

Ni(II), Zn(II) TERNARY METAL COMPLEXES: SYNTHESIS, CHARACTERISATION AND ANTI BACTERIAL ACTIVITY

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ABSTRACT: Two novel and air stable ternary Ni(II) and Zn(II) metal complexes namely $[\text{Ni}(\text{L}_1)(\text{L}_2)\text{H}_2\text{O}]$ (1) $[\text{Zn}(\text{L}_1)(\text{L}_2)\text{H}_2\text{O}]$ (2) where $\text{L}_1=2,6\text{-bis}(\text{benzimidazole-2-yl})\text{pyridine}$ (BBP) and $\text{L}_2= \text{Oxalate ion}(\text{AA})$ were synthesized and characterized by elemental analysis, molar conductance, magnetic susceptibility measurements, TGA, DTA studies, HRMS, IR, electronic spectra, SEM-EDX, powder XRD studies. Based on elemental analysis, electronic spectra, conductance and magnetic moment measurements, six coordinated geometries were assigned to all the four metal complexes. Both the complexes are non electrolytic in nature. Powder XRD studies proved that the complexes were in nano crystalline phase. Antibacterial activity of metal complexes was checked against 3 gram positive (MRSA, B.cereus, B.subtilis) and 3 gram negative bacterial pathogens (P.aeruginosa, E.coli, P.vulgaris). Both the metal complexes inhibited the growth of bacterial strains and exhibited highest zone of inhibition against P.aeruginosa at $100\mu\text{g/mL}$.

Keywords: Anti bacterial activity; benzimidazole; nano crystalline phase; ternary metal complex.

I. INTRODUCTION

Importance of metal complexes in coordination chemistry is enhancing continuously due to the synthesis of organic ligands containing variety of donor groups^{1,2} and it is multiplied many times when they have biological activity.^{3,4} Benzimidazoles are involved in a greater variety of biological processes. Substitution of benzimidazoles at 1, and 5 positions are interesting for their pharmacological effect.⁵ Benzimidazole and its derivatives are well known for their antibacterial⁶ antifungal, anti tumor, anti inflammatory⁷, antiviral⁸ anti convulsant⁹ anti cancer¹⁰ and anti malarial activities. Bis benzimidazole derivatives are still less developed¹¹. They are aromatic N donor organic linkers and have strong coordination activity. Hence we decided to synthesise 1:1:1 ternary metal chelates of 2,6 – bis(benzimidazol-2-yl) pyridine and Oxalic acid ligands. So the present communication comprises the synthesis, characterization and biological studies of ternary metal chelates containing N and O donors with Ni(II) and Zn(II) metal acetates.

2. MATERIALS AND METHODS

All the chemicals and solvents were of AR grade and were used as received without further purification. 2,6– pyridine dicarboxylic acid, O-phenylene diamine, Poly phosphoric Acid and Oxalic Acid were purchased from Sigma–Aldrich chemicals. All the experiments involving with the interaction of the ligand and complexes were dissolved in solvents ethanol, methanol, acetone DMSO and DMF. The C, H, and N percentage composition of complexes and ligand BBP were determined using micro analytical methods on Perkin Elmer 240C (USA) elemental analyzer. FT-IR spectra of the ligand and its complexes were recorded by using KBr pellets in the range $4000\text{--}400\text{ cm}^{-1}$ using FT-IR spectrometer. Magnetic moment measurements were carried out on a Guoy balance model 7550 using $\text{Hg}[\text{Co}(\text{NCS})_4]$ as standard. The electronic spectra of the primary ligand (BBP) and its metal complexes were carried out in DMSO using Elico SL159 spectrophotometer. The mass spectra of the compounds were recorded by the ESI technique on VG AUTOSPEC mass spectrometer. The conductivity measurements were carried out in DMSO (10^{-3}M) using Digisun Electronic Digital conductivity meter, 0.01 M KCl solution is used for calibration. ESR spectra of metal complexes were recorded on JEOL JES-FA200ESR spectrometer (X-band microwave unit). Scanning electron microscopy (SEM) and EDS was obtained for complexes using Tescan Vega-3 LMU electron microscope. The X-ray powder diffraction analysis was carried out by PAN Analytical X'pert Powder X-ray diffractometer with $\text{Cu K}\alpha$ radiation. The powder x- ray diffraction data was analysed using Match program.

2.1: Synthesis of ligand and metal complexes:

The primary ligand BBP was prepared according to the procedure already reported¹².

2.2: Synthesis of 1:1:1 Complexes 1,2,3, and 4: The ternary metal complexes 1,2, were synthesized by treating the hot ethanolic solution of acetates of Ni(II) (0.177gm,1mM) and Zn(II) (0.219gm,1mM) with warm ethanolic solution of primary ligand (BBP) (0.312 gm, 1mM) and the mixture was refluxed for 2 h . To this hot ethanolic solution of Oxalic Acid (0.126 gm, 1 mM) was added and refluxed at refluxing temperature for 3 h. The resulting products were filtered, washed with warm water, ethanol and finally with acetone and then evaporated in vacuum over anhydrous CaCl₂. The color of the Co complex was brown, Cu complex was green , Ni and Zn complexes were dull white. The purity of the metal complexes was checked by TLC and their yield was in between 65-70%.

2.3: Complex-1 Analytical data:

[Ni(BBP)(AA)H₂O]: C₂₁H₁₅N₅O₅Ni: Cal: C 52.98, H 3.18, N 14.71; found: C 52.45, H 3.57, N 14.24%. Molar conductance (10⁻³M DMF)21 Scm²mol⁻¹ μ_{eff} : 3.3 BM; UV-Vis (nm): 256, 275,314, 490,530,605 ,835 ESI-MS:476 [Ni(BBP)(AA)H₂O]

2.4: Complex-2 Analytical data:

[Zn(BBP)(AA)H₂O] C₂₁H₁₅O₅N₅Zn: Cal: C 52.25, H 3.13, N 14.51; found: C 52.46, H 3.50, N 14.12 %. Molar conductance (10⁻³M DMF) 10 Scm²mol⁻¹, μ_{eff} : 0.0 BM; UV-Vis (nm): 249,255, 277,330 (Fig.1) ESI-MS:482.5 [Zn(BBP)(AA)H₂O]

3. RESULTS AND DISCUSSION**3.1: Characterization by TGA/DTA:**

The thermo gravimetric analysis (TGA) and differential thermal analysis (DTA) of all the four complexes were carried out at temperature ranges from 27 to 800°C by using alumina as reference compound. A small weight loss in the temperature range of 160–220 °C for both the complexes indicates the loss of coordinated water molecule from the complex. The weight loss in the ranges of 200–600 °C is attributed to the decomposition of complexes.

3.2: Infra red spectral characterization:

in the ir spectrum of primary ligand (bbp) the peak observed in the range of 2985 to 3150 cm⁻¹ is assigned to $\nu_{\text{(N-H)}}$ stretching frequency, the band at 1573 cm⁻¹ is assigned to $\nu_{\text{(C=N)}}$ of the imidazole moiety¹³ and a peak at 1456 cm⁻¹ is assigned to $\nu_{\text{(N-H)}}$ bending frequencies. In the IR spectra of complexes 1458 cm⁻¹ is assigned for $\nu_{\text{(N-H)}}$ bending frequency of the imidazole moiety¹⁴ and a peak at 1610-1612 cm⁻¹ is assigned to $\nu_{\text{(C=N)}}$ stretching frequencies. In the complexes $\nu_{\text{(N-H)}}$ peak is replaced by a new absorption in the region 3047–3154 cm⁻¹, confirming the coordination of the metal ions through N-atom of the imidazole ring (Table 1.0). In the complexes a new broad band in the region of 3300–3400 cm⁻¹ is attributed to the $\nu_{\text{(O-H)}}$ of the coordinated H₂O to the metal ion. The IR spectra of the complexes also showed, shifted imidazole in plane resonance at 997–1024 cm⁻¹, pointing to further coordination of imidazole N atom to the metal. The Stretching and bending frequency $\nu_{\text{(N-H)}}$ remain unchanged in these suggested that NH nitrogen of the imidazole moiety was not involved in coordination. In the far IR spectra of the complexes reveals $\nu_{\text{(M-N)}}$ stretching vibrations in the region 424–428 cm⁻¹, $\nu_{\text{(M-O)}}$ stretching vibrations in the region of 580–586 cm⁻¹(Fig.2)

Table 1.0 FT-IR spectral studies of BBP and Ni(II), Zn(II) complexes.

Compound	ν_{OH}	$\nu_{\text{N-H}}$	$\nu_{\text{C-H}}$	$\nu_{\text{C=C}}$	$\nu_{\text{C=N}}$	$\nu_{\text{M-N}}$	ν_{MO}
BBP	-	3147	3080	1492	1635	-	-
Complex1	3361	3154	3048	1456	1610	424	580
Complex2	3381	3097	3064	1458	1612	428	586

3.3: Electronic , mass spectra and magnetic moment:

The electronic absorption studies are always very useful in the evaluation of results furnished by other methods of structural investigation. They provide quick and reliable information regarding the geometry of metal complexes based on the position and number of d-d transition peaks. The electronic absorption spectra of the BBP and its metal complexes were recorded at room temperature using DMSO as solvent. Ni(II) complex showed absorption bands in region of 490, 530,605 and 835 indicated that it has octahedral geometry.^{15,16} The Zn Complex was also assigned octahedral geometry from its infra red, absorption spectra and conductivity measurements. The strong bands in the UV region 300 nm to 400 nm are assigned to metal to ligand charge transfer (MLCT) transitions ¹⁷ . The ESI-Mass spectra of the complexes 1, 2 gave peaks at m/z: 482.5, 476.7 . The magnetic moment (μ_{eff}) values(Table 2.) of the complex 1 was in the range of 3.3-3.5 BM at room temperature, which is expected range for octahedral ¹⁸ nickel complex. Zn(II) complex has zero magnetic moment indicates its diamagnetic nature. These values indicate that the complexes are monomeric in nature (Table.2).

Table. 2 Some physical characteristics of the metal complexes 1-2

S.No.	Metal complex	Molecular formula (M weight)	Colour	Yield (%)	($\Omega^{-1}\text{cm}^2\text{mol}^{-1}$)	μ_{eff} (BM)
(2)	[Ni(BBP)(AA)H ₂ O]	NiC ₂₁ H ₁₅ N ₅ O (476.7)	Light yellow	65	10	3.3
(4)	[Zn(BBP)(AA)H ₂ O]	ZnC ₂₁ H ₁₅ N ₅ O ₅ (482.5)	White	70	21	0.0

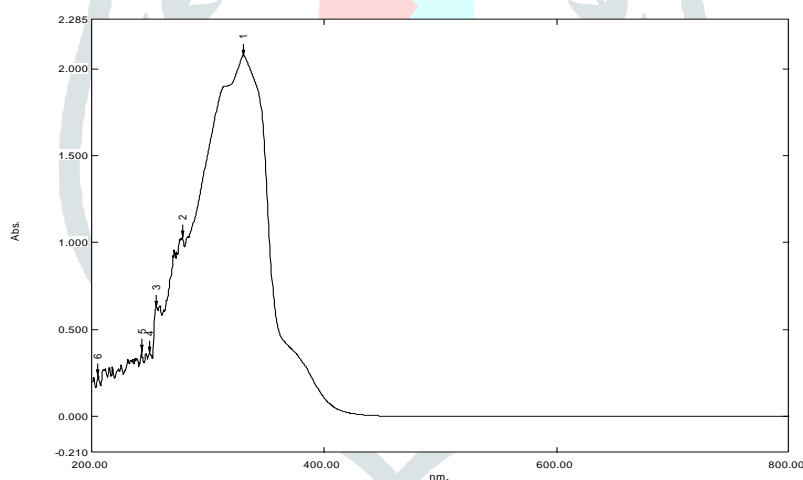


Fig.1 UV-Visible Spectrum of Zn complex

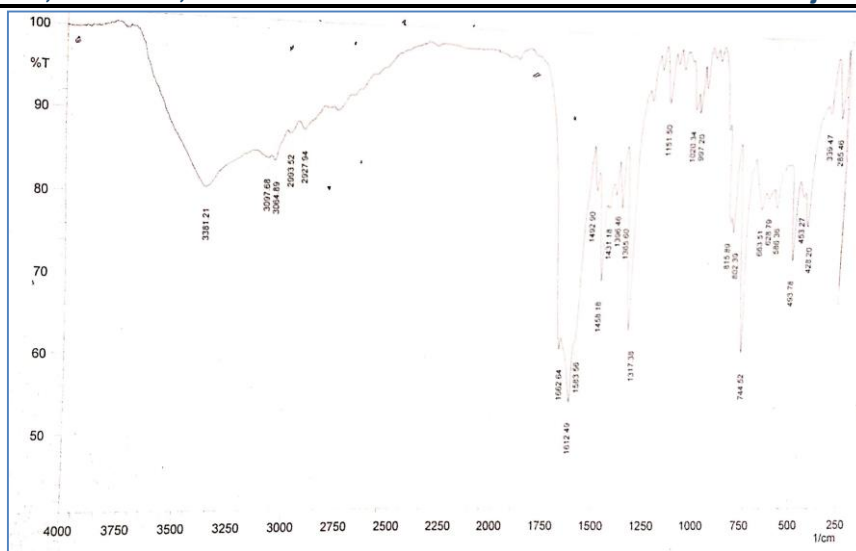


Fig.2 FT-IR spectrum of Zn complex

3.4 Powder XRD study :

The powder X-ray diffraction data for the complexes were obtained and used for structural characterization. The powder xrd pattern was recorded in between $2\theta=9^{\circ}$ - 79.9° . The powder XRD pattern of Zn (II) complex was shown in (fig. 3). All the complexes exhibited sharp peaks indicating their polycrystalline structure. The average crystallite size of the Zn complex is 23.74 nm which was calculated by Debye scherrer's formula¹⁹ indicating that this complex was in nano crystalline phase.

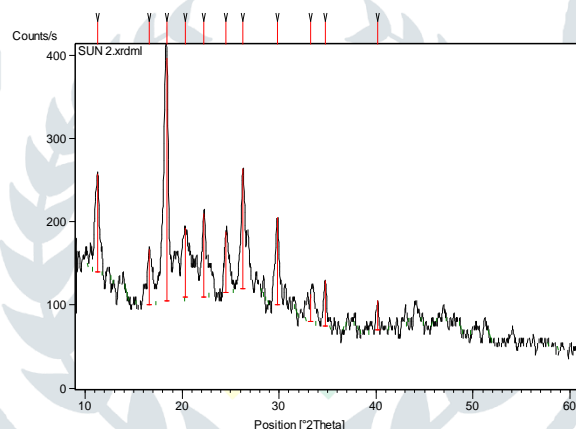


Fig.3 Powder XRD spectrum of Zn complex

3.5 Morphological study

The SEM micro graphs of the complexes were analysed for their morphology and grain size the SEM –EDS micro graph of the Zn(II) complex is shown in (Fig:4). It is observed from SEM- EDS micrographs that the complexes showed agglomerated thin plates, ice granular irregular spherical structures and ice plates like morphologies with average grain size of 23.7 to 65 nm which is confirmed by powder XRD.

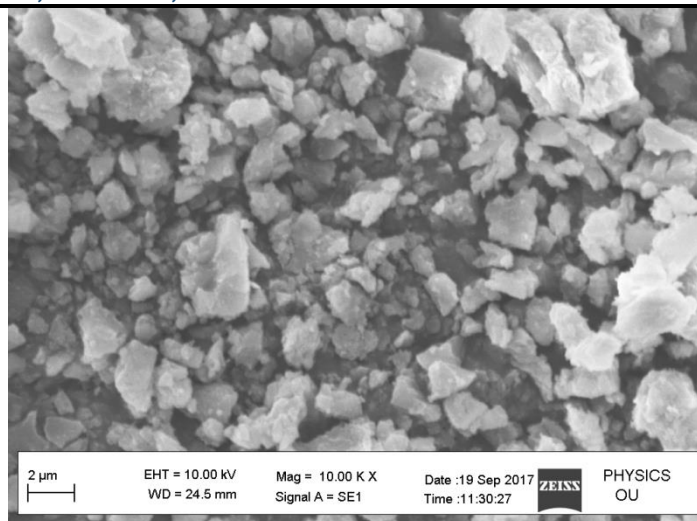


Fig.4 SEM EDS micro graph of Zn complex

3.6. ANTIBACTERIAL ASSAY

3.6.1: Test microbial strains:

The novel ternary metal complexes were screened against three Gram positive Strains Methicillin-resistant *Staphylococcus aureus*, *Bacillus subtilis*, *Bacillus cereus* and three Gram negative strains *Pseudomonas aeruginosa*, *Escherichia coli*, *Proteus vulgaris*, were procured from American Type Culture Collection, USA. Methicillin resistant *Staphylococcus aureus* which was purchased from Culture Collections, UK.

3.6.2: In vitro anti bacterial activity: Agar well diffusion assay

The newly synthesized ternary metal chelates were evaluated by using the agar well diffusion assay. The wells were created using a six mm diameter cork borer. These wells were filled with 25 μ L of the complexes of 50,75, and 100 μ g/ml concentration. Ciproflaxacin (10 μ g/ml) is used as a positive control. This test was carried out thrice for each bacterial strain used. The petri plates were incubated at 37 $^{\circ}$ C for 24 h. Zone reader was used to record the average diameter of inhibition zone of the test micro organisms in mm .

3.6.3: Minimum inhibitory concentration (MIC)

The MIC of the four complexes against different bacterial strains was tested through modified agar well diffusion method²⁰ The MIC values of the metal complexes were found in the range of 67 to 200 μ g/ml against all the microbial strains. Metal complex 1 showed the lowest MIC value (67 μ g/ml) against *P.Aeruginosa* given in the(table 3.0)

Table 3.0 Minimum Inhibitory Concentrations (μ g/ml) of complexes 1,2

Compounds	MRSA	<i>B. subtilis</i>	<i>B. cereus</i>	<i>P. aeruginosa</i>	<i>E.coli</i>	<i>P.vulgaris</i>	<i>S.typhi</i>
Complex 1	68.7	73.7	>150	67.0	>150	>200	-
Complex 2	76.4	87.3	>150	98.6	>150	>200	-
Ciproflaxacin	3.0	2.5	4.2	2.1	3.3	4.0	3.1

CONCLUSION

Primary ligand (BBP) and the four novel ternary metal complexes of Ni(II), Zn(II) were synthesized and characterized by elemental analysis, electrical conductance, magnetic moment and various spectral techniques. The primary ligand BBP(L₁) acts as a tridentate ligand coordinating through 3 nitrogen atoms and Oxalate ion as bidentate ligand(L₂) confirmed by spectral, analytical, thermal and magnetic studies. Water molecules are also coordinated to the metal ions. Six coordinated geometries are assigned to both the complexes. They inhibited the growth of bacterial strains and exhibited moderate to good antibacterial activity. The anti bacterial activity results of the complexes were compared with reference drug ciprofloxacin at 10 mg/mL. The Ni(II) complex is more active than the Zn complex. Among the Gram negative strains *P. vulgaris* was found to be least susceptible and *S. typhi* was resistant to all the compounds. The Ni(II) complex exhibited highest zone of inhibition against *P. aeruginosa* at 100 μ g/mL.

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REFERENCES

1. A.B.P Lever 1968 Inorganic Electronic Spectroscopy, Amsterdam, Elsevier
2. Addison, A.W., Burke, P., J. Heterocyclic. chem (1981). 18.803-805
3. Aneja KR, Sharma C, Joshni R., J Microbiol 2011;4;175-83.
4. Ayhan-Kilcigil G. and Altanlar N., Synthesis and antifungal properties of some benzimidazole derivatives, turk.J.Chem., 30. 223 (2006)
5. B.E Warren, X-Ray Diffraction (Dover books on physics), New York. 1990.
6. Castillo-Blum S.E and Barba- Behrens N., Coord. Chem. Rev., (3), 196 (2000)
7. Hyappa P.B., Young J.K. Moore J.S. and Suslic K.S. Dendrimer., (1996) J. Am. Chem. Soc., 118, 5708
8. Kamal. A., Pogula, P.K., Khan, M.N., Seshadri, B.N., Sreekanth, K., 2013. Med.Chem.9 (5), 651-659
9. Kong D., Reibbencies J., Mao J. and Clearfield A., (2003) Inorg.Chem. Acta, 342, 158
10. Kulkarni, R.G., Laufer, S.A., CV, M., Garlapati, A., 2013. Med.Chem. 9 (1), pp. 91-99
11. Li, Z.X., Hu, T.L., Ma, H., Zeng, Y.F., Li, C.J., Tong, M.L., Bu, X.H., 2010. Cryst. Growth Des. 10 (3), 1138.
12. M.Sunitha, J.Pragathi, K.Mounika, C.Gyanakumari., Bulletin of pure and applied sciences., 2007, 26C(1), 47.
13. Mohan G., and Rajesh N., Indian J. Pharm, 24, 207 (1992)
14. Mohani, B., Arjmand, F., Tabassum, S., 2002. Trans. Met. Chem. 27, pp 741-747.
15. N.Thakkar, S. Bootwala [1995] Indian journal of chemistry section A, Inorganic Bio- Inorganic physical Theoretical & Analytical Chemistry, 34:370
16. Ozkay, Yusuf, Tunali, Yagmur, Karaca, Hu"lya, Isikdag, I_lhan, 2011. Arch. Pharm. Res., 427.
17. Raman .N., Kulandaisamy, A., Jeyasubramanian, K., Indian J.Chem., 2002, 41, 942-949
18. Rostom, S.A.F., Ashour, H.M.A., Razik. H.A.A.E., Fattah, A.E.F.H.A.E., El-Din, N.N., 2009. Bioorg. Med. Chem. 17 (6), pp 2410-2422.
19. Suneetha koppu, Jyothi pilli, B. Venkata Bhaskar Rao, C. Gyanakumari J. Applicable.Chem. 2019, 8(5), 2074
20. Ujjinamatada. R.K., Baier. A., Borowski. P., Hosmane, R.S Bioorg. Med. Chem. Lett., 17(8) (2007), pp. 2285-2288.