)_2Cl_2$	9.96 (s, 2H, OH, exchangeable), 8.47 (s, 2H, N=CH), 7.13 (d, 2H, J = 7.4, =CH), 6.55–7.07 (m, 8H, Ar-H), 5.61 (d, 2H, =CH), 5.44 (d, 2H, $J_{1',2'}$ = 3.1 Hz, H-1'), 4.94-5.36 (m, 4H, H-2',3',OH), 4.67-4.88 (t, 2H, J = 4.7 Hz, OH-5'), 4.21-4.61 (m, 6H, H-2',3',4'), 2.71-2.91 (m, 4H, CH2-5').

spectral band was determined by the slope of the upper level. This results in the broadening of the band. Thus in Mn(II) complexes such bands were found at 19800-19760, 20525-20650, 24580-24500 and 26680-26710 corresponding to the transition to $^4E_g(G)$, $^4A_{1g}$, $^4E_g(D)$ and $^4A_{2g}(F)$, respectively. The last two bands were not sharp as the first one. In fact since the transition gap of $^6A_{2g} \rightarrow ^4E_g(D)$, $^4A_{1g}(G)$ corresponds to that of $^6S \rightarrow ^4G$. The band *ca.* 26000 cm⁻¹ should be equal to the frequency of free ion (M²⁺).

The absorption spectra of newly synthesized Co(II) complex of high spin d^7 system are particularly informative. The Co²⁺ in octahedral coordination has the ground state either $^4T_{1g}(t_{2g})^5(e_g)^2$ or $^2E_g(t_{2g})^6(e_g)^1$ depending upon the strength of ligand field. For the ground state $^4T_{1g}$ of the octahedral high spin Co(II) complexes a subnational amount of spin orbit coupling is expected[37]. A resolved absorption band is observed around 8470 cm⁻¹ and a multiple absorption band comprising three overlapping peaks about 20275 cm⁻¹. The lowest energy at ν_1 8470 and 8500 cm⁻¹ is assigned to the transitions. The multiple bands have three peaks at *ca.* 17950, 19000 and 20400 cm⁻¹. Two of these low energy peaks are generally accepted

due to $^4T_{1g} \rightarrow ^4A_{2g}$ (ν_2) and $^4T_{1g} \rightarrow ^4T_{2g}(P)$ (ν_2) transitions. The extra band is attributed to the spin orbit coupling effects or transitions to doublet states. The $T_{1g} \rightarrow ^4A_{2g}$ (ν_2) transition is essentially two electron transition as the excited state configurations $t_{2g}^3 e_g^4$, while the ground states is $t_{2g}^5 e_g^2$.

The electronic spectra indicate that the three transitions can be assigned *i.e.*, $^3A_{2g}(3T,P)$, $^3E_g(^3T,P)$ and $^3A_{2g}(^3T,F)$. This indicate that the high energy bands arise the P-state and assignment of $^3A_{2g}(P)$, $^3E_g(P)$ was predictable in view of the ligand taking as an example, the $Ni(C_{16}H_{17}N_3O_6)_2SO_4$ pronounced tetragonal splitting for the excited $^3T_{2g}$ (F) and $^3T_{1g}$ (F) has been observed. For $^3T_{2g}$ splitting these bands were observed in the region 8200 and 10780 cm⁻¹ and for $^3T_{1g}(F)$ splitting these bands were observed 14400 and 16780 cm⁻¹, respectively.

The electronic spectral properties of Cu(II) complex reveal that the environment about the copper ion is increasingly distorted from octahedral to tetrahedral, a corresponding decrease to lower energies observed in the main ligand field. So tetragonal distortion is generally assumed to be most common in Cu(II) ion coordination complexes. The ground

state of Cu(II) is an elongated tetragonally distorted octahedral crystal field of D_{4th} symmetry may be described as single electron $d_{x^2-y^2}(B_{1g})$ orbital $^2B_{1g}$ spectroscopic state[38]. The labelling of the excited state may be done similarly. In tetragonal field, transitions expected were, $^2B_{1g} \rightarrow ^2A_{1g}$, $^2B_{1g} \rightarrow ^2B_{2g}$ and $^2B_{1g} \rightarrow ^2E_g$ and they were found in the range 11780-11900, 15650-15800 and 17300-17520 cm^{-1}, respectively. The transition $^2B_{1g} \rightarrow ^2B_{2g}$ is independent of D_s and D_t and it is a measure of 10Dq. The increased bonding of the $d_{x^2-y^2}$ copper orbital than leads to the larger splitting of the ground state $^2E_{2g}$. The approximate positions of the ^2E_g and $^2B_{2g}$ states can be estimated from the g factor obtained from EPR.

Magnetic susceptibility measurements: The value of magnetic moment is close to the spin only 5.92 for Mn(II) in obtained complexes. In present Mn complexes, the value was found to be 5.75 BM. The present Mn(II) complex of Schiff base showed a slightly lower value of magnetic moments in high spin complexes, which can be explained on the basis of anti ferromagnetic interaction between Mn(II) ions in solid state.

The magnetic moment values for newly synthesized Co(II) complex was 4.48 BM, suggesting for the high spin octahedral geometry[39]. The value obtained was slightly higher than the spin only value of 3.87 BM. This can be explained on the basis of octahedral symmetry involving a higher degree of orbital contribution due to the three fold degeneracy of the $^4T_{1g}$ ground state.

The effective magnetic moment value of Ni(II) complex 2.75 BM. The observed value has good relation with the complexes having $^2A_{2g}$ or $^3B_{1g}$ ground term and these vaslues also depends on the magnitude of the orbital contribution expected for similar hexa coordinated Ni(II) ions. The observed values are slightly higher than the spin only value of 2.83 BM, due to slight distortion from pure octahedral from to tetrahedral symmetry[40].

Cu(II) being a d^9 system shows Paramagnetism equivalent to unpaired electrons of distorted octahedral geometry. The value of 1.762 BM is close to theoretical value of 1.73 BM for Cu(II) complexes. Hence observed magnetic moment for the Cu(II) complexes under study indicates that it has distorted octahedral configurations[41].

Antifungal studies: The fungal data revealed that azomethine Schiff base and their respective Mn(II), Cu(II), Co(II) and Ni(II) chelate were screened against *Aspergillus niger* and *Aspergillus flavus* to asses their potentiality as antifungal agents. The fungal activity of bivalent metal complexes has increased considerably as compared to free ligand against fungal organisms. The increase in activity of these metal complexes may be attributed to the combined bioactive effect of metal and ligands present in the complexes and traces elements present in fungi species because of breaking peptide linkage due to their liposoluble nature. It is also noted that nitrogen donor ligand as well as their metal complexes are more active than their oxygen donor counterparts. In other words, complexes of the ligands derived *p*-hydroxybenzaldehyde have greater activity toward fungi. So that nitrogen atom, which coordinates to metal, increases the fungicidal activity of a complex.

The activity was highly marked in case of fungus, *Aspergillus niger*, the growth of which was completely inhibited even at 500 ppm, concentration in some compounds. At 250 ppm concentration, the inhibition of the growth was generally *ca.* 50 % and which increased with an increase in concentration. At 1000 ppm, the inhibition of growth was 90 % and in some complexes the growth was completely inhibited at 1000 ppm Co(II) complexes. The measured zone of inhibition against the growth of various microorganisms is listed in Table-4.

TABLE-4
ANTIFUNGAL DATA OF SCHIFF BASE AND ITS METAL COMPLEXES

Schiff base/ Metal(II) complexes	% Inhibition zone					
	Aspergillus niger			*Aspergillus flavus*		
	250 ppm	500 ppm	1000 ppm	250 ppm	500 ppm	1000 ppm
$C_{16}H_{17}N_3O_6$	28	41	53	14	35	48
$Mn(C_{16}H_{17}N_3O_6)_2Cl_2$	35	88	100	28	70	100
$Co(C_{16}H_{17}N_3O_6)_2Cl_2$	77	97	100	70	78	100
$Ni(C_{16}H_{17}N_3O_6)_2SO_4$	44	30	86	16	40	72
$Cu(C_{16}H_{17}N_3O_6)_2Cl_2$	58	85	90	55	80	100

Conclusion

The substituted Schiff bases of 4-hydroxybenzaldehydenyl-N-4'-cytidinylazomethine and their metal complexes of 4-hydroxybenzaldehydenyl-N-4'-cytidinylazomethine with Mn(II), Co(II), Ni(II) and Cu(II) are synthesized and characterized. The overall experimental evidences showed that the studied metal complexes, $Mn(C_{16}H_{17}N_3O_6)_2Cl_2$, $Co(C_{16}H_{17}N_3O_6)_2Cl_2$, $Ni(C_{16}H_{17}N_3O_6)_2SO_4$ and $Cu(C_{16}H_{17}N_3O_6)_2Cl_2$, display a coordination number six and have an octahedral environment around the metal ion. The complexes appear to be moderate antifungal agents.

REFERENCES

1. Y. Ikeuchi, S. Kimura, T. Numata, D. Nakamura, T. Yokogawa, T. Ogata, T. Wada and T. Suzuki, *Nat. Chem. Biol.*, **6**, 277 (2010).
2. M Orbe and A Claesson, *Eur. J. Med. Chem.*, **24**, 447 (1989).
3. I. Seong, *Korean J. Med. Mycol.*, **11**, 19 (2006).
4. M.A. Rojo, F.J. Arias, R. Iglesias, J.M. Ferreras, R. Munoz, C. Escarmis, F. Soriano, J. López-Fando, E. Mendez and T. Girbes, *Planta*, **194**, 328 (1994).
5. L.E. Moore, F.D. Boudinot and C.K. Chu, *Cancer Chemother. Pharmacol.*, **39**, 532 (1997).
6. N.R. Bachur, R. Johnson, F. Yu, R. Hickey, N. Applegren and L.X. Malkas, *Mol. Pharmacol.*, **44**, 1064 (1997).
7. P.W. Thompson, J.R. Kirwan, D.D. Jones and H.L. Currey, *Ann. Rheum. Dis.*, **47**, 308 (1988).
8. C. Brunner, J. Seiderer, A. Schlamp, M. Bidlingmaier, A. Eigler, W. Haimer, H.A. Lehr, A.M. Krieg, G. Hartmann and S. Endres, *J. Immunol.*, **165**, 6278 (2000).
9. J.J. Fox, N. Yung, I. Wempen and I.L. Doerr, *J. Am. Chem. Soc.*, **79**, 5060 (1957).
10. V.C. Dewey and G.W. Kidder, *Biochem. Pharmacol.*, **23**, 773 (1974).
11. V. Kumar, S. Singh, S. Sharma and A. Kumar, *Int. J. Drug Desig. Dis.*, **1**, 239 (2010).
12. E. Ispir, S. Toroglu and A. Karyaldiz, *Transition Met. Chem.*, **33**, 953 (2008).
13. K.Y. Lau, A. Mayr and K.K. Cheung, *Inorg. Chim. Acta*, **285**, 223 (1999).
14. C.T. Supuran, M. Barboiu, C. Luca, E. Pop, M.E. Brewster and A. Dinculescu, *Eur. J. Med. Chem.*, **31**, 597 (1996).

15. V.E. Kuzamin, A.G. Artemenko, R.N. Lozytska, A.S. Fedtchouk, V.P. Lozitsky, E.N. Muratov and E.N. Mescheriakov, *SAR QSAR Environ. Res.*, **16**, 219 (2005).

16. K.P. Sharma, V.S. Jolly and P. Phatak, *Ultra Scient. Phys. Sci.*, **10**, 263 (1998).

17. S. Singh, V. Kumar, S.K. Sharma, A. Kumar and S. Sharma, *Orient. J. Chem.*, **26**, 93 (2010).

18. K. Vashi and H.B. Naik, *Eur. J. Chem.*, **1**, 272 (2004).

19. M.E. Hossain, M.N. Allam, J. Begum, M.A. Akbar, M.N. Uddin, F.E. Smith and R.C. Hynes, *Inorg. Chim. Acta*, **249**, 207 (1996).

20. R. Mtrei, M. Yadawe and S.A. Patil, *Orient. J. Chem.*, **12**, 101 (1996).

21. M. Verma, S.N. Pandeya, K.N. Singh and J.P. Stables, *Acta Pharm.*, **54**, 49 (2004).

22. N. Sari, S. Arslan, E. Logoglu and L. Sakiyan, *G.U.J. Sci.*, **16**, 283 (2003).

23. P. Rathelot, N. Azas, H. El-Kashef, F. Delmas, C. Di Giorgio, P. Timon-David, J. Maldonado and P. Vanelle, *Eur. J. Med. Chem.*, **37**, 671 (2002).

24. Vogel's, A Text Book of Organic Chemistry, Longman's, edn. 4, p. 777 (1987).

25. A. Rabjohn and C. Horning, Organic Chemistry Collections, John Wiley & Sons, Vol. 3, p. 14 (1960).

26. A.W. Baur, W.M. Kirby, J.C. Sherris and M. Turk, *Am. J. Clin. Path.*, **45**, 493 (1966).

27. C.J. Alexopoulos and E.S. Beneke, Laboratory Manual for Introductory Mycology, Burgess Pub. Co, Minneapolis (1962).

28. K. Nonoyenna, S. Tomita and K.K. Yamaekas, *Inorg. Chim. Acta*, **12**, 33 (1975).

29. J.T. Makode and A. Aswar, *Indian J. Chem.*, **43A**, 2120 (2004).

30. M.D. Reily, K. Wilkowski, K. Shinozuka and L.G. Marzilli, *Inorg. Chem*, **24**, 37 (1985).

31. D. Camboli, J. Besancan, J. Tirouflet, B. Gautheron and P. Meunier *Inorg. Chim. Acta*, **78**, 51 (1983).

32. B.T. Khan, S.V. Kumari, K.M. Mohan and G.N. God, *Indian J. Chem.*, **31A**, 28 (1992).

33. K. Serbest, I. Digermencioglou, S. Karabocek and S.X. Guner, *Transition Met. Chem.*, **26**, 295 (1986).

34. A.C. Green, H. Place, R.D. Willett and J.I. Legg, *Inorg. Chem.*, **25**, 4672 (1986).

35. G. Percy, *Spectrochim. Acta*, **32A**, 1287 (1976).

36. W.W. Simmons, The Sadtler Handbook of Proton NMR Spectra, Sadtler Research Laboratories, Philadelphia, PA (1978).

37. K. Singh, M.S. Barwa and P. Tyagi, *Eur. J. Med. Chem.*, **41**, 147 (2006).

38. C.J. Ballhausen, An Introduction to Ligand Field Theory, McGraw Hill, New York (1962).

39. P.P. Dholakiya and M.N. Patel, *Synth. React. Inorg. Met.-Org. & Nano-Met. Chem.*, **32**, 819 (2002).

40. K.E.M. Saied, *Indian J. Chem.*, **33A**, 830 (1994).

41. D.P. Singh, R. Kumar, V. Malik and P. Tyagi, *Transition Met. Chem.*, **32**, 1051 (2007).