PAPER ID: 20260201031

Synthesis, Characterization and Antimicrobial Screening of 2,2'-((1E,1'E)-((4-methyl-1,3-phenylene)bis(azaneylylidene))bis(methaneylylidene))bis(4-bromophenol)) and its Cu(II) and Ni(II) Complexes

Garima[1], Ravi Kumar Rana[1]* and Niranjan Singh Rathee[2]
[1]Department of Chemistry, Baba Mastnath University, Rohtak (Haryana)-124001, India
[2]Department of Science, Jagannath University, Delhi NCR, Bahadurgarh
E-mail: garima94malik@gmail.com, drnsrathee@gmail.com
*Corresponding author: E-mail: hit.ravirana@gmail.com

Abstract: A novel Schiff base ligand *(2,2'-((1E,1'E)-((4-methyl-1,3-phenylene)bis (azaneylylidene))bis(methaneylylidene))bis(4-bromophenol))* was synthesized from condensation reaction of 5-bromo salicylaldehyde and 4-methyl -1,3-phenylenediamine in the current study. Ni(II) and Cu(II) metal complexes were prepared using the synthesized ligand. The synthesized samples were examined by Proton-NMR, Electronic, Mass, EPR, IR spectroscopy and TGA. Octahedral geometry for the metal complexes was proposed from EPR and electronic spectrum data. Using IR and NMR spectrum data, the synthesized ligand was recognized as a tetradentate ligand, with 2-N and 2-O atoms coordinating to a metal center. The antimicrobial activity of the Schiff base ligand and its metal complexes was evaluated against a variety of pathogens, including strains of fungus, Gram-positive and Gram-negative bacteria. All the samples were effective against these microorganisms, showing antibacterial and antifungal activity.

Keywords: Schiff Bases, Antimicrobial Screening, Complexes

Introduction

Schiff bases are essential chemical substances in many areas of chemistry, including inorganic, medicinal and analytical chemistry, because of their versatility. When combined with different transition metal ions, they have the capacity to create a variety of stable complexes and can function as chelating agents. As a result, metal complexes containing Schiff bases have received a lot of attention recently due to their diverse range of applications and chemical features [1,2]. Schiff bases have a general formula of RC=NR. They consist of an azomethine group that is synthesized through the condensation of primary amines and carbonyl compounds [3,4].

Schiff base ligand and their metal complex derived from Salicyaldehyde have shown remarkable potential in various field of research. Schiff bases derived from aromatic aldehydes such as salicylaldehyde and aryl amines possess a strong coordination ability and exhibit diverse coordination modes due to the presence of oxygen and nitrogen coordination sites [5]. Salicyaldehyde, also known as ortho-hydroxybenzaldehyde, serves as a significant precursor to aspirin. It plays a crucial role in the synthesis and technology involved in drug manufacturing. Furthermore, salicyaldehyde serves as a vital intermediate compound in the production of herbicides and pesticides [6]. The chelated Schiff base derived from halogenated salicyaldehyde, which contains nitrogen and oxygen donor sites, exhibits various activities such as anticancer [7], antifungal [8], antibacterial [9], antioxidant [10] and anti-inflammatory [11]. As a result, extensive research has been conducted on these compounds [12].

Schiff bases are easily prepared, have strong solubility and show structural diversity therefore they are widely used [13]. Schiff bases are utilized in industry [14] and have proven to be highly effective sensors, solar cells and catalysts. [15] Additionally, they serve as beneficial substances for environmental preservation [16] and are also useful in enantioselective epoxidation of alkenes and regioselective ring opening of epoxides [17].

Schiff base ligands and their metal complexes are widely used in various applications, and there is ongoing research to explore their potential in even more diverse areas [18].

In the current study, structure elucidation and biological activity evaluation of a novel Schiff base derived from of 4-methyl-1,3-phenylenediamine and 5 bromosalicylaldehyde have been evaluated. Additionally, four complexes of prepared Schiff bases have been prepared with Ni(II) and Cu(II). The structure of the synthesized ligand and its complexes was confirmed using various spectroscopic techniques such as IR, NMR, UV-Visible, Electronic and Mass spectra. Biological activity of Schiff base and complexes was evaluated against various bacteria and fungi.

Experimental Section

Materials and Methods

Chemicals, 4-methyl-1,3-phenylenediamine and 5-bromosalicylaldehyde, provided by Sigma-Aldrich utilised in this study. The ^{1}H- NMR spectra of the ligand complexes were obtained using an Advanced III 400MHz NMR spectrophotometer. A Perkin Elmer BX II spectrophotometer was used to record the FT-IR spectra of the ligand and its metal complexes, which were recorded in the 4000 to 400 cm^{-1} range. A Bruker A 300-9.5/12/S/W spectrophotometer was used to

record the EPR spectra of the Cu(II) complex at room temperature. Mass spectra of samples were recorded using Liquid Chromatography Mass Spectrometry SLI EX Triple TOF 5600 & 5600+ / SCIEX. UV-Visible spectra of the samples were recorded in the range of 200 to 1200 nm using a Cary 5000 UV-Vis-NIR spectrophotometer. TGA analysis of samples were performed in between 25°C to 900°C using a Simultaneous Thermal Analyzer SDT 650. The produced compounds were screened for antibacterial activity in vitro using the disc diffusion method.

Synthesis of the Schiff base

A stirred solution of 4-methyl-1,3-phenylenediamine (10 mmol, 1.22 g) in absolute ethanol was combined with a solution of 5-bromo salicylaldehyde (20 mmol, 4.02 g) in absolute ethanol, and the resultant combination was heated at 80°C for three hours. The light yellow colour precipitate was formed. After the precipitation, the solid was separated by filtration and subsequently washed multiple times with ethanol. Following the washing steps, the solid was then dried in a desiccator.

Synthesis route of metal (II) complexes

The Cu(II) and Ni(II) complexes of the prepared Schiff Base were prepared by mixing a solution of a Schiff base ligand with an ethanolic solution of metal (II) chloride in a 1:1 molar ratio of ligand to metal. The resulting mixture was stirred for half an hour and heated at 80°C for 3-4 hours until a precipitated product was formed. The mixture was allowed to cool to ambient temperature following the reaction, and the precipitate was then filtered, cleaned with ethanol, and dried in a desiccator.

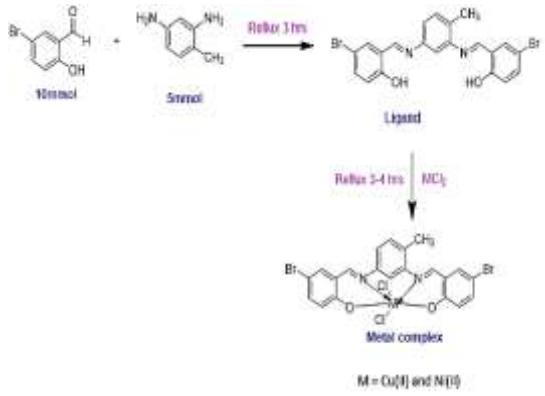

Fig. 1: Schematic representation of Schiff base (H_2L) and its metal complexes.

In vitro Antimicrobial activity

The study investigated the antimicrobial properties of a Schiff base ligand and its metal complexes against Gram-positive bacteria (*B. Subtilis and Staphylococcus aureus*), Gram-negative bacteria (*Pseudomonas aeruginosa and E. coli*), and fungi (*Candida Albicans and Aspergillus Fumigatus*). The antimicrobial and antifungal activities were tested using the agar well plate diffusion method. The process involved preparing nutrient agar or Sabouraud dextrose agar medium, inoculating it with the test microorganisms, creating wells in the agar, and adding samples of the Schiff base and its complexes at different concentrations into the wells. The plates were then incubated under optimal conditions for bacterial or fungal growth. After the incubation period, the diameter of the zone of inhibition around the wells was measured to assess the effectiveness of the samples against the microorganisms. The results indicated enhanced antimicrobial and antifungal activity of the samples, as compared to the control. The experiments were conducted in triplicate to ensure reliability, and mean values with standard deviations were reported for each sample and microbial strain.

Results and discussion

FT-IR Spectra

The infrared spectrum illustrates the functional groups present in the compound.In the FT-IR spectrum of the Schiff base ligand, a broad peak appeared at 3449cm^{-1}. This peak indicates the presence of a phenolic -OH group [19,20]. A signal at 1615 cm^{-1} in the Schiff base ligand spectrum indicated the possible presence of an azomethine group. This peak in the metal complexes was found to be between 1615 and 1602 cm^{-1}. [21]. A phenolic C-O stretching group was detected by another signal in the ligand spectra at 1276 cm^{-1} [22]. In the case of metal complexes, the phenolic C-O stretching peak moved to a lower frequency. Peak in the range 1473-1531cm^{-1} indicated the presence of C=C, and some additional peaks appeared in the range 623-628 cm^{-1} and 507-515cm^{-1} were assigned to M-O and M-N, respectively. These peaks indicate that the azomethine group of nitrogen and phenolic group of oxygen form coordination bonds with the metal ion in the metal complexes [23].

Table-1: FT-IR Spectral data of ligand and its metal complexes

	$\nu_{(C=N)}$	$\nu_{(C=C)}$	$\nu_{(C-O)}$	$\nu_{(M-O)}$	$\nu_{(M-N)}$
L	1615.30	1473	1276	-	-
Cu –	1602.00	1512.94	1255.18	623.60	507
Ni – L	1615.32	1531.02	1239.18	628.90	515

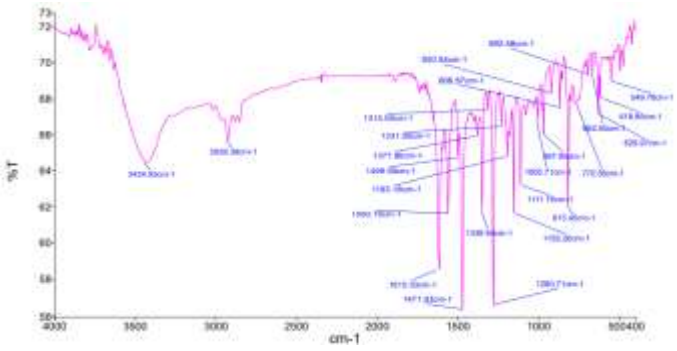

Fig. 2: FT-IR spectrum of ligand

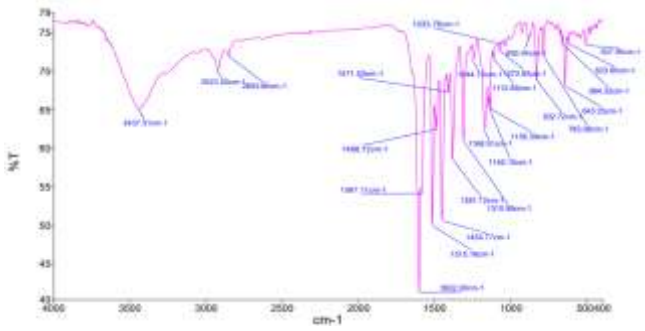

Fig. 3: FT-IR spectrum of Cu(II) - L Complex

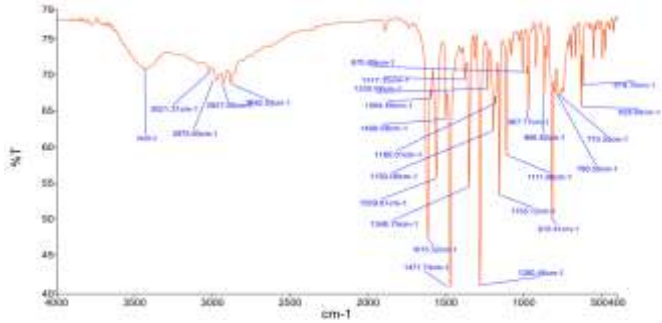

Fig. 4: FT-IR spectrum of Ni(II) -L Complex

^{1}H-NMR spectrum

The proton NMR spectra of the Schiff base ligand were shown in Fig. The spectroscopic grade solvent DMSO-d_6 was used, while TMS was used as the internal standard. The Schiff base ligand proton NMR spectrum showed a singlet signal at 9.0 ppm, indicating the existence of the azomethine proton. [24]. At 13.0 and 13.2 ppm, two singlet peaks appeared, suggesting the presence of phenolic -OH protons [25]. In the 6.9–8.0 ppm range, a multiplet was appeared that suggested the existence of aromatic protons [26].

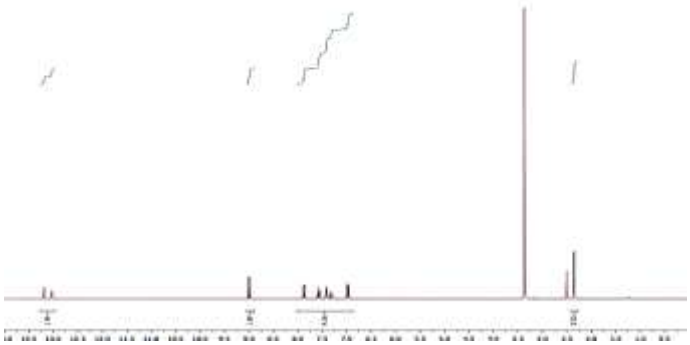

Fig.5: ^{1}H-NMR spectrum of the ligand [H_2L].

Mass Spectrometry

The synthesized Schiff base ligand mass spectra examination reveals particular peaks that provide evidence in support of the proposed formula. The Schiff base molecular ion peak is the major peak that was seen at m/z 488.18. The calculated atomic mass of the Schiff base is 488.96 amu.

According to the data collected, the measured and estimated molecular weights of the investigated substances are in good agreement. This finding provides further support for the accuracy of the proposed formula for all the compounds [28].

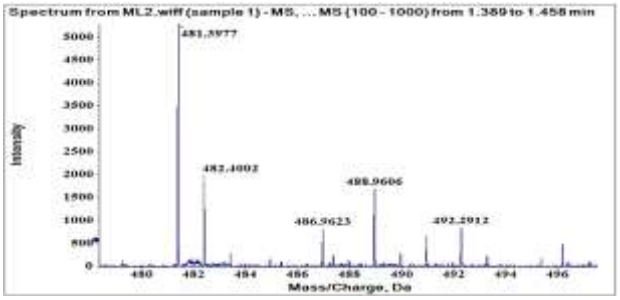

Fig. 6: Mass spectrum of ligand

UV-Visible Spectra

The UV-visible spectra of synthesized compound were recorded in DMSO and displays in the Table. In the spectrum of ligand three bands were observed at 231, 272, & 355 nm. The band at 231 nm was assigned for the benzene π-π* transition, the band at 272 nm for the azomethine group's n-π* transition, and the band at 355 nm for the phenolic group's n-π* transition [29,30]. The Cu(II) complex exhibited three bands at 225, 268 and 354 nm, and 3.85 B.M. was determined to be the measured magnetic moment. The bands at 225 & 268 nm may be caused by intraligand (π-π* & n-π*) transition, and the band at 354nm was due to LMCT transition respectively. This suggests the presence of octahedral geometry.

Three bands were identified in the Ni(II)-Schiff base complex at 227, 270 and 357 nm, and the measured magnetic moment was determined to be 2.84 B.M. The band at 357 nm corresponded to the ligand to metal charge transfer (LMCT), while the band at 227 & 270 nm was induced by the intraligand transition. This suggests the existence of octahedral geometry [20,31].

Table-2: UV-Visible spectral data of Schiff base and its Metal Complexes

Compound	Wavelength (nm)	Wavenumber (cm^{-1})	Assignment
H_2L	231 272 355	43290 36764 28169	π-π* n-π*(azomethine) n-π*(phenolic group)
Cu: L (1:1)	225 268 354	44444 37313 28248	π-π* n-π* LMCT
Ni: L (1:1)	227 270 357	44052 37037 28011	π-π* $^3A_{2g} \longrightarrow {}^3T_{1g}(P)$ LMCT

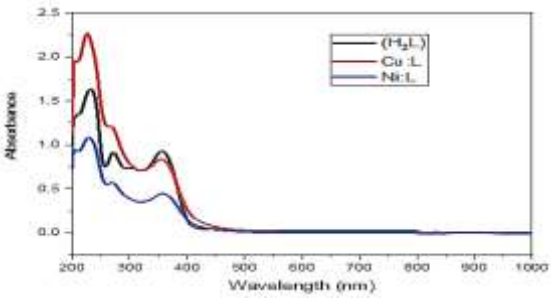

Fig. 8: UV-Visible Spectra of the Schiff base (H_2L) and its Cu(II) & Ni(II) complexes

TGA Curve

With the use of thermogravimetric analysis techniques, the behaviour of compounds towards the thermal stabilities was clarified or understood. Thermograms are a graphical representation of the thermal data were measured by keeping a heating rate 10°C / min between a range of 25 -750°C. The absence of any degradation in any part of the curve before 170°C indicates that the ligand & its complex are thermally stable up to 170°C [32,33]. In H_2L the 1st & 2nd decomposition happens between 270-455°C & 525-725 °C. Complexes almost had the same thermal behaviour. In Co: L & Ni: L complex the 1st,2nd & 3rd decomposition happens between 170-200 °C,270-350 °C & 490-740°C respectively indicating the breakdown of different molecule. These curves indicate that aqua molecule is not present in all the compound.

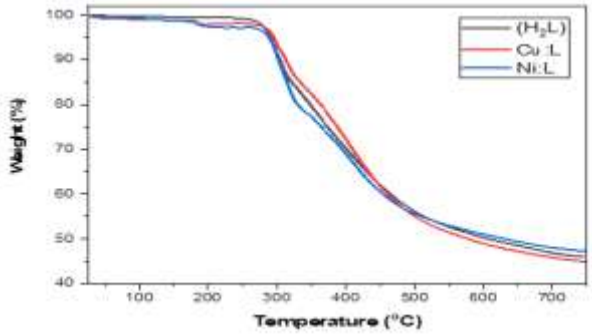

Fig. 9: TGA curve for ligand and its Cu(II) & Ni(II) metal complexes

EPR Spectrum of Cu(II) complex

The EPR spectrum of Cu(II) complex provides the information of metal ion environment. The EPR spectra were captured at room temperature. The isotropic, non-hyperfine signal splitting EPR spectra are given in Fig.10. From the spectrum the calculated g_{iso} value is 1.97. The g_{iso} value demonstrating that the environment around the Cu ion is symmetrical along its principal axis and the geometry is octahedral [35].

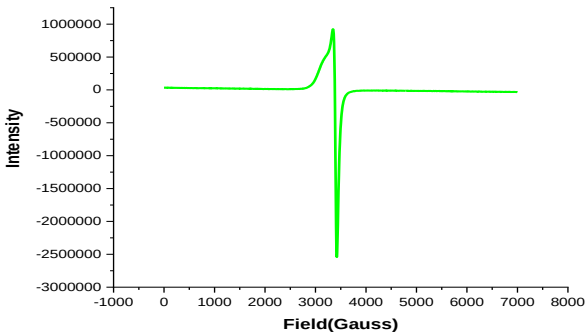

Fig. 10: EPR spectrum of the ligand (H_2L) at room temperature

Antimicrobial Activity

The antibacterial and antifungal activity of all samples shown in Table-3 & 4. The zones of inhibition of all sample for different bacteria and fungi were recorded and compared with standard bacterial drug Streptomycin and standard fungal drug Itraconazole. All the sample shows antimicrobial activity.

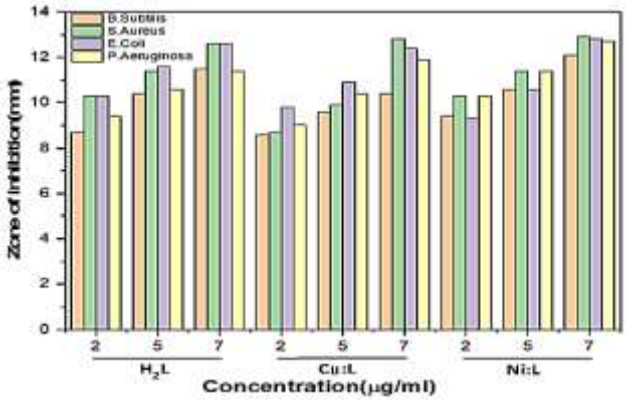

Fig. 11: Antibacterial activity of ligand and its Cu(II) & Ni(II) metal complexes

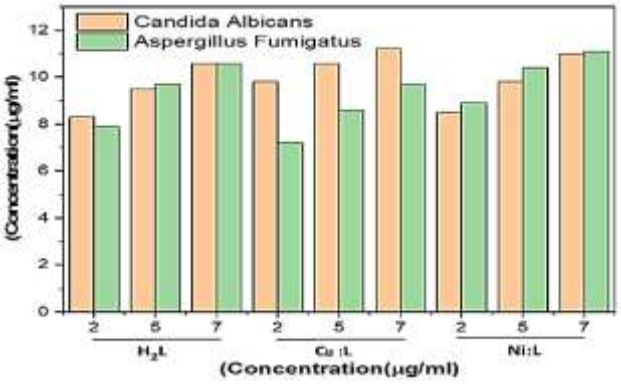

Fig. 12: Antifungal activity of ligand and its Cu(II) & Ni(II) metal complexes

Conclusion

Novel Schiff base and its complexes with Cu(II) and Ni(II) have been synthesized and analyzed in the current study. A number of methods, including IR, mass, proton-NMR, EPR, electronic spectroscopy, and TGA were used during the characterization procedure. The octahedral geometry of all the produced metal

complexes was revealed by the UV and EPR spectra. ^{1}H-NMR and FT-IR spectroscopy provided confirmation of the tetradentate binding site between the synthesized ligand and the metal ions by demonstrating bonding between the metal ion and 2-N and 2-O atoms. All of the sample's molecular weight and formula were determined using mass spectra. All compounds show antimicrobial activity.

References

1. T. A. Alorini, A. N. Al-Hakimi, S. El- Sayed Saeed, E. H. L. Alhamzi, Abuzar E.A.E. Albadri, Synthesis, characterization and anticancer activity of some metal complexes with a new Schiff base ligand. Arab. J. Chem. 15, 103559, **2022.**
2. M. S. Nair, D. Arish, R. S. Joseyplus, synthesis, characterization, antifungal, antibacterial and DNA cleavage studies of some heterocyclic Schiff base metal complexes. J. Saudi Chemical Society 16(1), 83, **2013.**
3. A.K. Ibrahim, B. A. Yusuf, A. Hamisu, Synthesis, characterization and antimicrobial studies of Cu (II) and Zn (II) complexes with the Schiff base N-salicylidene-4-chloroaniline. J. ChemSearch 8(2), 68, **2017.**
4. M. Chaurasia, D. Tomar and S. Chandra. Synthesis, spectroscopic characterization and DNA binding studies of Cu (II) complex of Schiff base containing benzothiazole moiety. J. Taibah University For Science. 13(1) 1050, **2019.**
5. Xin Li, Z. Liu, Y. Xiu, D. Wang. Synthesis, Crystal Structure and Hydrolysis Activity of a Novel Hetrobinuclear Cobalt (III) Sodium (I) Schiff base Complex. J. of Inorganic Biochemistry 171, 37, **2017.**
6. E. I. Obasuyi, O. Iyekowa. Synthesis, Characterization and Antimicrobial of Schiff Base from 5-Bromo-Salicylaldehyde and P-Toluidine J. Appl. Sci. Environ. Manage. 22 (11), 1733, **2018.**
7. P. Kavitha, K. L. Reddy, Pd (II) complexes bearing chromone based Schiff base: Synthesis, characterization and biological activity studies. Arab. J. Chem. 9,640, **2016.**
8. H. Karger, A. A. Ardakani, M. N. Tahir, M. Ashfaq, K. S. Munawar, Synthesis, spectral characterization, crystal structure determination and antimicrobial activity of Ni (II), Cu (II), Zn (II) complexes with the Schiff base ligand derived from 3,5-dibromosalicyladehyde. J. Mol. Str.1229,129842, **2020.**
9. M.M. Miloud, MM El-ajaily, TH Al- noor, NS Al-barki, Antifungal activity of some mixed ligand complexes incorporating Schiff bases. J. Bacterial Mycol 7(1), 1122, **2020**.
10. H. Keypour, M. Mahmoudabadi, A. Shooshtatri, M. Bayat, E. Saltani, R. Karamian, S.H.M. Farida. Synthesis, spectral, theoretical and antioxidant studies of copper (II)and Cobalt (III) macrocyclic Schiff base complexes containing homopiperazine moiety. Chem. Data Collect,26,100354,**2020.**
11. H. B. Howsaui, A. A. Sharfalddin, M. H. Abdellattif, A. S. Basaleh, M. A. Hussien. Synthesis, spectroscopic characterization and biological studies of Mn (II), Cu(II), Ni (II), Co(II) and Zn(II) complexes with new Schiff base of 2-((Pyrazine-2-ylimino) methyl) phenol. J. applied science 11,9067, **2021.**
12. E. Yousif, A. Majeed, K. A. Sammarrae, N. Salih, J. Salimon, Metal complexes of Schiff base: preparation, characterization and antibacterial activity. Arabian J. chem. 10, S-1639, **2017.**
13. O.E. Gammel, F. Sh. Mohamed, G.N.Rezk, A.E. Bindary, Synthesis, characterization, catalytic, DNA binding and antibacterial activities of Co(II), Ni(II) and Cu(II) complexes with new Schiff base ligand. J. Mol. Liquid 326 ,115223,**2021.**
14. M. A. Betiha, S.B. El-Henawy, A.M. Al-Sabagh, N.A. Negm, T. Mahmoud. Experimental evaluation of cationic-Schiff base surfactants based on 5-chloromethyl salicylaldehyde for improving crude oil recovery and bactericide. J. Mol. Liq. 316, 113862, **2020.**
15. A. Bocian, M. Skrodzki, M. Kubicki, A. Gorczynski, P. Pawluc, V. Patroniak. The effect of Schiff base ligands on the structure and catalytic activity of cobalt complexes in hydrosilylation of olefins. Appl. Catal. A Gen. 602, 117665, **2020.**
16. Zaman Brohi, R. O., Khuhawar, M. Y., Mahar, R.B. Graphene oxide functionalized with a Schiff base for the removal of Pb (II) ions from contaminated water: experimental and modeling approach. J. Chem. Technol. Biotechnol. 95, 1694, **2020.**
17. H. Naeimi, J. Safari, A. Heidarnezhad. Synthesis of Schiff base ligands derived from condensation of salicylaldehyde derivatives and synthetic diamine. J. Dyes and Pigments 73, 251, **2007.**
18. M.N. Uddin, S.S. Ahmed, and S.M. Rahatul Alam, Biomedical applications of Schiff base metal complexes. J. Coordination Chem. 73(23), 3109, **2020.**
19. F.K. Ommenya, E.A. Nyawade, D.M.Andala and J.Kinyua. Synthesis, Characterization and Antibacterial activity of Schiff base, 4- Chloro-2-E-4-Fluorophenyl imino methylphenol metal complexes. Hindawi J. Chemistry. 2020, 8, **2019.**
20. V. Govindraj, S. Ramanathan and S. Murgasen. Synthesis, Characterization, Antibacterial, Antifungal Screening and Cytotoxic Activity Of Nickel (II) Complexes with Substituted Benzylidine Aminobenzoic Acid. Pelagia Research Library Der Chemica Sinica 9(3), 736, **2018.**
21. A.M. Hammam, Z.A. Khafagi and S.A. Ibrahim. Synthesis and characterization of some new antimicrobial transition metal complexes with 1,2,4- Traizole- 3- thione Schiff bases. J. material and environmental science 6(6), 1596, **2015.**

22. N.P. Singh, U. Agarwal, A. Kumar and K. Kumar. Novel Cr (III), Co (II), Zn (II) and Cd (II) complexes of base league and derived from Salicyaldehyde and 3,4 -diaminotoluene: Synthesis, characterization and biological screening. Asian J.Chem.,32(5),1091, **2020.**
23. A.S. El-Tabl, F.A. El-Saied, W. Plass, A.N.Al-Hakimi. Synthesis, spectroscopic characterization and biological activity of the metal complexes of the Schiff base derived from phenylaminoacetohydrazide and dibenzoylmethane. Spectrochim Acta Part A Mol. Biomol. Spectrosc. 71, 90, **2008.**
24. B. Naureen, G.A. Miana, K. Shahid, M. Asghar, S. Tanveer, A. Sarwar. Iron (III) and zinc (II) monodentate Schiff base metal complexes: Synthesis, characterization and biological activities. Journal of Molecular Structure 1231, 129946, **2021.**
25. C. Selvi, D. Nartop. Novel polymer anchored Cr (III) Schiff base complexes: Synthesis, characterization and antimicrobial properties. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 95, 165, **2012.**
26. T. I. Hussein, M. A. Ahmed, I. A. Arbab, A. S. Ibrahim, M. Al-Bratty, H. A. Alhazmi and A. Najmi. Synthesis, characterization and biological activity of a Schiff base derived from o-amino benzoic acid and its Co (II), Cd (II) and Ni (II) complexes. European Journal of Chemistry 11 (1), 15-20, **2020.**
27. N. Jaiswal, A.K. Kushwaha, A. P. Singh and R.K. Dubey. Synthesis, spectroscopic characterization and computational studies of Schiff base complexes of tin (IV) chloride. Main Gp. Metal chem. 42, 28, **2018.**
28. Ahmed A. El-Sherif, Taha M.A. Eldebss. Synthesis, spectral characterization, solution equilibria, in vitro antibacterial and cytotoxic activities of Cu (II), Ni (II), Mn (II), Co (II) and Zn (II) complexes with Schiff base derived from 5-bromosalicylaldehyde and 2-aminomethylthiophene. Spectrochimica Acta Part A 79, 1803, **2011.**
29. A. M. Shaker, L. A. E. Nassr, M. S. S. Adam, and I. M. A. Mohamed, "Hydrophilicity and acid hydrolysis of water-soluble antibacterial iron (II) Schiff base complexes in binary aqueous solvents," Russian Journal of General Chemistry,83 (12), 2460, **2013.**
30. D. M. Boghaei, E. Askarizadeh, and A. Bezaatpour. "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, **2008.**
31. T. Sujeshwari, E. Akila & P. Maheswaran. Effective Biopotencial properties of novel Schiff base Metal(II) complexes derived from (1-Methyl-4-nitro-benzene(2-imino-1,2-dihydro-indol-3- ylidene)-(4-nitro-phenyl)-amine) European Journal of Molecular & Clinical Medicine 07, 2515, **2020.**
32. Wail Al Zoubi, Abbas Ali Salih Al-Hamdani, Susan Duraid Ahmed, Young Gun Ko. Synthesis, characterization, and biological activity of Schiff bases metal complexes. J Phys Org Chem.,31(2); e3752, **2017.**
33. A.Z. El-Sonbati, W.H. Mahmoud, Gehad G. Mohamed, M.A. Diab, Sh.M. Morgan, S.Y. Abbas. Synthesis, characterization of Schiff base metal complexes and their biological investigation Applied Organometallic Chemistry 33(9), e5048, **2019.**
34. J.S. Kumaran, S. Priya, N. Jayachandramani, and S. Mahalakshmi. Synthesis, Spectroscopic Characterization, and Biological Activities of Transition Metal Complexes Derived from a Tridentate Schiff base. J. of Chemistry 2013, 10, **2012.**
35. N. Kavitha, P.V. Anantha Lakshmi. Synthesis, Characterization and thermogravimetric analysis of Co (II), Ni (II), Cu (II) & Zn (II) complexes supported by ONNO tetradentate Schiff base ligand derived from hydrazine benzoxazine. J. Saudi Chemical Society 21, S457, **2017**.