

# Synthesis, Characterization and Antimicrobial activities of Co(II), Ni(II) and Cu(II) Metal complexes derived from 2- {[2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl}phenol derivatives as ligands

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## ABSTRACT:

The Co(II), Ni(II) & Cu(II) Schiff base complexes of composition  $ML_2H_2O$  were synthesized using tetradentate O, N, N, N-Schiff base ligands viz. 2- $\{[2-(5,7\text{-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl}\}$ phenol [ $HL^1$ ] and 2- $\{[2-(5,7\text{-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl}\}$ -5-methoxyphenol [ $HL^2$ ]. Different spectroscopic tools such as magnetic susceptibility measurement, electronic, FT-IR, UV-Vis, and <sup>1</sup>H NMR spectroscopy are utilized for characterizing all metal complexes. Nevertheless, based on the spectroscopic data and structures of similar metal (II) complexes published in the literature, it is possible to argue that complexes assume octahedral geometries in a single metal center coordinated to ligands. In acetonitrile solution, each compound exhibits properties of an electrolyte. Two gram-positive and negative bacterial strains respectively and two fungus strains were used to test in vitro antibacterial properties of produced ligands and their complexes. When compared to Schiff base ligands, metal complexes showed promising activity.

**KEYWORDS:** Activities, Antimicrobial, Complexes, Ligands, Octahedral,

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## I. INTRODUCTION

Coordination chemistry aims to discover novel, multipurpose ligands that have potential in a wide range of biological settings [1,2], due to their versatility in forming bonds with transition metal ions [1,2], Schiff base ligands have found several biological uses when composed of a variety of donor atoms (such as N, S, O, etc.). The synthetic stability of these donor groups makes them an important type of ligand toward the core metal atom [3,4]. Their value originates from the fact that they include Schiff base ligand with a (-N=CH-) group, that aids in explaining mechanisms of several reactions in living systems [2,5]. The heteroatoms in Schiff bases also attract a lot of interest as of prospective uses into catalysis, antibiotics and anti-inflammatory medicines, and industry as corrosion resistance [6-10]. In addition, the carcinostatic, anticancer, and antiviral activity [11] of ligands containing transition metal complexes comprising nitrogen, oxygen, and sulfur donor atoms is of great importance. Common heterocyclic compounds, such as thiazole, play a significant role as pharmacophores in the pharmaceutical industry's drug research and development processes. The majority of heterocyclic compound such as thiazole as well as their derivatives covers a broad spectrum of therapeutics targets like anti-inflammatory [12, 13], antifungal [14], antiviral [15], analgesic [16], antioxidant [17,18], antipsychotic [15], anticonvulsant [20], antidiabetic [21, 22], anti-tubercular [23, 24] and anti-cancer [25] etc. Thiazole occurs in thiamin (vitamin B-1) in a naturally occurring form. Because of its water-solubility, this vitamin plays a crucial function in the decarboxylation of beta-keto acid like electron sink, and it also helps the body release energy from carbs during metabolism. It aids in the production of acetylcholine, a neurotransmitter necessary for healthy brain function. Cancer is the most prevalent deadly illness that results from uncontrolled cell development. Specifically, it alters cellular gene expression [26, 27]. Cancer is one of the world's biggest killers. In 2018, the World Health Organization estimated that cancer killed 10 million people worldwide. In children ages 1–19, about 0.3 million new cases of cancer are detected each year [28,29]. Cancer may affect people of any age. Multiple drug resistivity, ill-effects and selectivity are all negative outcomes of cancer treatment. Benzothiazole with Schiff's base [30] might upsurge biological activities. Keeping all these facts into consideration, synthesis and characterization is observed also antimicrobial and stability constant observation of Co(II), Ni(II) and Cu(II) with complex of 2- $\{[2-(5,7\text{-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl}\}$ phenol [ $HL^1$ ] and 2- $\{[2-(5,7\text{-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl}\}$ -5-methoxyphenol [ $HL^2$ ].

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## II. EXPERIMENTAL:

### 2.1. MATERIALS AND REAGENTS:

Merck, Loba chemie, and Sigma Aldrich all contributed chemicals for synthesis of Schiff's base. Using thin-layer chromatography (TLC) and mixed melting point, we confirmed that all of our products were pure and had successfully completed their respective reactions. The metal content was calculated with the use of conventional techniques[31]. We used a Veeco melting point device to measure the melting points of substances in capillary tubes immersed in a bath of silicon oil. We used an Elico SL 159 spectrophotometer in DMF solution ( $10^{-3}$ ) to analyze the complexes' electronic spectra in the 200-1000 nm region. We used a BRUKER AVANCE Neo 500 MHz NMR spectrometer to get our  $^1\text{H}$  NMR spectra. Dissolving the material in  $\text{CHCl}_3$  was the first step. Using an in-house tetramethylsilane standard, we report chemical changes in  $\delta$  units. We used a BRUKER AVANCE IVDR FTIR to get the infrared spectrum. We used a Shimadzu GC-MS to capture spectra. Ligands and complexes' elemental analyses results came from a HERAEUS C, H, N-O fast analyzer. Using DPPH as a standard and a field strength of 3200 Gauss, we measured the E.S.R. of a VARAN E-109 GHZ. Utilizing Model 300 Lewis Coil Force Magnetometer calibrated with Hg  $[\text{Co}(\text{SCN})_4]$ [32], we measured magnetic susceptibilities by the Faraday technique at room temperature and a field strength of one Tesla in the coil. All of the ligands and complexes that were studied for their antibacterial properties were tested using a cup plate assay. Hi-Media, the company that supplied the dry Mueller Hinton agar powder, provided detailed directions for making the medium. Dimethyl sulfoxide (DMSO) had been utilized for dissolving test ligand and their metal complexes at a concentration of  $100\mu\text{g/ml}$ . The antibacterial & antifungal reference standards utilized were ciprofloxacin ( $100\mu\text{g/ml}$ ) and flucanazole ( $100\mu\text{g/ml}$ ), respectively, both dissolved in dimethyl sulfoxide (DMSO).

### 2.2 Synthesis of 2-hydrazinyl-5,7-dimethyl-1,3-benzothiazole:

For 6-8 hours at  $80^\circ\text{C}$ , 2, 4-dimethylaniline (1) and ammonium thiocyanate were agitated in 30% hydrochloric acid (1.1mmol), while GC monitored the reaction's development. Solid filtered gave (2). The reaction mixture consisted of (2), industrial waste salt, and sulphuric acid. Thin-layer chromatography (TLC) was used to observe while it was agitated at  $80^\circ\text{C}$  for 1 to 2 hours. The solid filtered gave (3). At  $100-110^\circ\text{C}$  for 1-2 hours, we mixed a mixture of (3) in water before adding hydrazine hydrate (1.5 mmol). TLC had been utilized for checking on development [33]. After filtration, the solid obtained is 2,6-dimethyl-1,3-benzothiazole (4).

### 2.3 Preparation of 2-{{2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene}methyl}phenol derivatives :

In 50mL round bottom flask and taking water like an solvent, 1.0 mol of 2-hydrazinyl-4, 6-dimethyl-1, 3-benzothiazole (4) and 1.05 mol of replaced aromatic ketones moiety were combined and refluxed for 4 hours. TLC analysis confirmed reaction was proceeding as expected. By stirring mixture at irregular intervals, we were able to regulate reaction rate. The result was a crystalline substance. Filtration, washing, and recrystallization from ethanol: water yielded expected benzothiazole derivatives..  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ - $d_6$ , ppm), study of synthesized compounds as 2-{{2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene}methyl}phenol and 2-{{2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene}methyl}-5-methoxyphenol.

### 2.4 Preparation of complexes

Warm ethanolic solution of metal chlorides (0.01M) were added in ethanolic solution 2-{{2-(5,7-dimethyl-1,3-benzothiazol-2-yl) hydrazinylidene} methyl} phenol and 2-{{2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene} methyl}-5-methoxyphenol of (0.02 M) in about 25ml of ethanol. The resulting solution was refluxed for about 6-8 hours. The complexes thus formed were suction filtered and cleared by alcohol and dried into vacuum over fused  $\text{CaCl}_2$ .

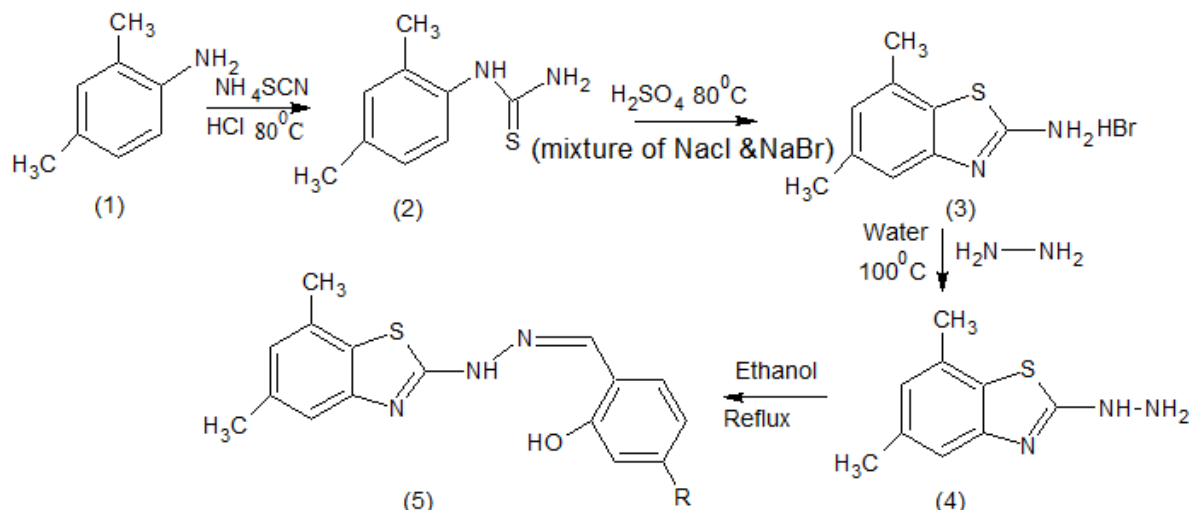


Fig-1. Scheme for the synthesis 2-[[2-(5,7-dimethyl-1,3-benzothiazol-2-yl) hydrazinylidene] methyl}phenol derivatives

### III. RESULTS AND DISCUSSION

Table-1 displays analytical results that are consistent with the hypothesis as every metal ion originate from 1:1 (M:L)2H<sub>2</sub>O complex having both ligands. Yields were satisfactory, and the complexes are stable in air. Because of their 1:1 electrolytic nature[34], the complexes operate as electrolytes in acetonitrile solution. Cobalt(II) complexes have magnetic moment values between 5.10 and 5.28BM, between 4.46 and 5.33 B.M.[35-40] is shown to be magnetic moment of cobalt(II) octahedral complexes. Consequently, evaluated magnetic moment for studied Co(II) complexes is indicative of octahedral geometry. The results of this investigation put the B.M. value at 3.12–3.23. At room temperature, Ni(II) complexes had magnetic moments of 3.08–3.15 BM. This research lends credence to the idea that Ni(II) complexes have an octahedral structure. Magnetic moment of copper(II) complexes is 1.73–1.78 B.M., that is identical to spin-only value. According to reports[41], the distorted octahedral geometry of a copper (II) complex without spin interaction demonstrates a magnetic moment into 1.80–1.93 B.M. range. It follows as copper (II) complex must possess substantial spin interaction.

**TABLE-1.** Elemental analytical and conductance data for ligands and metal complexes.

Ligands/ Complexes	Analysis % Found (Calculated)					Molar Conductance Ohm <sup>-1</sup> cm <sup>2</sup> mol <sup>-1</sup>
	C	H	N	M	S	
HL <sup>1</sup> C <sub>16</sub> H <sub>15</sub> N <sub>3</sub> OS	65.38 (65.44)	5.15 (5.11)	14.35 (14.31)	--	10.87 (10.90)	--
Co(L <sup>1</sup> ).2H <sub>2</sub> O Co(C <sub>16</sub> H <sub>14</sub> N <sub>3</sub> OS).2H <sub>2</sub> O	50.01 (49.44)	4.67 (4.63)	10.87 (10.81)	15.22 (15.17)	8.31 (8.24)	97.21
Ni(L <sup>1</sup> ).2H <sub>2</sub> O Ni(C <sub>16</sub> H <sub>14</sub> N <sub>3</sub> OS).2H <sub>2</sub> O	49.48 (49.47)	4.59 (4.63)	10.76 (10.82)	15.17 (15.12)	8.30 (8.25)	99.45
Cu(L <sup>1</sup> ).2H <sub>2</sub> O Cu(C <sub>16</sub> H <sub>14</sub> N <sub>3</sub> OS).2H <sub>2</sub> O	48.90 (48.86)	4.66 (4.58)	10.74 (10.68)	16.23 (16.17)	8.20 (8.14)	110.50
HL <sup>2</sup> C <sub>17</sub> H <sub>17</sub> N <sub>3</sub> O <sub>2</sub> S	62.36 (62.30)	5.25 (5.19)	12.85 (12.82)	--	9.82 (9.77)	--
Co(L <sup>2</sup> ).2H <sub>2</sub> O Co(C <sub>17</sub> H <sub>16</sub> N <sub>3</sub> O <sub>2</sub> S).2H <sub>2</sub> O	48.25 (48.30)	4.78 (4.73)	9.88 (9.94)	13.89 (13.95)	7.62 (7.57)	109.65
Ni(L <sup>2</sup> ).2H <sub>2</sub> O Ni(C <sub>17</sub> H <sub>16</sub> N <sub>3</sub> O <sub>2</sub> S).2H <sub>2</sub> O	48.37 (48.33)	4.80 (4.74)	9.89 (9.95)	13.85 (13.90)	7.65 (7.58)	106.22
Cu(L <sup>2</sup> ).2H <sub>2</sub> O Cu(C <sub>17</sub> H <sub>16</sub> N <sub>3</sub> O <sub>2</sub> S).2H <sub>2</sub> O	47.84 (47.78)	4.75 (4.68)	9.87 (9.83)	14.65 (14.88)	7.55 (7.49)	103.38

\* Values portrayed in parenthesis are calculated one

Electronic spectra of Co(II), Ni(II), and Cu(II) complexes with [HL<sup>1</sup>] and [HL<sup>2</sup>] have been examined to learn more about stereochemistry of these complexes and lend credence to inference drawn from magnetic data. The electronic spectra of cobalt(II) complexes having mixed ligands into DMF solution exhibit the 3 bands into range of 10,050-11,146, 14,567-18,587 and 19,355-22,398 cm<sup>-1</sup> assignable to <sup>4</sup>T<sub>1g</sub>(F)→<sup>4</sup>T<sub>1g</sub>(P) (ν<sub>3</sub>), <sup>4</sup>T<sub>1g</sub>(F)→<sup>4</sup>A<sub>2g</sub> (ν<sub>2</sub>), <sup>4</sup>T<sub>1g</sub>(F) →<sup>4</sup>T<sub>2g</sub>(ν<sub>1</sub>), correspondingly portraying distorted octahedral stereochemistry around Co(II) into complexes. Generated mixed ligand complexes show extremely wide and low-intensity ν<sub>2</sub> bands and

very narrow  $\nu_1$  bands. According to the ligand absorption band,  $\nu_3$  bands, having sturdy absorbing bands, are indistinguishable at larger concentrations yet appear like a separate band at lower concentrations. Co(II) complexes having mixed ligands had their electronic spectra investigated and compared to previous research. At high concentrations,  $\nu_3$  bands' strong absorption bands aren't distinguishable from the ligand absorption band, but at low quantities, the bands do emerge separately. [42-44]. Analysed Ni(II) complexes have transitioning of 3 bands around  $10218.09\text{ cm}^{-1}$ ,  $12834.60\text{ cm}^{-1}$ ,  $22748.55\text{ cm}^{-1}$ , because of d-d transition of  ${}^3A_{2g}(F) \rightarrow {}^3T_{2g}(F)(\nu_1)$ ,  ${}^3A_{2g}(F) \rightarrow {}^3T_{1g}(F)(\nu_2)$ ,  ${}^4A_{2g}(F) \rightarrow {}^3T_{1g}(P)(\nu_3)$  signifying octahedral geometry both for Ni(II) complexes. Band peaks and complexes of Cu(II) with which they are related. Cu(II) is a  $d^9$  ion which serves as a good example of the Jahn Teller effect. Three bands, located at  $14735.65\text{ cm}^{-1}$ ,  $18160.17\text{ cm}^{-1}$ ,  $32245.10\text{ cm}^{-1}$ , are considered for Cu(II) complexes and are attributed to corresponding transitions  ${}^2B_{1g} \rightarrow 2A_{1g}$ ,  ${}^2B_{1g} \rightarrow {}^2B_{2g}$  and  ${}^2B_{1g} \rightarrow {}^2E_g$  correspondingly. Such changes support an octahedral shape with six valence electrons for the Cu(II) complexes. There is some discussion of the IR spectral bands occupied by 2-[2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene] methyl phenol [ $HL^1$ ] and 2-[2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl-5-methoxyphenol [ $HL^2$ ] and the complexes of these two compounds. Absorption of both ligands in the area between  $1618$  and  $1615\text{ cm}^{-1}$  is indicative of the presence of an azomethine group in Schiff bases. In metal complexes, the azomethine group [45, 46] moves to a low frequency between  $1600$  and  $1580\text{ cm}^{-1}$ . Addition of a new band between  $1600$  and  $1589\text{ cm}^{-1}$  in the vicinity of this location owing to  $\nu C=N$  [47] is noteworthy. In current complexes,  $C=N$  shifts to a higher frequency region, indicating involvement of the azomethine nitrogen in the coordination process. Unavailability of the phenolic (O-H) band at  $3385\text{ cm}^{-1}$  in the spectra of complexes, that is present in the spectra of Schiff base ligands  $HL^1$  and  $HL^2$ , suggests that phenolic (O-H) is involved in the formation of the complexes through O of phenolic OH via deprotonation. The NH group contributes to a medium-intensity band seen for both ligands between  $3436$  and  $3465\text{ cm}^{-1}$ ; but, in complexes, this band is no longer present owing to the NH group's participation in the synthesis of complexes' coordination via N of the NH group through deprotonation. Water's symmetric and antisymmetric stretching mode,  $\nu(O-H)$ , appears as a broad band in the  $3500-3000\text{ cm}^{-1}$  range in complexes, wherein H-O-H bending modes arise into  $1630-1610\text{ cm}^{-1}$  area. It is theorized that two water molecules lie outside of the coordination sphere that centers on the metal. Stretching frequency associated with M-S, C-S,  $-C \equiv N$ , with aryl ring vibrations in the ligands, metal heterocyclic nitrogen vibrations, and O-H vibrations in water are some of the most characteristic aspects of the ligands' metal(II) complexes. (Co-O) [48] and (Co-N) [49] modes, which emerged at  $505-515\text{ cm}^{-1}$  and  $423-382\text{ cm}^{-1}$ , correspondingly, are likely responsible for non-ligand bands in complexes.

Two singlets, at  $2.20$  and  $3.83\text{ ppm}$ , represent methoxy ( $OCH_3$ ) proton peaks in the  ${}^1H$  NMR spectra of ligands  $HL^1$  and  $HL^2$ . Whereas ligands exhibit a multiplet at  $6.96-7.55\text{ ppm}$  owing to aromatic protons. For complexes, complexation amongst phenolic OH oxygen and nitrogen of  $C=N$  group caused a multiplet detected between  $6.56$  and  $7.25\text{ ppm}$  owing to aromatic protons and signals at  $3.62$  and  $3.77\text{ ppm}$  because of methoxy protons moving downfield. Signal between  $11.40$  and  $11.51\text{ ppm}$  is caused by resonance acting of phenolic OH protons; in complexes, such signals aren't present because of complexity via oxygen of phenolic OH group as well as shifted to the lower field because of complexity in nitrogen of  $C=N$  and O of phenolic group to metal ion. Singlets at  $8.75-7.60\text{ ppm}$  in the  ${}^1H$ -NMR spectra correspond to the -NH moiety in structures of both ligands; however, these bands vanish in complexes due to complexation through N of the NH group.

We obtained ESR spectra of copper complexes at ambient temperature. Kivelson and Neiman [50] stated that a  $g$  value of less than  $2.3$  specifies a covalent metal-ligand association, whereas a  $g$  value of more than  $2.3$  indicates an ionic one. This research shows that metal-ligand interactions in both Cu(II) complexes are more ionic in nature, with  $g$  values of  $2.55$  and  $2.65$ . In an effort to learn more regarding the composition of copper (II) complexes, there were ESR investigations of complexes. The spectral evaluation of the magnetic parameters reveals a tendency  $g_{\parallel} > g_{\perp}$  in the  $g'$  values, which is consistent with the existence of an unpaired electron in  $d_{x^2-y^2}$  orbital [51, 52]. These data suggest that copper(II) complexes contain an octahedral shape.

The elemental analysis, IR,  ${}^1H$  NMR, and ESR spectrum data, and observations have led to the preliminary structures of such complexes for a coordination number of six with octahedral geometry.

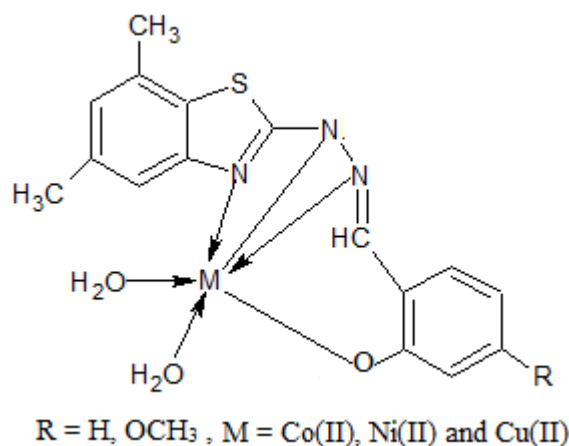


Fig.2. Proposed structure of metal complexes

### 3.1 Antimicrobial Activities:

Both the investigated ligands, 2-[[2-(5,7-dimethyl-1,3-benzothiazol-2-yl) hydrazinylidene] methyl]phenol [HL<sup>1</sup>] and 2-[[2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl]-5-methoxyphenol [HL<sup>2</sup>] and the metal complexes were analysed for antifungal and antibacterial activity with cup plate technique, with varying concentrations into DMSO solvent with MIC technique[53]. We tested for its antibacterial efficacy against *Escherichia coli* and *Staphylococcus aureus* also its antifungal efficacy against *Aspergillus niger* and *Cladosporium*. We also examined the antibacterial and antifungal efficacy of the standard medications gentamycine and fluconazole with similar concentration and under conditions similar to those of test chemical. Based on data shown in Table-3, it seems that the quicker diffusion of the Cu(II) complexes makes them the most effective against bacteria and fungi, whereas ligands (HL<sup>1</sup>) and (HL<sup>2</sup>) are only somewhat effective.

TABLE-2: Antimicrobial activity of ligands and their Co(II), Ni(II) and Cu(II) complexes assessed by (mm).

Ligands / Complexes	InhibitionZone in mm			
	Antibacterial activity		Antifungal activity	
	<i>Escherichia Coli</i>	<i>S. Aureus</i>	<i>Aspergillus Niger</i>	<i>Cladosporium</i>
HL <sup>1</sup> C <sub>16</sub> H <sub>15</sub> N <sub>3</sub> OS	16	19	18	19
Co(L <sup>1</sup> ).2H <sub>2</sub> O Co(C <sub>16</sub> H <sub>14</sub> N <sub>3</sub> OS).2H <sub>2</sub> O	19	20	19	21
Ni(L <sup>1</sup> ).2H <sub>2</sub> O Ni(C <sub>16</sub> H <sub>14</sub> N <sub>3</sub> OS).2H <sub>2</sub> O	18	21	21	22
Cu(L <sup>1</sup> ).2H <sub>2</sub> O Cu(C <sub>16</sub> H <sub>14</sub> N <sub>3</sub> OS).2H <sub>2</sub> O	25	27	23	24
HL <sup>2</sup> C <sub>17</sub> H <sub>17</sub> N <sub>3</sub> O <sub>2</sub> S	17	20	20	18
Co(L <sup>2</sup> ).2H <sub>2</sub> O Co(C <sub>17</sub> H <sub>16</sub> N <sub>3</sub> O <sub>2</sub> S).2H <sub>2</sub> O	19	22	21	19
Ni(L <sup>2</sup> ).2H <sub>2</sub> O Ni(C <sub>17</sub> H <sub>16</sub> N <sub>3</sub> O <sub>2</sub> S).2H <sub>2</sub> O	23	21	22	20
Cu(L <sup>2</sup> ).2H <sub>2</sub> O Cu(C <sub>17</sub> H <sub>16</sub> N <sub>3</sub> O <sub>2</sub> S).2H <sub>2</sub> O	26	26	27	23
Gentamycine	28	30	--	--
Fluconazole	--	--	29	25

## IV. Conclusion

Both 2-[2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methylphenol [HL<sup>1</sup>] and 2-[2-(5,7-dimethyl-1,3-benzothiazol-2-yl)hydrazinylidene]methyl-5-methoxyphenol [HL<sup>2</sup>] were synthesized and characterized as novel tetradentate ligands. complexes of these elements with cobalt(II), nickel(II), and copper(II) were investigated. Each complex has its own unique color and stability in air; although they are all insoluble into water and most organic solvents, they are all soluble in polar solvents like acetonitrile, DMF, and DMSO. 1:1(M:L).The observed analytical results tended to support a 2H<sub>2</sub>O stoichiometry for all complexes. In acetonitrile solution, all of the complexes exhibit electrolytic behavior. Data from elemental analysis, magnetic susceptibility, conductivity, electrical, infrared (<sup>1</sup>H NMR), and electron spin resonance (ESR) spectroscopy, as well as other findings, led to the preliminary structures of such complexes for coordination number six

possessing octahedral geometry. Antimicrobial activity was tested for the ligands [HL<sup>1</sup>] and [HL<sup>2</sup>], and their cobalt(II), nickel(II), and copper(II) complexes. Because of rapid penetration of Cu(II) complexes through the cell membrane of bacteria, it was discovered that all copper complexes (Cu(L<sup>1</sup>)<sub>2</sub>H<sub>2</sub>O and Cu(L<sup>2</sup>)<sub>2</sub>H<sub>2</sub>O) were seen to be more active against all the microbes tested.

## REFERENCES

- [1]. L. Shi, W.-J. Mao, Y. Yang and H.-L. Zhu, *J. Coord. Chem.*, 62, 3471 (2009); <https://doi.org/10.1080/00958970903093694>
- [2]. M.S. More, P.G. Joshi, Y.K. Mishra and P.K. Khanna, *Today Chem.*, 14, 100195 (2019); <https://doi.org/10.1016/j.mtchem.2019.100195>
- [3]. M. Thankamony and K. Mohanan, *Indian J. Chem.*, 46A, 247 (2007).
- [4]. K. Venkatesh, B. Venkanna, C. Sekhar and K. Mukkanti, *J. Chem. Pharm. Res.*, 7, 437 (2015).
- [5]. H.A. Saadeh, E.A.A. Shaireh, I.M. Mosleh, A.G. Al-Bakri and M.S. Mubarak, *Med. Chem. Res.*, 21, 2969 (2012); <https://doi.org/10.1007/s00044-011-9830-y>
- [6]. A. Budakoti, M. Abid and A. Azam, *Eur. J. Med. Chem.*, 41, 63 (2006); <https://doi.org/10.1016/j.ejmech.2005.06.013>
- [7]. E. Raczuk, B. Dmochowska, J. Samaszko-Fiertek and J. Madaj, *Molecules*, 27, 787 (2022); <https://doi.org/10.3390/molecules27030787>
- [8]. A.A. Osowole, *E-J. Chem.*, 5, 130 (2008); <https://doi.org/10.1155/2008/654054>
- [9]. K.C. Gupta, A. Kumar Sutar and C.-C. Lin, *Coord. Chem. Rev.*, 253, 1926 (2009); <https://doi.org/10.1016/j.ccr.2009.03.019>
- [10]. W. Trakarnpruk and W. Kanjina, *Ind. Eng. Chem. Res.*, 47, 964 (2008); <https://doi.org/10.1021/ie070710e>
- [11]. R. Ramesh and M. Sivagamasundari, *Synth. React. Inorg. Met.-Org. Chem.*, 33, 899 (2003); <https://doi.org/10.1081/SIM-120021656>
- [12]. Zheng X J, Li C S, Cui M Y, Song Z W, Bai X Q, Liang C W and et al, Synthesis, biological evaluation of benzothiazole derivatives bearing a 1,3,4-oxadiazole moiety as potential anti-oxidant and anti-inflammatory agents, *Med. Chem. Lett.* 30, 127237. <https://doi.org/10.1016/j.bmcl.2020.127237>.
- [13]. Ghoniem A E, Ligresti A, Rabbito A, Mahmoud A M, Di Marzo V and et al, , Structure-activity relationships of thiazole and benzothiazole derivatives as selective cannabinoid CB2 agonists with in vivo anti-inflammatory properties, *J. Med. Chem.* 180, 2019, 154. <https://doi.org/10.1016/j.ejmech.2019.07.002>
- [14]. Singh T, Srivastava V K, Saxena K K and Goel S L, Synthesis of New Thiazolythiazolidinylbenzothiazoles and Thiazolyazetidinybenzothiazoles as Potential Insecticidal, Antifungal, and Antibacterial Agents, *Arch. Pharm.* 339(8), 2006,466. <https://doi.org/10.1002/ardp.200500265>
- [15]. Asiri Y I, Alsayari A, Muhsinah A B, Mabkhot Y N and Hassan M Z, , Benzothiazoles as potential antiviral agents, *J. Pharm. Pharmacol.* 72, 1459, 2020, <https://doi.org/10.1111/jphp.13331>
- [16]. Kumar K R, Karthik K N S, Begum P R and Rao C M M P, , Synthesis, characterization and biological evaluation of benzothiazole derivatives as potential antimicrobial and analgesic agents, *Asian J. Pharm. Sci.* 7(2), 115, 2017, <https://doi.org/10.5958/2231-5659.2017.00018.2>
- [17]. Mistry B M, Patel R V, Keum Y S and Kim D H, , Chrysin– benzothiazole conjugates as antioxidant and anticancer agents, *Bioorg. Med. Chem. Lett.*, 25, 5561, 2015, <https://doi.org/10.1016/j.bmcl.2015.10.052>.
- [18]. Haider K, Haider M R, Neha K and Yar M S, , Free radical scavengers: An overview on heterocyclic advances and medicinal prospects, *J. Med. Chem.* 204, 112607, 2020, <https://doi.org/10.1016/j.ejmech.2020.112607>
- [19]. Gawai A A, Das S and Nemade M, Synthesis, Preliminary Pharmacological and Acute Toxicity Studies of a New Series of 7-(2(Benzo[d]thiazol-2-ylamino)ethoxy)-4-methyl-2H-chromen-2-one Derivatives with Atypical Antipsychotic Activity, *J. Pharm. Sci.* 81, 2019, 241. <https://doi.org/10.36468/pharmaceutical-sciences>.
- [20]. Murtuja S, Shaquiquzaman M, Amir M, Design, Synthesis, and Screening of Hybrid Benzothiazoly-Oxadiazoles as Anticonvulsant Agents, *Lett. Drug Des. Discov.* 15, 398, 2018. <https://doi.org/10.2174/1570180814666170526154914>
- [21]. Bhutani R, Pathak D, Kapoor G, Husain A and Iqbal M A, Novel hybrids of benzothiazole-1,3,4-oxadiazole-4-thiazolidinone: Synthesis, in silico ADME study, molecular docking and in vivo anti-diabetic assessment, *Bioorg. Chem.* 83, 6, 2019. <https://doi.org/10.1016/j.bioorg.2018.10.025>
- [22]. Haider K, Pathak A, Rohilla A, Haider M R, Ahmad K and Yar M S, , Synthetic strategy and SAR studies of C-glucoside heteroaryls as SGLT2 inhibitor: A review, *Eur. J. Med. Chem.* 184 111773, 2019. <https://doi.org/10.1016/j.ejmech.2019.111773>
- [23]. Shaikh N B, Sanna G, Busonera B, Colla P L and Rajani D P, ,2015, Synthesis of some new 2-amino-6-thiocyanato benzothiazole derivatives bearing 2,4-thiazolidinediones and screening of their in vitro antimicrobial, antitubercular and anti-viral activities, *Med. Chem. Res.* 24, 3129. <https://doi.org/10.1007/s00044-015-1358-0>
- [24]. Chikhale R, Menghani S, Babu R, Bansode R, Bhargavi G, Karodia N and et al, Development of selective DprE1 inhibitors: Design, synthesis, crystal structure and antitubercular activity of benzothiazolylpyrimidine-5-carboxamides, *Eur. J. Med. Chem.* 96, 30, 2015. <https://doi.org/10.1016/j.ejmech.2015.04.011>
- [25]. Pathak N, Rathi E, Kumar N, Kini S G and Rao C M, , A Review on Anticancer Potentials of Benzothiazole Derivatives, *Mini-Rev. Med. Chem.* 20, 12, 2020. <https://doi.org/10.2174/1389557519666190617153213>
- [26]. Jones P A and Baylin S B, *The Epigenomics of Cancer Cell*, 128, 683, 2007. <https://doi.org/10.1016/j.cell.2007.01.029>
- [27]. Dunn G P, Old L J and Schreiber R D, *The Immunobiology of Cancer Immun-surveillance and Immunoeediting Immunity*, 21, 137, 2004. <https://doi.org/10.1016/j.immuni.2004.07.017>
- [28]. World Health Organization, WHO Report on Cancer: Setting Priorities, Investing Wisely and Providing Care for All, 2020.
- [29]. Yar M S, Haider K, Gohel V, Siddiqui N A and Kamal A, Synthetic lethality on drug discovery: an update on cancer therapy, *Expert Opin. Drug Discov.* 15, 823, 2020. <https://doi.org/10.1080/17460441.2020.1744560>
- [30]. Mokhtar A M, El- Messery S M, Ghaly M A and Hassan G S, Targeting EGFR tyrosine kinase: Synthesis, in vitro antitumor evaluation, and molecular modeling studies of benzothiazole-based derivatives, *Bioorg. Chem.* 2020, 104, 104259, <https://doi.org/10.1016/j.bioorg.2020.104259>.
- [31]. A.I. Vogel, *A Text Book of Quantitative Inorganic Analysis*, ELBS and Longmans: London, Edn. 3 (1961).
- [32]. Setwood P. W., *Magneto Chemistry 2nd Edition Interscience*, New York, 1958 17.
- [33]. Mubashshir Ahmed, Seema Kothari, Manohar V.Lokhande, *Green Synthesis, Characterization and their Biological Activities of Schiff's Bases of Certain Benzothiazole Derivatives*, *International Journal of Applied Chemistry* ,18, 1 (2022) 15-26.
- [34]. T.S. Basu Baul, S. Kundu, P. Singh, S. Shaveta and M.F.C. Guedes da Silva, *Dalton Trans.*, 44, 2359 (2015); <https://doi.org/10.1039/C4DT03151B>
- [35]. V. K. Jetty, J.Singh, M. Sukla, Rehman and S.N. Rastogi, *J. Ind.Chem. Soc.*, 67,1990, 987.

- [36]. N.R. Gandhi and K.N. Munshi, J. Ind. Chem. Soc., 59, 1982,1290,  
[37]. H.B. Panchali and M.M. Patel, Thermochim. Acta., 196,1992, 317.  
[38]. B.T. Thaker, A.J.Lekhadia, P.Thaker, Ind.J.Chem., 35A,1996, 483.  
[39]. R.J. Bartlett and B R James, Mobility and bioavailability of Chromium in soils (John Wiley and sons Inc.), 1988,267,  
[40]. E Nakayama, Anal . Chim. Acta., 130, 1981, 289.  
[41]. R H Holm, G W Everelte, Jr.and A Chakravorty, Prog. Inorg. Chem., 7,1996, 83,  
[42]. A.B.P. Lever, Inorganic Electronic Spectroscopy, Elsevier Publishing Company: New York, (1968), 318.  
[43]. F.A. Cotton, G. Wilkinson, C.A. Murillo and M. Bochmann, Advanced Inorganic Chemistry, John Wiley & Sons, Inc.: New York, Edn. 6, p. 820 (1999).  
[44]. M. Azam, I. Warad, S. Al-Resayes, M. Zahin, I. Ahmad and M. Shakir, Z. Anorg. Allg. Chem., 638, 881 (2012)  
[45]. K. Lama Reddy, S. Shrikari and P. Ligiiah, J. Ind. Chem. Soc.,60,1983, 1020  
[46]. C N R Rao Chemical application Infrared spectroscopy Academic press New York, 260,1963, 262,  
[47]. B S Garg, and P C Gupta Synth. React. Inorg. Met. Org. Chem. 23(3), 1993,337- 346,  
[48]. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Wiley-Interscience, New York, Edn. 3 (1978).  
[49]. G.N. Schrauzer and V.P. Mayweg, J. Am. Chem. Soc., 87  
[50]. O. Kivelson and R. Neiman J. Chem. Phys., 35, 1961, 149 .  
[51]. B. A. Goodmm and J.B. Rayner, Advanced in Inorganic Chemistry and Radio Chemistry Ed.By H.T. Emelous and A.G. Sharpe 13, 1970, 135.  
[52]. Singh and V. Srivastava Synth. Reent, Inorg. Met. Org. Chem. 18(5), 1988, 515- 518.  
[53]. P. Ikechukwu, Ejidike and A. A. Peter,; Synthesis, Characterization and Biological Studies of Metal(II) Complexes of (3E)-3-[(2-{{(E)-[1-(2,4-Dihydroxyphenyl) ethylidene]amino}ethyl)imino]-1-phenylbutan-1-one Schiff Base, Molecules, 2015; 20; 9788. <https://doi.org/10.3390/molecules20069788>