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**Synthesis, Characterization and Antimicrobial Studies on
Cu(II), Co(II), Ni(II), Zn(II), Cd(II) and Hg(II) Complexes with
Biologically Active Benzothiazole Schiff Bases**

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Abstract

Novel Schiff bases derived from 7-chloro-6-fluoro-2-aminobenzothiazole with substituted salicylaldehydes and its transition metal complexes of Cu(II), Co(II), Ni(II), Zn(II), Cd(II) and Hg(II) have been synthesized and characterized by elemental analysis, conductivity measurements, magnetic susceptibility, X-ray, electronic, IR, ¹HNMR, ESR spectra, Elemental analysis, TGA and DTA studies. These studies indicates the formation of 1:2 complexes of the type ML₂(H₂O)₂. The spectral results indicate that, the ligands coordinate through azo-methine nitrogen and phenolic oxygen to the metal ions. The study projects octahedral geometry for these complexes. X-ray powder diffraction studies of copper complexes reveal that, these form hexagonal or tetragonal structures. The antimicrobial activities of the ligands and their metal complexes have also been studied.

Key-Words: Schiff bases, Antimicrobial activity, Benzothiazoles

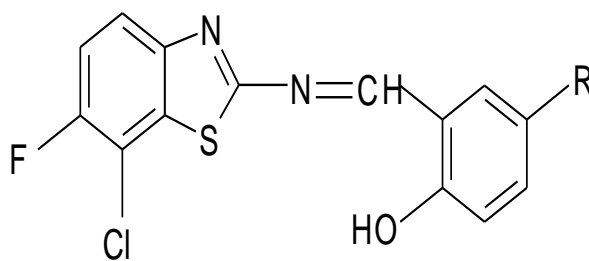
Introduction

Benzothiazoles and their derivatives are well known biologically active compounds. They possess CNS depressant¹, antiviral², anti-inflammatory³, antimicrobial⁴, antitubercular⁵, antiallergic⁶, anticonvulsant⁷, diuretic⁸, sedative⁹ and anticancer¹⁰ activities etc. In addition, benzothiazole forms an important pharmacophore in herbicidal¹¹ and insecticidal¹² agents. The azomethine of benzothiazole Schiff bases exhibits considerable biological importance¹³. The biological activity of these compounds may be connected to their ability to form complexes with certain metal ions which may lead to "locked geometry" via coordination mechanism so that, only certain substances are able to become attached to the frame work of this interaction¹⁴. Schiff base can be considered as a useful chelating agent when a suitable functional groups like -OH, -SH, -COOH etc., are present sufficiently close to azo-methine group so as to form five or six member chelate ring upon reaction with metal ion^{15,16}.

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By changing nature and position of the donor atoms and groups, it is possible to control the size of the chelate ring formed and exploit the effect of substitution. All these factors make Schiff bases good chelating agents and potential analytical reagents. As the biological activity is often augmented when the ligand forms the complexes, the resulting complex may be of potential biological importance¹⁷.



R	Ligand (L)
H	CFBIMP
CH ₃	CFBIMMP
Cl	CCFBIMP

Fig. (1); Substituted 2-amino-7-chloro-6 fluorobenzothiazole Schiff base.

Therefore, in this paper, we report the synthesis of highly stable six member chelate ring metal complexes of Cu(II), Co(II), Ni(II), Zn(II), Cd(II) and Hg(II) with benzothiazole Schiff bases derived from 2-amino-7-chloro-6-fluorobenzothiazole (Fig.1). These complexes were characterized by elemental, spectral, thermal and magneto-chemical studies. Preliminary antibacterial and antifungal activities of the ligands and their complexes have also been screened.

Material and Methods

IR spectra of the ligands and complexes were recorded in KBr matrix using Parkin Elmar 1000 FTIR spectrometer in the range of 4000 – 250 cm^{-1} . Electronic spectra of the complex in DMSO solution were recorded using Hitachi 150-20 model spectrophotometer in the range of 200-1100 nm. Magnetic susceptibility of the metal complexes were measured at a temperature of 25°C, using Guoy method. The ESR spectra of copper (II) complexes in polycrystalline state were recorded on Varian X – band ESR spectrometer. The proton magnetic resonance spectra of the few ligands and their complexes in CDCl_3 were recorded on a Bruker NMR spectrometer using TMS as internal standard. The X – ray data were recorded on Philips Pw 1050/70 X – ray machine attached with diffractogram using $\text{Cu K}\alpha$ radiation ($\lambda = 1.54178 \text{ \AA}$), Nickel filter at voltage of 30 KV and current strength of 15 mA.

Experimental

Substituted salicylaldehydes and 2-amino-7-chloro-6-fluorobenzothiazole were prepared as reported earlier^{18,19}.

Preparation of 2-Amino-7-Chloro-6-Fluorobenzothiazole Schiff Bases

2-Amino-7-chloro-6-fluorobenzothiazole and 5-substituted salicylaldehyde in 1:1 molar ratio in ethanolic medium were refluxed for about 5-6 hours in presence of catalytic amount of sulphuric acid. The reaction mixture was concentrated and cooled. The product separated is filtered and recrystallized from ethanol.

Synthesis of Metal Complexes

An ethanolic solution of the ligand (0.02 mol) and metal (II) chloride (0.01 mol) was refluxed on water bath for about three hours. About 1.0g of sodium acetate was added and the refluxation was continued for another hour. The reaction mixture was cooled and added to crushed ice. The complex was filtered, dried and purified by Soxhlet extraction with alcohol.

Results and Discussion

The analytical data and the conductance values are presented in Table-1. Elemental analysis confirms

formation of complexes of 1:2 stoichiometry with the empirical formula $\text{ML}_2(\text{H}_2\text{O})_2$.

The molar conductance values of all the complexes were measured in DMF at 10^{-3}M concentration. The values are too low to account for their electrolytic behavior. Hence, these complexes were regarded as non-electrolytes.

IR spectra Important IR frequencies of ligands, complexes and their assignments are given in Table-2. In the ligands, a high intensity band was observed in the region 1594-1572 cm^{-1} has been assigned to $\nu(\text{C}=\text{N})$ azo-methine vibrations in view of previous reports^{20, 21}. A medium intensity band in the region 1580-1528 cm^{-1} was observed in the complexes, this has been assigned to $\nu(\text{C}=\text{N})$ of azo-methine. The shifting of $\nu(\text{C}=\text{N})$ of azo-methine band to the lower frequency as compared to the ligands indicates the involvement of $\text{C}=\text{N}$ in coordination with metal atom^{20, 21}.

The band appearing in the region 2800-2731 cm^{-1} of the ligands disappears in the complexes indicating the deprotonation of phenolic –OH group with the formation of coordinated bond with the metal during complexation²². A band appears in the region 3527-3442 cm^{-1} indicates the presence of coordinated water in these complexes²². In addition to these, the new bands observed in the region 596-534 cm^{-1} and 470-440 cm^{-1} have been assigned to $\nu(\text{M}-\text{N})$ and $\nu(\text{M}-\text{O})$ vibrations respectively²⁰⁻²².

¹HNMR spectra

The NMR spectrum of the ligand CFBIMP exhibit a peak at δ 12.10 due to the phenolic OH integrating for one proton and multiplet in the region of δ 7.00 to 8.00 due to six aromatic protons and one $\text{N}=\text{CH}-\text{R}$ proton appeared at δ 9.25.

The disappearance of a singlet at δ 12.10 in the Zn(II) and Hg(II) complexes of CFBIMP can be attributed to the deprotonation of the phenolic OH upon complex formation²³.

Other characteristic peak due to azo-methine proton at δ 9.25 shows considerable downfield shift of δ 0.2 to 0.3 in the Zn(II) and Hg(II) complexes of CFBIMP, suggesting that coordination of azo-methine group with metal ions²³.

Magnetic measurements

The magnetic susceptibility measurements were used in combination with electronic spectral data to establish the structure of complexes. The effective magnetic moment (μ_{eff}) values observed at room temperature (300 K) for the complexes have been listed in Table-3.

The observed magnetic moment values for Co(II) complexes of CFBIMP, CFBIMMP and CCFBIMP fall in the range 4.58-4.65 BM which indicates

octahedral geometry for Co(II) complexes²⁴. These values lie in the range expected for μ_s and μ_{s+1} . This is due to the partial quenching of orbital contribution to the magnetic moment.

The magnetic moment values for Ni(II) complexes of ligands CFBIMP, CFBIMMP and CCFBIMP fall in the range 3.33-4.42 BM which are well within the range expected for octahedral geometry around the central metal ion²⁵⁻²⁶.

The observed magnetic moment values for Cu(II) complexes of ligands CFBIMP, CFBIMMP and CCFBIMP are 1.90, 1.75 and 1.86 B.M respectively. These magnetic moment data are agreeable to the spin only value for Cu(II) systems and the values suggest that there is no major coupling interaction in these complexes. Hence, observed magnetic moment for the Cu(II) complexes indicates distorted octahedral²⁷ configurations.

Electronic spectra

The electronic spectra of Co(II), Ni(II) and Cu(II) complexes were recorded in DMSO solution at 10^{-3} M concentration and are given in the Table-3.

In the present investigation, the electronic spectra of Co(II) complexes of ligands exhibited bands in the region 10416.66-10438.41 cm^{-1} , 17857.14-18115.94 cm^{-1} and 22988.50- 23640.66 cm^{-1} due to the ${}^4T_{1g}(F) \rightarrow {}^4T_{2g}(F) (v_1)$, ${}^4T_{1g}(F) \rightarrow {}^4A_{2g}(F) (v_2)$ and ${}^4T_{1g}(F) \rightarrow {}^4T_{1g}(P) (v_3)$ transitions respectively. These transitions suggest octahedral geometry for the Co(II) complexes. These assignments are in good agreement with the reported values²⁸⁻²⁹.

The electronic spectra of Ni(II) complexes of all the ligands exhibited three bands in the region 10869.56 – 11111.11 cm^{-1} , 15151.51 – 15408.32 cm^{-1} and 23809.52 – 24390.24 cm^{-1} respectively. . These bands are assigned ${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)(v_1)$, ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F) (v_2)$ and ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(P) (v_3)$ transitions respectively. All these observations favour octahedral geometry for Ni(II) complexes³⁰.

Cu(II) complexes of ligands showed broad band at 15873.01, 15974.44 and 16155.08 cm^{-1} respectively. The observed broad band in the case of present Cu(II) complex of ligands can be assigned to envelope of ${}^2B_{1g} \rightarrow {}^2E_g$, and ${}^2B_{1g} \rightarrow {}^2E_{2g}$ transitions in distorted octahedral geometry³⁰.

ESR spectra

In order to obtain more information about the magnetic environment of the Cu(II) complexes, powder samples were used to record X-band ESR spectra of the complexes at room temperature using DPPH as a reference standard. Copper(II) complexes measured in polycrystalline sample at room temperature, gave values: $g_{\parallel} = 2.06$, $g_{\perp} = 2.13$ for the

[Cu(CFBIMMP)₂2H₂O] and $g_{\parallel} = 2.03$, $g_{\perp} = 2.10$ for the [Cu(CFBIMP)₂2H₂O]. The trend, $g_{\parallel} < g_{\perp}$ showed that the electron is delocalized in d_z^2 orbital of the ground state of Cu(II) and the spectra are characteristic of axial (compressed octahedral) symmetry. The parameter G, determined as $G = (g_{\parallel} - 2) / (g_{\perp} - 2)$, is found to be much less than 4 suggesting considerable interaction in the solid state³¹.

X-ray studies

Powder XRD pattern for Cu(II) complexes of the ligands CFBIMMP and CFBIMP have been studied. The diffraction pattern for the Cu(II)CFBIMMP and Cu(II)CFBIMP complex showed 17 and 9 reflections in the range 0-40° (2 θ) arising from the diffraction of X-rays by planes of Cu(II) complexes. The inter-planar spacing 'd' has been calculated from the positions of intense peaks using the Bragg's relation $n\lambda = 2d \sin\theta$. The calculated inter planar spacing together with relative intensities with respect to most intense peaks are recorded in Table-4. The 2 θ values with maximum intensities of the peak for the complexes were found to be 6.360, 15.620 and 27.380 (2 θ), that correspond to $d = 13.8864$, 5.6686 and 3.2570 Å for Cu(II) complexes respectively. All the important peaks have been indexed and the observed values of inter planar distances have been compared with the calculated ones. It was observed that there is good agreement between the calculated and observed values.

The experimental values of $\sin^2\theta$ is common factor are recorded for each peak in the Table-4. The $((h^2+k^2+l^2))$ values obtained were 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, etc., in all the complexes. The presence of forbidden numbers 7, 15 indicated that compounds may belong to hexagonal or tetragonal system³²

Thermal analysis

TGA and DTA studies of few selected Cu(II) complexes have been studied and the results are summarized as follows:

TGA analysis of Cu(CFBIMP)₂H₂O indicates first stage decomposition is observed in the range 141-184 °C and the weight loss corresponds to 4.9% (calculated 5.1%) which attributes decomposition of two molecules of water from the complex. The second stage decomposition occurs in the temperature range 500-600°C and the weight loss observed is 51.7% against 52.2% (calculated) due to the decomposition of L(H₂O)₂. At temperature higher than 1000 °C, the weight loss corresponds to 88.8% (calculated 88.9%) due to decomposition of ligand moiety with the formation of copper oxide.

On the basis of elemental analysis, infrared, electronic, ESR, XRD and thermal studies reveals the following structure for these complexes.

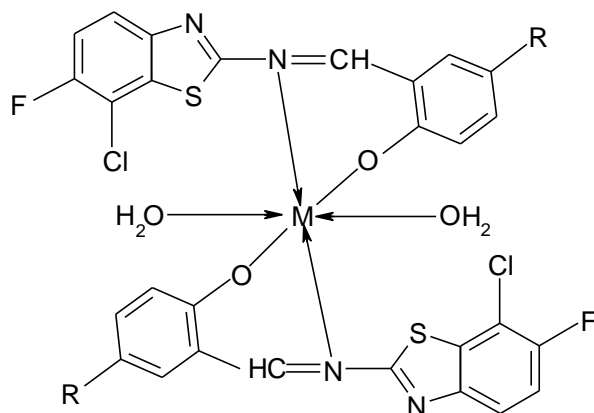


Fig (2): Metal complexes of Substituted 2-amino-7chloro-6-fluorobenzothiazole Schiff base.
Where M= Cu(II), Co(II), Ni(II), Zn(II), Cd(II) and Hg(II) and R= H, CH₃, Cl

Antimicrobial activity

Antimicrobial activity was carried out by the Cup-plate method²². The ligands and their Cu(II), Co(II), Ni(II), Zn(II), Cd(II) and Hg(II) complexes have tested for their antibacterial and antifungal activities. The antibacterial and antifungal results of the ligands and its complexes were tabulated in Table-5.

All the ligands have shown moderate to good activity against the bacteria, *E. coli* & *S. aureus* and fungi *A.niger* and *F.oxysporum* respectively.

The Cu(II), Co(II), Zn(II) and Mn(II) complexes of all the ligands synthesized have shown moderate to good activity against the pathogenic bacteria, whereas, the Cu(II) and Ni(II) complexes have displayed moderate to good activity against the tested fungi *A.niger* and *F. oxysporum*. Especially, Zn(II), Cd(II) and Hg(II) complexes of the ligands have shown very good activity against the fungi *A.niger* and *F. oxysporum*. The Co(II), Zn(II), Cd(II) and Hg(II) complexes of the ligands showed good activity against *E. coli* & *S. aureus*. This enhanced activity of the complexes compared to that of ligands can be attributed to the presence of metal ions and stereo chemical configurations in the molecule.

Conclusion

Condensation of 2-amino-7-chloro-6-fluoro benzothiazole and 5-substituted salicylaldehyde have yielded a new Schiff bases having potential binding sites towards metal ions to form six member chelates. Schiff base acts as bidentate ligand by coordinating

through azomethine nitrogen and phenolic oxygen. It forms octahedral complexes with Cu(II), Co(II), Ni(II), Zn(II), Cd(II) and Hg(II) ions. Thermal studies support the presence of coordinated water in these complexes.

References

1. Liozzo, A. and Longo, V. G., *Physiology and Behavior*, **3**, 1968, 91.
2. Stig Akerfeldt, *J. Med. Chem.* **13**, 1970, 1012.
3. Wada, J.; Suzuki, T.; Iwasaki, M. and Miyamatsu, H. Ueno, S. and Shimizu, M., *J. Med. Chem.* **16**, 1973, 930.
4. Russo, F. and Santagati, M., *Farmaco [Sci]*, **31(1)**, 1976, 41.
5. Mikulasek, S.; Sutoris, V.; Odlerova, Z.; Perjessy, A. and Konecny, V., *Chem. Zvest*, **33(4)**, 1979, 550; *Chem Abstr.* **93**, 1980, 8071q.
6. Wade, J. J.; Toso, C. B.; Matson, C. J. and Stelzer, V. L. *J. Med. Chem.*, **26(4)**, 1983, 608.
7. Mizoule, J.; Meldrum, B., Mazadier, M.; Croucher, M.; Ollat, C.; Uzan, A.; Legrand, J. J.; Gueremy, C. and Le Fur, G., *Neuropharmacology*, **24**, 1985, 767.
8. Lu, D. W.; Chiang, C. H.; Kao, K. D. and Y Wen, L., *J. Ocul. Pharmacol.* **6(4)**, 1990, 271.
9. Trapani, G.; Carotti, A.; Franco, M.; Latrofa, A.; Genchi, G. and Liso, G., *Eur. J. Med. Chem.* **28**, 1993, 13.
10. Bradshaw, T. D.; Wringley, S.; Shi D. F.; Schuitz, R. J.; Paull, K. D. and Stevens M. F G., *Br. J. Cancer*, **77**, 1998, 745.
11. Seybold, G. and Wuerzer, B. *Ger Pat Offen*, **3**, 1983, 727.
12. Sawada, Y.; Yanai, T.; Nakagawa, H.; Tsukamoto, Y.; Yokoi, S.; Yanagi, M.; Toya, T.; Sugizaki, H.; Kato, Y.; Shirakura, H.; Watanabe, T.; Yajima, Y.; Kodama, S. and Masui, A., *Pest. Manag. Sci.* **59(1)**, 2003, 25
13. Dey, A. K., *Ind. Res.* **33**, 1974.
14. Williams, D.R., *Metals, Ligands and Cancer. Chem Rev*, **72(3)**, 1972, 203.
15. Lindoy, L. F., *Quart. Rev.* **25B**, 1971, 379.
16. Castonoga, J.; Vergas, J.; Lathorre, R. and Nena, G. *Coord. Chem. Rev.* **119**, 1992, 67.
17. Maurya, R.C.; Sharma, P and Sutradhar, D., *Synth. React. Inorg. Met-Org. Chem.* **33(3)**, 2003, 387.
18. Duff, J. C. *J. Chem. Soc.*, 1941, 547.
19. Gurupadaiah, B. M.; Jayachandran, E.; Shiva Kumar, B.; Nagappa, A. N. and Nargund, L.

- V. G. , *Indian Journal of Heterocyclic Chemistry*, **7**, 1998, 213.
20. Biradar N. S. and Kulkarni, V. H. , *J. Inorg. Nucl. Chem.* **33**, 1971, 2451.
21. T.Suresh , D.Nagesh shastry, M. Revanasiddappa and suresh, *J.Ind.Chem.Soc.*, Vol.**83**, pp-1 to 3, **2006**.
22. Suresh, Srinivas, P.; Suresh, T.; Revanasiddappa, M. and Syed Khasim, *E. J. Chem*, **5**, 2008, 627.
23. Fazlur Rahaman,; Basavaraj Hiremath,; Basavarajaiiah, S. M.; Jayakumarwamy, B. H. M. and Mruthyunjayaswamy, B. H. M. *J. Indian Chem. Soc.* **85**, 2008, 1.
24. Sinan Saydam, *Synth. React. Inorg. Met-Org. Chem.* **32(3)**, 2002, 433.
25. Raman, N.; Kulandaisamy, A. and Jeyasubramanian, K. , *J. Indian Chem.Soc.*,**41A**, 2000, 942 .
26. Patel, K. M.; Patel, N. H.; Patel, K. N. and Patel, M. N., *J. Indian Council Chem.* **17**, 2000, 19.
27. Carlin, R. L., *Trans. Met. Chem.* **5**, 1969, 1.
28. Biradar, N. S and Havinale, B. R., *Inorg. Chim. Acta.* **17**, 1979, 157.
29. Lakshmi, R. A. Rai, *J. Inorg. Nucl. Chem.* **42**, 1984, 450.
30. Satpathy, K. C.; Jal, B. B. and Mishra, R., *Trans. Met. Chem*, **9**, 1984, 8.
31. Lever, A. B. P. , “*Inorganic Electronic Spectroscopy*”, Elsevier, Amsterdam, 1984
32. Hathway. B.T., *Struct. Bonding*, **14**, 1973, 60.
33. Cullity, B.D., “*Elements of X-ray Diffraction*”, Wesley Publishing Co. INC England, 1959.

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Table 1: Elemental Analysis, Color, Melting Point and Conductance Data for Ligands and Metal Complexes

S.N.	Ligand / complex	Mol.Wt.	Analysis % Found (Calculated)					M.P °C	Color	Molar Conductance $\Omega^{-1}\text{Cm}^2\text{Mol}^{-2}$
			C	H	N	S	M			
01	$\text{C}_{14}\text{H}_8\text{N}_2\text{OSFCI}$ (CFBIMP)	306.50	54.38 (54.81)	2.59 (2.61)	9.16 (9.13)	10.40 (10.44)	-	175	Pale yellow	10
02	$\text{C}_{15}\text{H}_{10}\text{N}_2\text{OSFCI}$ (CFBIMMP)	320.50	56.08 (56.16)	3.07 (3.12)	8.80 (8.73)	9.96 (9.98)	-	204	Yellow	13
03	$\text{C}_{14}\text{H}_7\text{N}_2\text{OSFCI}_2$ (CCFBIMP)	341.00	49.27 (49.20)	1.99 (2.05)	8.23 (8.21)	9.40 (9.38)	-	165	Yellow	11
04	$[\text{Co}(\text{CFBIMP})_2(\text{H}_2\text{O})_2]$	703.93	47.75 (47.73)	2.22 (2.27)	7.98 (7.95)	9.07 (9.09)	8.43 (8.37)	215	Dark brown	17
05	$[\text{Co}(\text{CFBIMMP})_2(\text{H}_2\text{O})_2]$	731.93	49.13 (49.18)	2.16 (2.18)	7.69 (7.65)	8.77 (8.74)	7.97 (8.05)	222	Dark brown	29
06	$[\text{Co}(\text{CCFBIMP})_2(\text{H}_2\text{O})_2]$	772.93	43.48 (43.47)	1.80 (1.81)	7.29 (7.24)	8.30 (8.28)	7.74 (7.62)	235	Brown	24
07	$[\text{Ni}(\text{CFBIMP})_2(\text{H}_2\text{O})_2]$	703.69	47.77 (47.74)	2.32 (2.27)	7.90 (7.95)	9.06 (9.09)	8.59 (8.34)	200	Pale green	41
08	$[\text{Ni}(\text{CFBIMMP})_2(\text{H}_2\text{O})_2]$	731.69	49.13 (49.20)	2.78 (2.73)	7.60 (7.65)	8.76 (8.74)	7.99 (8.02)	220	Pale yellow	26
09	$[\text{Ni}(\text{CCFBIMP})_2(\text{H}_2\text{O})_2]$	772.69	43.53 (43.48)	1.78 (1.81)	7.19 (7.24)	8.25 (8.28)	(7.55) (7.59)	>300	Pale green	37
10	$[\text{Cu}(\text{CFBIMP})_2(\text{H}_2\text{O})_2]$	708.54	47.48 (47.42)	2.20 (2.25)	8.02 (7.90)	9.05 (9.03)	9.05 (8.96)	280	Brown	18
11	$[\text{Cu}(\text{CFBIMMP})_2(\text{H}_2\text{O})_2]$	736.54	48.90 (48.87)	2.76 (2.71)	7.63 (7.60)	8.65 (8.68)	8.56 (8.62)	205	Brown	35
12	$[\text{Cu}(\text{CCFBIMP})_2(\text{H}_2\text{O})_2]$	777.54	43.16 (43.21)	1.80 (1.80)	7.28 (7.20)	8.28 (8.23)	8.30 (8.17)	250	Brown	23
13	$[\text{Zn}(\text{CFBIMP})_2(\text{H}_2\text{O})_2]$	710.39	47.31 (47.29)	2.22 (2.25)	7.90 (7.88)	9.04 (9.00)	9.29 (9.20)	210	Yellow	37
14	$[\text{Zn}(\text{CFBIMMP})_2(\text{H}_2\text{O})_2]$	738.39	48.79 (48.75)	2.73 (2.70)	7.69 (7.58)	8.61 (8.66)	9.01 (8.85)	216	Yellow	19
15	$[\text{Zn}(\text{CCFBIMP})_2(\text{H}_2\text{O})_2]$	779.39	43.20 (43.11)	1.80 (1.79)	7.13 (7.18)	8.24 (8.21)	8.44 (8.38)	225	Yellow	26
16	$[\text{Cd}(\text{CFBIMP})_2(\text{H}_2\text{O})_2]$	757.41	44.32	2.07	7.40	8.40	14.92	215	Pale yellow	15

17	[Cd(CFBIMMP) ₂ (H ₂ O) ₂]	785.41	(44.36) 45.88 (45.83)	(2.11) 2.58 (2.54)	(7.39) 7.19 (7.13)	(8.44) 8.17 (8.14)	(14.84) 14.37 (14.31)	216	Pale yellow	32
18	[Cd(CCFBIMP) ₂ (H ₂ O) ₂]	826.41	(40.65) 40.59 (40.65)	(1.69) 1.70 (1.69)	(6.77) 6.80 (6.77)	(7.74) 7.70 (7.74)	(13.60) 13.79 (13.60)	252	Pale yellow	33
19	[Hg(CFBIMP) ₂ (H ₂ O) ₂]	845.59	(39.73) 39.75 (39.73)	(1.89) 1.93 (1.89)	(6.62) 6.55 (6.62)	(7.56) 7.51 (7.56)	(23.72) 23.86 (23.72)	235	White	17
20	[Hg(CFBIMMP) ₂ (H ₂ O) ₂]	873.59	(41.20) 41.25 (41.20)	(2.28) 2.31 (2.28)	(6.41) 6.44 (6.41)	(7.32) 7.37 (7.32)	(22.96) 23.08 (22.96)	209	Gray	21
21	[Hg(CCFBIMP) ₂ (H ₂ O) ₂]	914.59	(36.73) 36.67 (36.73)	(1.53) 1.59 (1.53)	(6.12) 6.09 (6.12)	(6.99) 7.04 (6.99)	(21.93) 22.08 (21.93)	242	White	31

Table 2: Important IR Frequencies of Ligands, Complexes and Their Assignments

S.N.	Ligand/ Complex	H-bonded -OH	v(H ₂ O)	v (C-O)	v (C=N) in thiazole	v (C=N) in azomethine	v(C-S-C)	v(M- H ₂ O)	v(M-N)	v(M-O)
01	C ₁₄ H ₈ N ₂ OSFCI (CFBIMP)	2735	-	1287	1612	1572	730	-	-	-
02	C ₁₅ H ₁₀ N ₂ OSFCI (CFBIMMP)	2800	-	1290	1663	1582	694	-	-	-
03	C ₁₄ H ₇ N ₂ OSFCI ₂ (CCFBIMP)	2731	-	1297	1660	1594	723	-	-	-
04	[Co(CFBIMP) ₂ (H ₂ O) ₂]	-	3442	1307	1664	1558	731	846	596	462
05	[Co(CFBIMMP) ₂ (H ₂ O) ₂]	-	3481	1327	1663	1558	692	837	558	442
06	[Co(CCFBIMP) ₂ (H ₂ O) ₂]	-	3470	1307	1660	1558	724	846	596	452
07	[Ni(CFBIMP) ₂ (H ₂ O) ₂]	-	3477	1306	1616	1528	735	833	556	450
08	[Ni(CFBIMMP) ₂ (H ₂ O) ₂]	-	3481	1327	1664	1558	692	808	587	449
09	[Ni(CCFBIMP) ₂ (H ₂ O) ₂]	-	3495	1306	1667	1550	722	833	550	449
10	[Cu(CFBIMP) ₂ (H ₂ O) ₂]	-	3480	1308	1615	1539	731	826	590	442
11	[Cu(CFBIMMP) ₂ (H ₂ O) ₂]	-	3480	1320	1660	1540	680	850	563	440
12	[Cu(CCFBIMP) ₂ (H ₂ O) ₂]	-	3490	1320	1660	1540	720	840	536	470
13	[Zn(CFBIMP) ₂ (H ₂ O) ₂]	-	3480	1320	1619	1550	730	800	540	445
14	[Zn(CFBIMMP) ₂ (H ₂ O) ₂]	-	3451	1346	1663	1538	692	842	588	457
15	[Zn(CCFBIMP) ₂ (H ₂ O) ₂]	-	3480	1320	1665	1580	720	800	540	440
16	[Cd(CFBIMP) ₂ (H ₂ O) ₂]	-	3527	1311	1615	1568	730	858	596	460
17	[Cd(CFBIMMP) ₂ (H ₂ O) ₂]	-	3460	1307	1615	1558	731	846	570	458

18	[Cd(CCFBIMP) ₂ (H ₂ O) ₂]	-	3460	1311	1659	1568	721	858	534	460
19	[Hg(CFBIMP) ₂ (H ₂ O) ₂]	-	3486	1327	1615	1558	731	857	595	442
20	[Hg(CFBIMMP) ₂ (H ₂ O) ₂]	-	3463	1333	1663	1546	685	870	565	448
21	[Hg(CCFBIMP) ₂ (H ₂ O) ₂]	-	3460	1333	1662	1546	723	870	565	446

Table 3: Electronic Spectra and Magnetic Susceptibility Measurements Data

S.N.	Name of the complex	Bands in cm ⁻¹	Electronic spectral assignments	Magnetic moment (μ _{eff} B.M)
01	[Co(CFBIMP) ₂ (H ₂ O) ₂]	23255.81 17857.14 10416.66	⁴ T _{1g} (F) → ⁴ T _{2g} (F) ⁴ T _{1g} (F) → ⁴ A _{2g} (F) ⁴ T _{1g} (F) → ⁴ T _{1g} (P)	4.65
02	[Co(CFBIMMP) ₂ (H ₂ O) ₂]	23640.66 18115.94 10438.41	⁴ T _{1g} (F) → ⁴ T _{2g} (F) ⁴ T _{1g} (F) → ⁴ A _{2g} (F) ⁴ T _{1g} (F) → ⁴ T _{1g} (P)	4.88
03	[Co(CCFBIMP) ₂ (H ₂ O) ₂]	22988.50 17667.84 10341.26	⁴ T _{1g} (F) → ⁴ T _{2g} (F) ⁴ T _{1g} (F) → ⁴ A _{2g} (F) ⁴ T _{1g} (F) → ⁴ T _{1g} (P)	4.58
04	[Ni(CFBIMP) ₂ (H ₂ O) ₂]	24096.38 15384.61 10869.56	⁴ T _{1g} (F) → ⁴ T _{2g} (F) ⁴ T _{1g} (F) → ⁴ A _{2g} (F) ⁴ T _{1g} (F) → ⁴ T _{1g} (P)	4.42
05	[Ni(CFBIMMP) ₂ (H ₂ O) ₂]	23809.52 15151.51 11111.11	³ A _{2g} (F) → ³ T _{2g} (F) ³ A _{2g} (P) → ³ T _{1g} (F) ³ A _{2g} (F) → ³ T _{1g} (P)	3.33
06	[Ni(CCFBIMP) ₂ (H ₂ O) ₂]	24390.24 15408.32	³ A _{2g} (F) → ³ T _{2g} (F) ³ A _{2g} (P) → ³ T _{1g} (F) ³ A _{2g} (F) → ³ T _{1g} (P)	3.36

		10917.03		
07	[Cu(CFBIMP) ₂ (H ₂ O) ₂]	23809.52 15974.44	² B _{1g} → ² B _{2g} ² B _{1g} → ² E _{2g}	1.90
08	[Cu(CFBIMMP) ₂ (H ₂ O) ₂]	24390.24 15873.01	² B _{1g} → ² B _{2g} ² B _{1g} → ² E _{2g}	1.75
09	[Cu(CCFBIMP) ₂ (H ₂ O) ₂]	24038.46 16155.08	² B _{1g} → ² B _{2g} ² B _{1g} → ² E _{2g}	1.86

Table 4: Powder XRD Data of Complex

Complex	Peak No.	2θ	θ	Sinθ	Sin ² θ	h k l	d observed
[Cu (CFBIMMP) ₂ (H ₂ O) ₂]	1	6.360	3.18	0.04993	0.00249	200	13.8864
	2	11.402	5.701	0.089431	0.00799	211	7.7539
	3	14.319	7.1595	0.112242	0.01259	220	6.1803
	4	15.620	7.81	0.122371	0.01497	300	5.6686
	5	16.821	8.4105	0.131727	0.01735	311	5.2663
	6	23.960	11.69	0.182595	0.03334	222	3.7110
	7	27.380	13.69	0.213388	0.04553	321	3.2570
	8	31.081	15.5405	0.241692	0.05841	420	2.8272
[Cu (CFBIMP) ₂ (H ₂ O) ₂]	1	5.802	2.901	0.04555	0.0020750	(100)	12.659
	2	15.586	7.793	0.12210	0.014910	(111)	7.551
	3	15.640	7.82	0.12252	0.015013	(200)	6.357
	4	22.522	11.261	0.17596	0.030964	(210)	5.666
	6	24.039	12.0195	0.18768	0.035224	(300, 221)	4.243
	7	24.961	12.4805	0.194789	0.037943	(310)	3.958

	8	27.161	13.585	0.211707	0.044820	(400)	3.189
	9	27.420	13.71	0.21369	0.045665	(410, 322)	3.081
	10	30.180	15.09	0.234819	0.055140	(420)	2.824

Table 5: Antibacterial and Antifungal Activity Results of Ligands and Metal Complexes

S.N.	Ligand/Complex	Antibacterial activity (in mm)		Antifungal activity (in mm)	
		<i>E. coli</i>	<i>S. aureus</i>	<i>A. niger</i>	<i>F. oxysporum</i>
01	C ₁₄ H ₈ N ₂ OSFCI (CFBIMP)	11	11	17	17
02	C ₁₅ H ₁₀ N ₂ OSFCI (CFBIMMP)	13	14	16	18
03	C ₁₄ H ₇ N ₂ OSFCI ₂ (CCFBIMP)	13	15	17	16
04	[Co(CFBIMP) ₂ (H ₂ O) ₂]	16	15	14	19
05	[Co(CFBIMMP) ₂ (H ₂ O) ₂]	15	16	18	20
06	[Co(CCFBIMP) ₂ (H ₂ O) ₂]	16	14	12	16
07	[Ni(CFBIMP) ₂ (H ₂ O) ₂]	18	15	19	14
08	[Ni(CFBIMMP) ₂ (H ₂ O) ₂]	14	15	12	15
09	[Ni(CCFBIMP) ₂ (H ₂ O) ₂]	16	17	16	18
10	[Cu(CFBIMP) ₂ (H ₂ O) ₂]	13	12	13	13
11	[Cu(CFBIMMP) ₂ (H ₂ O) ₂]	17	11	14	12
12	[Cu(CCFBIMP) ₂ (H ₂ O) ₂]	12	11	15	14
13	[Zn(CFBIMP) ₂ (H ₂ O) ₂]	15	17	17	19
14	[Zn(CFBIMMP) ₂ (H ₂ O) ₂]	16	17	16	17
15	[Zn(CCFBIMP) ₂ (H ₂ O) ₂]	14	18	15	15
16	[Cd(CFBIMP) ₂ (H ₂ O) ₂]	17	19	13	18
17	[Cd(CFBIMMP) ₂ (H ₂ O) ₂]	19	20	14	15
18	[Cd(CCFBIMP) ₂ (H ₂ O) ₂]	20	20	16	18
19	[Hg(CFBIMP) ₂ (H ₂ O) ₂]	17	18	18	17
20	[Hg(CFBIMMP) ₂ (H ₂ O) ₂]	19	20	19	21
21	[Hg(CCFBIMP) ₂ (H ₂ O) ₂]	21	20	20	19
	Ciproflaxacin (Standard)	24	22	-	-
	Grisofulvin (Standard)	-	-	24	23
	DMF(Control)	0	0	0	0

