International Journal of Scientific Research in Chemistry
Available online at : www.ijsrch.com
OPEN ACCESS
Online ISSN: 2456-8457
doi : https://doi.org/10.32628/IJSRCH

Synthesis, Characterization and Antimicrobial Activity of Metal Complexes prepared from Schiff Base Ligand

Kishore N. Koinkar
Department of Chemistry, Amolak Science College, Kada, Asti, Beed, India

ARTICLEINFO

Article History:

Accepted: 05 April 2024

Published: 15 April 2024

Publication Issue
Volume 9, Issue 2
March-April-2024

Page Number
27-34

ABSTRACT

Coordination compounds of some transition metal ions Co(II) of synthesized ligand 4-chloro-2-(((4-chlorophenyl) imino)methyl) phenol. These Schiff base ligand were characterized by elemental analysis, FTIR, UV-Vis, 1H-NMR, 13CNMR, Mass spectral analysis ,magnetic susceptibility and molar conductance, whereas, Metal complexes is analyzed by IR, UV-Vis, Magnetic susceptibility, Molar Conductance, elemental analysis.Schiff base ligand and its metal (II) complexes were tested in vitro to evaluate their bactericidal activity against bacteria S. aureus and B.subtilis and antifungal activity against A. Niger and F. Oxysporum using the Kirby-Bauer disc diffusion method. antibacterial evaluation results revealed that the metal (II) complexes exhibited higher antibacterial activity than the free Schiff base ligand.

Keywords : Metal Complexes, Antifungal Activity, Schiff Base

I. INTRODUCTION

Transition metals are metallic elements that have an incomplete d or f shells in the neutral or cationic states. These incomplete valance shell orbitals allow it to accept electrons from Lewis bases to form coordination complexes very easily compared to other group of elements. Ligands therefore must be a Lewis base. They must contain at least one pair of non-bonding electrons that can be donated to a metal ion. The Schiff base is named after Hugo Schiff and is a compound with a functional group that contains a -C=N- double bond with the nitrogen connected to an aryl or alkyl group.[1] Schiff bases in a broad sense have the general formula $R_1 R_2 C = NR_3$, where R is an organic side chain. Schiff base is synonymous with azomethine and may also be referred to as imines. Recently, Schiff bases are used as intermediates for the synthesis of ligands for preparation of metal complexes having a series of different structures[2]

Schiff's base has an azomethine group which is reported to play an important role and shows high antibacterial activity [3]. Schiff bases are usually synthesized from the condensation of a primary amine and a carbonyl group by nucleophilic addition to form a hemiaminal, followed by dehydration to give azomethine [4]. So, to be able to synthesize Schiff bases, carbonyl precursors and amine precursors are needed.

Schiff base compounds and their metal complexes are very important as catalysts in various biological systems, [5]polymers,[6] dyes [7] and medicinal & pharmaceutical fields [8], they comprise miscellaneous therapeutically potent applications in the field of medicinal chemistry [9]. Schiff bases have played an important role in the development of coordination chemistry as they readily form stable complexes with most of the transition metals [10]. They have been shown to exhibit a broad range of biological activities, including antifungal, antibacterial,[11] anti malarial,[12] anti-inflammatory,[13] antiviral,[14] and antipyretic properties [15]. A variety of Schiff's base and its complexes have been studied extensively. Several model systems, including those with bidentate, tridentate, tetradentate multidentate Schiff base ligands,[16] and their coordination chemistry of Cu(II), Co(II) & Ni(II) attracts much attention because of its biological relevance and its own interesting coordination chemistry such as geometry, flexible redox property.[17]

Then, one of the efforts to increase the antibacterial activity of Schiff base compounds is to make complex compounds. According to Hashem et al. [18], the complex formation can increase the activity of Schiff base as an antibacterial. Schiff base complexes with Co(II), Ni (II), and Cu (II) metals are reported to have high antibacterial activity [19]. Schiff bases can act as mono-, di-, tri-, or tetra-dentate ligands depending on the number of coordination atoms present in the molecule and can generally form five- or six-membered chelate rings on reactions with metal ions. In addition, if it contains additional functional groups such as –OH, –NH_2, or –CO, the resulting Schiff base can serve as a mixed donor ligand that can participate in bi-, tri-, tetra-, and higher coordination modes [4].

In this paper the synthesis, spectroscopic and antimicrobial studies of Schiff's base derived from 4-chloroaniline and 5-chloro-2-hydroxybenzaldehyde and its cobalt (II) complexes were studied. In addition, research was also carried out on the chelating behavior of this ligand against transition metal ions Co (II) and its antimicrobial activity for the ligand and its complexes.

II. METHODS AND MATERIAL

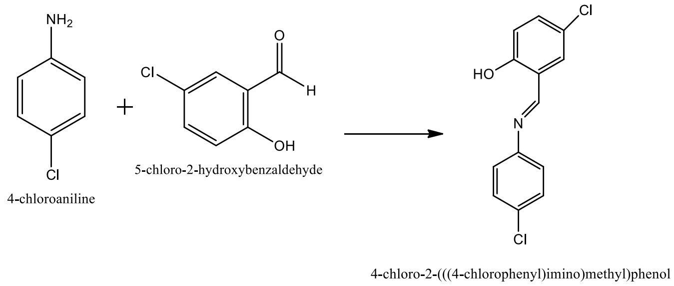
All the chemical of analytical grade. All salts are metal nitrates i.e.CO(NO3)2.6H2O(Sigma-Aldrich) were purchased from Sigma-Aldrich and used without further purification. 4-chloroaniline and 5-chloro-2-hydroxybenzaldehyde (Sigma-Aldrich) were purchased from Sigma-Aldrich and used without further purification. Distilled Ethanol used for synthesis of metal complexes and ligand diethyl ether (Sigma-Aldrich). IR Spectra recorded on Perkin Elmer Spectrometer in range 4000-400 cm-1 KBr pellets. 1H and 13CNMR Spectra were recorded on BRUKER AVANCE III HD NMR 500 MHz spectrophotometer. Room Temperature magnetic moments by Guoy's method in B.M.Electronic Spectra using DMSO on Varian Carry 5000 Spectrometer. Molar Conductance measurements in dry DMSO having 1×10-3 concentration on Systronics conductivity bridge at room temperature. Elemental analysis (C, H, N) were carried out by using perkin Elmer 2400 elemental analyzer. Mass Spectra were recorded on Bruker IMPACT HD.

Antimicrobial Activity

The synthesized compounds were screened *in vitro* fortheir antibacterial activities activity against bacteria *S. aureus* and *B.subtilis* and antifungal activity against *A. Niger* and *F. Oxysporum* using the Kirby-Bauer disc diffusion method. [20].

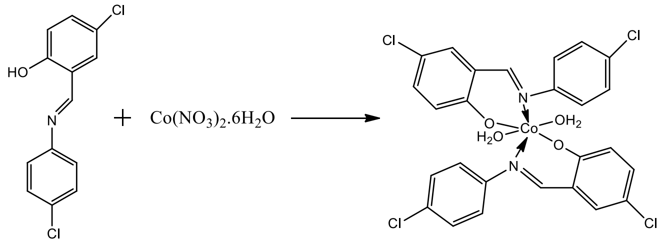
Synthesis of 4-chloro-2-(((4-chlorophenyl) imino) methyl) phenol

The ligand is synthesized by reported method.[21] The mixture 1:1 of 4-chloroaniline (0.255g, 2 mmol), 5-chloro-2-hydroxybenzaldehyde (0.313 g, 2 mmol) dissolved in 20 ml ethanol in a 50mL round bottomed Flask ask at room temperature. few drops of glacial acetic acid was added to the mixture, to adjust its pH to 6 upon which a thick yellow orange precipitate formed instantly. the precipitate was separated by filtration and purified by recrystallization from ethanol. The purity of compound was checked by TLC using Silica Gel method. (Scheme.1).



Scheme 1. Synthesis of Ligand

Synthesis of metal complexes of Co(II):- The schiff base metal (II) complexes (C) (Scheme 2) were prepared by reacting the schiff base with the metal (II) ions as per the literature methods[21].The metal complexes were prepared by mixing of metal nitrates i.e.Co(NO3)2. 9$H_2O$with (25 ml) ethanolic solution of Ligand 4-chloro-2- (((4-chlorophenyl) imino) methyl) phenol in (metal: ligand) 1:2 ratio. The resulting mixture was magnetically stirred and refluxed for 3 hours on an oil bath at 65°C where upon a precipitated product formed. A colored product obtain washed with ethanol, filtered, and recrystalised with ethanol. (Scheme.2).



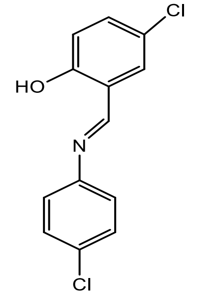
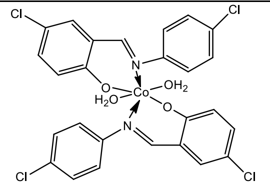
Scheme 2. Synthesis of metal complexes

III. RESULTS AND DISCUSSION

The ligand 4-chloro-2-(((4-chlorophenyl) imino) methyl) phenol (Scheme 1). and its Metal Complexes of Co(II) is stable at room temperature in solid state (Scheme 2).The schiff base ligand is soluble in hot ethanol and solvents such as DMF and DMSO. The imine and its metal (II) complexes are coloured solids which are stable in air. the complexes were insoluble in common organic solvents such as methanol, dichloromethane, ethanol, and acetone but soluble in DMSO and DMF. the melting points of the complexes were higher than that of the Schiff base ligand indicating that the complexes are more stable than the ligand.

The physical and analytical data shown in Table1. Spectral evaluation shows formation of ligand and its metal complexes. The synthesized complexes having 1:2 metal to ligand stoichiometric ratio.

Table 1: Proposed Structures of metal complexes M: Co(II)

Entry	product	Time h	Yield %	M.P. ^{0}C
Ligand		**3-4**	**90**	**138-140**
MC		**5-6**	**68**	**>300**

Chacterization of ligand 4-chloro-2-(((4-chlorophenyl) imino) methyl) phenol

Yellow orange Solid; $C_{13}H_9Cl_2NO$, M.P.:138^{o}C;Yield:90%;MS:(70eV)m/z:266 [M+H,100%], Anal. Calcd. For $C_{13}H_9Cl_2NO$ C, 58.67; H, 3.41;N, 5.26 Found : C, 56.21; H, 3.11;N, 5.62 Molar Cond. (DMSO 1×10-3conc., ohm^{-1} cm^2 mol^{-1}):5.12; UV(DMSO, cm^{-1})): 231 (π→π* tran. of benzene ring), 352 (n→π* azomethine moieties and phenolic -OH.); IR(KBr Cm^{-1}):ν =3390 (O-H str. in aromatic ring),ν= 1605 (C=N azomethine), ν=1278 (C-O Phenolic), 1H NMR (ppm d_6 400MHZ,DMSO) δ ppm: δ . 8.85 (s, 1H, CH=N), 11.95 (s, 1H, OH), 7.10–7.35 (m, 7ArH). ^{13}C NMR (DMSO-d6, 400 MHZ,) δ ppm : 135-122 (Ar, C=C), 161 (HC=N), 129(C-O).

Chacterization of metal complexes M: Co(II).

Cobalt (II) Complex, Brown Solid; $C_{26}H_{20}C_{14}CoN_2O_4$, M.P.:>300°C;Yield:68%;MS:(70eV)m/z:625[M+H,100 %],Anal. Calcd. For $C_{26}H_{20}C_{14}CoN_2O_4$,C, 49.95; H, 3.22;N, 4.48 Found : C, 48.27; H, 3.32;N, 4.52 Molar Cond. (DMSO 1×10-3conc., ohm^{-1} cm^2 mol^{-1}):18.2; UV(DMSO, cm^{-1})): 250,392,460 ($\pi\rightarrow\pi^*$, $n \rightarrow \pi^*$, d-d transition); IR(KBr Cm^{-1}):ν 3442.4 υ(O-H), 1560.4 υ(HC-N),1218.1 υ(C-O), 686.4 υ(H2O), 542.2 υ(Co-N), 472.7 υ(Co-O).

The Schiff base ligand was synthesized using the reflux method. In this research, however, the ligand was prepared using the room temperature method which afforded a higher yield Schiff base ligand is soluble in hot ethanol and solvents such as DMF and DMSO. ligand and its metal (II) complexes are coloured solids which are stable in air. The complexes were insoluble in common organic solvents such as methanol, dichloromethane, ethanol, and acetone but soluble in DMSO and DMF.

The ^1H and ^{13}C NMR spectra of the Schiff base ligand were recorded in DMSO-*d*6.The ^1H NMR spectrum of the Schiff base showed a singlet peak at δ = 8.85 ppm corresponding to the azomethine proton (–N=CH–) [22], an indication that the Schiff base was formed during the condensation reaction. The expected ^1H NMR peak, at δ =11.95 ppm, assignable to the phenolic proton in the free Schiff base ligand [23]Observation of a peak at δ = 161 ppm in the ^{13}C NMR Azomethine spectrum was further proof that the ligand was successfully synthesized [24]. The mass spectrum of the Schiff base ligand showed a molecular ion peak at *m/z* 266 [M+H,100%],which is consistent with the molecular weight of the Schiff base ligand.

The molar conductance values of the synthesized compounds in 10^{-3}M DMSO were measured at room temperature.the conductance values of the synthesized compounds were below 50 Ohm^{-1}cm^{2}mol^{-1},indicating their nonelectrolytic nature [25].the electronic spectral data of the Schiff base ligand showed three bands at 231 nm due to $\pi\rightarrow\pi^*$ transition of benzene ring), the band appearing at 271.2 nm is assignable to n–π∗ transition of nonbonding electrons present on the nitrogen of the azomethine group. the band at 325 nm is due to$n$– π ∗ transition of the phenolic group [26].The UV-Vis spectra of the Schiff base Co (II) metal complex. two bands were observed at 250 nm and 460 nm This was a shift towards longer wavelength with respect to the spectrum of the Schiff base ligand. The band at 250 nm was due to intraligand transition, and the band at 460 nm was as a result of d-d transition. which is within the range for octahedral configuration as reported inmany octahedral cobalt (II) complexes [27-28].

The binding mode of the Schiff base ligand to the metal ions in complexes was determined by comparing the FT-IR spectrum of the free ligand with the spectra of the metal (II) complexes. The azomethine peak of ligand observed at 1605 cm^{-1} (-C=N- azomethine) while in metal complexes it is observed at 1560 cm^{-1}. a shift to lower wave numbers. this is indicated coordination of Schiff base through the azomethine nitrogen [29]. Moreover, the appearance of additional weak bands in the region 536.4–546.2 cm^{-1} and 456.3–478.7 cm^{-1} attributed to υ(M-N) and υ(M-O), respectively[30], further confirmed complexation [31]. This showed that the Schiff base ligand coordinated to the metal via “N” and “O” atoms. The FT-IR spectra of the complexes also showed strong bands in the 3152.2–3442.4 cm^{-1} regions, suggesting the presence of coordinated/lattice water in the complexes. This was further confirmed by the appearance of nonligand band in the 682.1–686.4 cm−1 region, assignable to the rocking mode of water [31]. In the free Schiff base ligand, the band at 1278 cm^{-1} due to υ(C-O, phenolic) shifted to lower wave number by 60–62.1 cm^{-1} in the complexes indicating the coordination of the phenolic oxygen atom to the metal ion [32]. Therefore, it can be concluded that coordination took place via phenolic oxygenand azomethine nitrogen of the Schiff base ligand molecule.

The microanalysis data suggested that all the complexes were mononuclear where two moles of the ligand and two moles of water molecules were coordinated to the central metal atom. The data, therefore, suggested that the metal to ligand ratio in the complex was 1 : 2 the general formula for the complexes as $[M(L)_2(H_2O)_2]$ (*M*=Co (II); *L* = deprotonated imine) [33].The theoretical (calculated) values were found to be in good agreement with the experimental values.

Antimicrobial Activity

The antimicrobial activity in vitro on selected two gram positive bacteria *S. aureus and B.Subtlis* two fungi *A. niger* and *F.Oxysporum* was carried out shown in table.2. The ability of the Schiff base ligand and its metal (II) complexes to inhibit the growth of the bacteria and fungi was compared to that of the known standard antibacterial and antifungal drugs, Ciprofloxacin and Miconazole repectively.4-chloro-2-(((4-chlorophenyl) imino) methyl) phenol show substantial antimicrobial activity against bacteria S. aureus ,B.Subtlis and fungal species A. niger and F.Oxysporum. The results indicated that synthesized metal complexes show good antibacterial and antifungal activity as compared to free ligand against all tested bacteria and Fungi. Overall, the inhibition zones of the Schiff base ligand and its complexes showed that the complexes had enhanced bactericidal activity than the ligand [34].

Table 2. Antimicrobial activity of Imidazole

Compounds	**Antibacterial Activity**		**Antifungal Activity**	
	S.aureus	***B.subtilis***	***A.niger***	***F.oxysporum***
	Diameter of inhibition Zone in mm	Diameter of inhibition Zone in mm	Diameter of inhibition Zone in mm	Diameter of inhibition Zone in mm
	500 ppm	500 ppm	500 ppm	500 ppm
Ligand	23	22	21	19
MC	29	28	27	24
Ciprofloxacin (Standard)	34	33	----	----
Miconazole (Standard)	----	----	31	27

IV. CONCLUSION

The Schiff base ligand was prepared. The synthesized Schiff base ligand were formed with Co (II) complex,. The structure of the synthesized compounds was elucidated with the help of various spectral and physicochemical techniques. Preliminary in vitro antibacterial and antifungal study indicated that the prepared complex showed slightly higher activity against the tested bacterial and fungal strains as compared to the ligand.

V. REFERENCES

[1] Elango, G., Arumugam, A., & Guhanathan, S. (2017). Co (II), Ni (II) and Cu (II) Complexes with Schiff Base Ligand: Syntheses, Characterization, Antimicrobial Studies and

Molecular Docking Studies. SOJ Mater. Sci. Eng, 5, 1-12.

[2] Dalia, S. A., Afsan, F., Hossain, M. S., Khan, M. N., Zakaria, C., Zahan, M. E., & Ali, M. (2018). A short review on chemistry of schiff base metal complexes and their catalytic application. Int. J. Chem. Stud, 6(3), 2859-2867.

[3] Joseyphus, R. S., & Nair, M. S. (2008). Antibacterial and antifungal studies on some schiff base complexes of zinc (II). Mycobiology, 36(2), 93-98.

[4] Akitsu, T. (Ed.). (2023). Schiff Base in Organic, Inorganic and Physical Chemistry. BoD–Books on Demand.

[5] Juyal, V. K., Pathak, A., Panwar, M., Thakuri, S. C., Prakash, O., Agrwal, A., & Nand, V. (2023). Schiff base metal complexes as a versatile catalyst: A review. Journal of Organometallic Chemistry, 122825.

[6] Gupta, K. C., & Sutar, A. K. (2008). Catalytic activities of Schiff base transition metal complexes. Coordination Chemistry Reviews, 252(12-14), 1420-1450.

[7] Ispir, E. (2009). The synthesis, characterization, electrochemical character, catalytic and antimicrobial activity of novel, azo-containing Schiff bases and their metal complexes. Dyes and Pigments, 82(1), 13-19.

[8] Boulechfar, C., Ferkous, H., Delimi, A., Djedouani, A., Kahlouche, A., Boublia, A., ... & Benguerba, Y. (2023). Schiff bases and their metal Complexes: A review on the history, synthesis, and applications. Inorganic Chemistry Communications, 150, 110451.

[9] Maher, K. A., & Mohammed, S. R. (2015). Metal complexes of Schiff base derived from salicylaldehyde-A review. International Journal of Current Research and Review, 7(2), 6.

[10] Abu-Dief, A. M., & Mohamed, I. M. (2015). A review on versatile applications of transition metal complexes incorporating Schiff bases. Beni-suef university journal of basic and applied sciences, 4(2), 119-133.

[11] Kumar, R., Singh, A. A., Kumar, U., Jain, P., Sharma, A. K., Kant, C., & Faizi, M. S. H. (2023). Recent advances in synthesis of heterocyclic Schiff base transition metal complexes and their antimicrobial activities especially antibacterial and antifungal. Journal of Molecular Structure, 1294, 136346.

[12] Rani, M., Devi, J., Kumar, B., & Rathi, M. (2024). Unveiling Anti-malarial, Antimicrobial, Antioxidant Efficiency and Molecular Docking Study of Synthesized Transition Metal Complexes Derived From Heterocyclic Schiff Base Ligands. Chemistry–An Asian Journal, 19(19), e202400676.

[13] Sandhu, Q. U. A., Pervaiz, M., Majid, A., Younas, U., Saeed, Z., Ashraf, A., ... & Jelani, S. (2023). Schiff base metal complexes as anti-inflammatory agents. Journal of Coordination Chemistry, 76(9-10), 1094-1118.

[14] Uddin, M. N., Ahmed, S. S., & Alam, S. R. (2020). Biomedical applications of Schiff base metal complexes. Journal of Coordination Chemistry, 73(23), 3109-3149.

[15] Parashar, R. K., Sharma, R. C., Kumar, A., & Mohan, G. (1988). Stability studies in relation to IR data of some schiff base complexes of transition metals and their biological and pharmacological studies. Inorganica chimica acta, 151(3), 201-208.

[16] Liu, X., Manzur, C., Novoa, N., Celedón, S., Carrillo, D., & Hamon, J. R. (2018). Multidentate unsymmetrically-substituted Schiff bases and their metal complexes: Synthesis, functional materials properties, and applications to catalysis. Coordination Chemistry Reviews, 357, 144-172.

[17] Lumb, I., Sran, B. S., Sood, H., Arora, D. S., & Hundal, G. (2017). Coordination chemistry of Cu (II), Co (II), Zn (II) and Ag (I) complexes of isomeric pyridine 2-and 4-carboxamides and

their biological activity evaluation. Polyhedron, 127, 153-166.

[18] Hashem, H. E., Nath, A., & Kumer, A. (2022). Synthesis, molecular docking, molecular dynamic, quantum calculation, and antibacterial activity of new Schiff base-metal complexes. Journal of Molecular Structure, 1250, 131915.

[19] El-Gammal, O. A., Mohamed, F. S., Rezk, G. N., & El-Bindary, A. A. (2021). Synthesis, characterization, catalytic, DNA binding and antibacterial activities of Co (II), Ni (II) and Cu (II) complexes with new Schiff base ligand. Journal of Molecular Liquids, 326, 115223.

[20] Zaidan, M. R., Noor Rain, A., Badrul, A. R., Adlin, A., Norazah, A., & Zakiah, I. (2005). In vitro screening of five local medicinal plants for antibacterial activity using disc diffusion method. Trop biomed, 22(2), 165-170.

[21] Ommenya, F. K., Nyawade, E. A., Andala, D. M., & Kinyua, J. (2020). Synthesis, Characterization and Antibacterial Activity of Schiff Base, 4-Chloro-2-{(E)-[(4-Fluorophenyl) imino] methyl} phenol Metal (II) Complexes. Journal of Chemistry, 2020(1), 1745236.

[22] Orlova, N., Nikolajeva, I., Pučkins, A., Belyakov, S., & Kirilova, E. (2021). Heterocyclic schiff bases of 3-Aminobenzanthrone and their reduced analogues: Synthesis, properties and spectroscopy. Molecules, 26(9), 2570.

[23] Kareem, M. J., Al-Hamdani, A. A. S., Jirjees, V. Y., Khan, M. E., Allaf, A. W., & Al Zoubi, W. (2021). Preparation, spectroscopic study of Schiff base derived from dopamine and metal Ni (II), Pd (II), and Pt (IV) complexes, and activity determination as antioxidants. Journal of physical organic chemistry, 34(3), e4156.

[24] Tolan, D. A., Kashar, T. I., Yoshizawa, K., & El-Nahas, A. M. (2021). Synthesis, spectral characterization, density functional theory studies, and biological screening of some transition metal complexes of a novel hydrazide–hydrazone ligand of isonicotinic acid. Applied Organometallic Chemistry, 35(6), e6205.

[25] El Saied, F. A., Shakdofa, M. M., El Tabl, A. S., & Abd Elzaher, M. M. (2014). Coordination behaviour of N′ 1, N′ 4-bis ((1, 5-dimethyl-3-oxo-2-phenyl-2, 3-dihydro-1H-pyrazol-4-yl) methylene) succinohydrazide toward transition metal ions and their antimicrobial activities. Main Group Chemistry, 13(2), 87-103.

[26] Boghaei, D. M., Askarizadeh, E., & Bezaatpour, A. (2008). Synthesis, characterization, spectroscopic and thermodynamic studies of charge transfer interaction of a new water-soluble cobalt (II) Schiff base complex with imidazole derivatives. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 69(2), 624-628.

[27] Shakir, M., Azim, Y., & Parveen, S. (2006). Synthesis, characterization of complexes of Co (II), Ni (II), Cu (II) and Zn (II) with 12-membered Schiff base tetraazamacrocyclic ligand and the study of their antimicrobial and reducing power. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 65(2), 490-496.

[28] Mohamed, G. G., Zayed, M. A., & Abdallah, S. M. (2010). Metal complexes of a novel Schiff base derived from sulphametrole and varelaldehyde. Synthesis, spectral, thermal characterization and biological activity. Journal of Molecular Structure, 979(1-3), 62-71.

[29] Devi, J., Sharma, S., Kumar, S., Kumar, B., Kumar, D., Jindal, D. K., & Das, S. (2022). Synthesis, characterization, in vitro antimicrobial and cytotoxic studies of Co (II), Ni (II), Cu (II), and Zn (II) complexes obtained from Schiff base ligands of 1, 2, 3, 4-tetrahydro-naphthalen-1-ylamine. Applied Organometallic Chemistry, 36(8), e6760.

[30] Ferraro, J. R. (2012). Low-frequency vibrations of inorganic and coordination compounds. Springer Science & Business Media.

[31] Nakamoto, K. (2009). Infrared and Raman spectra of inorganic and coordination compounds, part B: applications in coordination, organometallic, and bioinorganic chemistry. John Wiley & Sons.

[32] Kavitha, N., & Lakshmi, P. A. (2017). Synthesis, characterization and thermogravimetric analysis of Co (II), Ni (II), Cu (II) and Zn (II) complexes supported by ONNO tetradentate Schiff base ligand derived from hydrazino benzoxazine. Journal of Saudi Chemical Society, 21, S457-S466.

[33] Hammam, A. M., El-Gahami, M. A., Khafagi, Z. A., Al-Salimi, M. S., & Ibrahim, S. A. (2015). Synthesis and characterization of some new antimicrobial transition metal complexes with 1, 2, 4-Traizole-3-thione schiff bases. J. Mater. Environ. Sci, 6(6), 1596-1605.

[34] Yousif, E., Majeed, A., Al-Sammarrae, K., Salih, N., Salimon, J., & Abdullah, B. (2017). Metal complexes of Schiff base: preparation, characterization and antibacterial activity. Arabian Journal of Chemistry, 10, S1639-S1644.