



Original Research Article

Synthesis, Characterization and Antibacterial Activity of Semicarbazide Based Schiff Bases and their Pb(II), Zr(IV) and U(VI) Complexes

Chandra Mohan^{1,*}, Vinod Kumar², Neeraj Kumari¹, Sarla Kumari³, Jatin Yadav¹, Tarun Gandass¹, Sonam Yadav¹

¹Department of Chemistry, SBAS, K. R. Mangalam University, Gurugram 122103, India

²Department of Pharmacy, SMAS, K. R. Mangalam University, Gurugram 122103, India

³Department of Chemistry, S. P. C. Government College, Ajmer 305001, India

ARTICLE INFO

Article history

Submitted: 2020-05-23

Revised: 2020-07-13

Accepted: 2020-08-11

Available online: 2020-09-04

Manuscript ID: [AJCB-2005-1037](#)

DOI: [10.22034/ajcb.2020.113663](https://doi.org/10.22034/ajcb.2020.113663)

KEYWORDS

Semicarbazide,
Ligand,
Schiff base,
Antibacterial activity
Bacterial strain

ABSTRACT

Schiff bases are compounds with the general structure $R_2C=NR'$. They can be prepared by the condensation of the primary amines with carbonyl compounds. In this paper, we have synthesized new Schiff base ligand (L) by reacting semicarbazide with 2-acetylthiophene in ethanol solvent and its metal complexes have also been synthesized by using Zr^{4+} , Pb^{2+} and U^{6+} ions. Schiff bases of semicarbazide are often having promising biological activities like anti-inflammatory, antidepressant, antiglycation, antibacterial, etc. Schiff base ligand and metal complexes were characterized and have shown appropriate results when analyzed on UV-Vis., NMR, FT-IR and antibacterial activities. They were tested against gram- negative [*E. Coli*. (MTCC No: 452)] and gram- positive [*Bacillus sp* (MTCC No: 297)] bacterial strains by using Kirby-Bauer's method. Schiff base complexes of Zirconium [$Zr(L)_4Cl_2$] and lead [$Pb(L)_2Cl_2$] were found to be more active against both bacterial strains having a zone of inhibition 11.14 ± 0.2 & 10.23 ± 0.5 mm and 12.02 ± 0.3 & 11.05 ± 0.3 mm on *E. Coli*. and on *Bacillus* species respectively.

* Corresponding author: Chandra Mohan

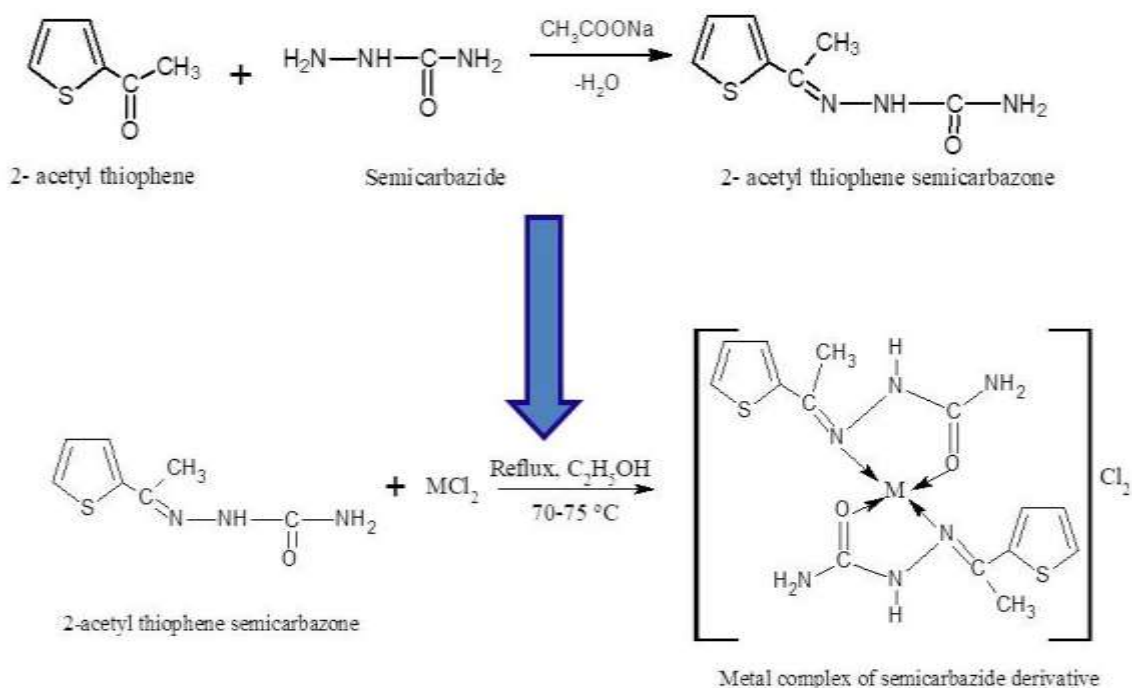
✉ E-mail: chandra.mohan@krmangalam.edu.in

☎ Tel number: +91 9999825418

© 2020 by SPC (Sami Publishing Company)



GRAPHICAL ABSTRACT



Introduction

From past few decades, coordination chemistry has been enriched due to synthesis of various types of coordination complexes where metal ions are coordinated with various types of ligands [1]. In coordination chemistry, Schiff bases are generally known to combine with various metal ions which make them very useful as stereospecific catalysts for the oxidation, reduction, hydrolysis, biological activity and many other reactions in organic and inorganic chemistry [2, 3]. Schiff base plays a vital role in designing metal complexes which proved significant to synthetic chemistry and as natural oxygen carrier [4-6].

Schiff bases are the compound containing azomethine group ($-\text{HC}=\text{N}-$) and was first reported in 1864 by Hugo Schiff [7]. They are usually prepared by the condensation of carbonyl compounds with primary amines in the presence of acid or base catalyst and heating the mixture. The common structural

features of these compounds are azomethine group with a general formula $\text{R}_2\text{C}=\text{NR}'$ where, R and R' are alkyl, aryl, cycloalkyl or heterocyclic groups and substituted derivatives [8]. Schiff base complexes with specific metal ions such as Ag(II), Au(II), Ni(II), Al(III), Cu(II), Gd(III), Y(III) show excellent catalytic activity in various types of reactions that occurs at high temperature ($> 100^\circ\text{C}$) and in the presence of moisture [9].

The application of Schiff bases is found in the food industry, dye industry, analytical chemistry, as catalysts, fungicidal, agrochemical and as biologically active compounds. In recent years, attention on Schiff bases and their metal complexes are increasing due to their remarkable biological and pharmacological applications [10-14].

In continuation of this approach, the present paper describes the synthesis, characterization and antibacterial activity of 2-acetylthiophene (L) based Schiff bases and their Pb(II), Zr(IV) and U(VI) complexes. The antibacterial

activities are shown by gram positive (*Bacillus* sp) and gram negative bacteria (*E. Coli.*).

Researchers from various fields are working on the synthesis and characterization of transition metal complexes with semicarbazones but only a few works have shown satisfactory results on the antibacterial activity of Pb(II), Zr(IV) and U(VI) complexes synthesized by using different substituted semicarbazone ligands.

Materials and Methods

Chemicals and Apparatus

All required chemicals used in the present work were of analytical grade (AR) and in their purest form. It includes Semicarbazide (CDH), Sodium acetate (CDH), Ethanol, 2-acetylthiophene (CDH), Lead Chloride (E. Merck), Uranyl acetate (CDH) and Zirconium Oxychloride (CDH).

The C, H, N and S were analyzed on Vario Micro Cube elemental analyzer (Model Vario-III). ^1H and ^{13}C NMR spectra were recorded on a Bruker (Model DPX-300) NMR spectrophotometer using DMSO as solvent. The IR spectra were recorded in KBR matrix using Perkin Elmer FT-IR spectrophotometer (Model No. BX-2) in the wavenumber range of 4000 cm^{-1} to 400 cm^{-1} employing a total of 64 scans collected at 4 cm^{-1} resolution.

The UV-Visible spectra were recorded on Shimadzu UV-Vis. Spectrophotometer (Model No. UV-2600) in the wavelength range of 200 cm^{-1} to 800 cm^{-1} .

Ligand and Complex Preparation

2-acetylthiophene semicarbazone ligand (L) [15]

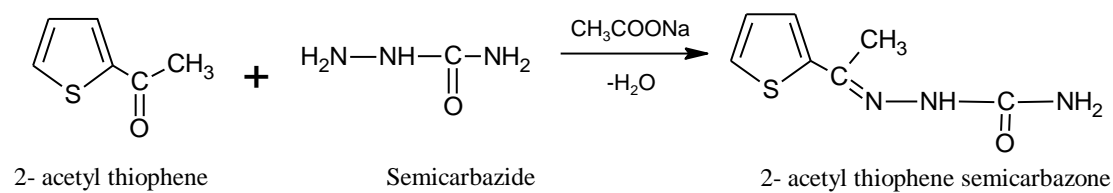
1.12 gm of semicarbazide hydrochloride mixed with 0.82 gm of sodium acetate in 30 mL ethanol solvent in a round bottom flask. This mixture was heated till it completely dissolved. An ethanolic solution of 1.26 mg thiophene-2-aldehyde then added dropwise with constant stirring into this mixture and refluxed for about 2 h at $40\text{--}50\text{ }^\circ\text{C}$. The product was filtered and washed with 50% ethanol, dried and recrystallized using methanol solvent (Scheme 1). Yield (90.0%), mp: $190\text{ }^\circ\text{C}$.

Synthesis of metal complexes [16,17]

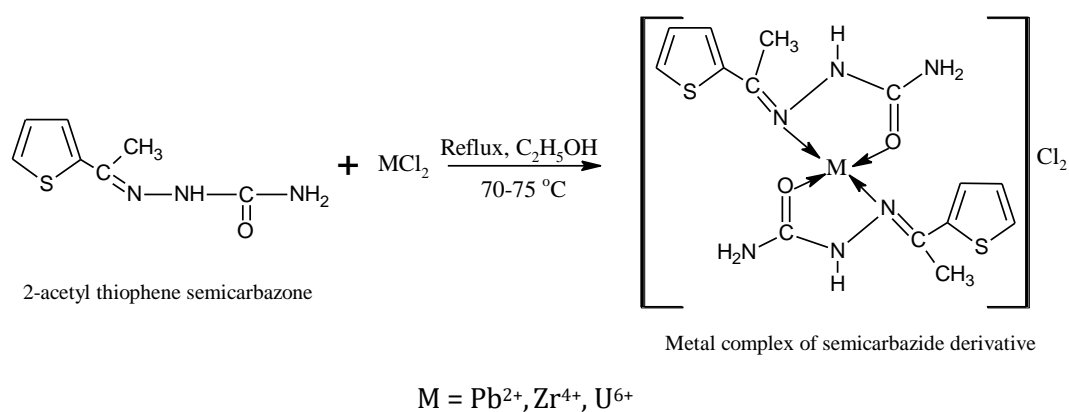
The metal complexes (Scheme 2) were prepared by adding a hot aqueous solution of metal ion (0.01 M) into the hot ethanolic solution (0.02 M) of ligand L dropwise with constant stirring. The mixture was refluxed for 6-7 h at $70\text{--}75\text{ }^\circ\text{C}$. The metal complex was precipitated, filtered, washed with 50% ethanol and dried over anhydrous calcium chloride and then recrystallized from methanol.

Antibacterial studies

Synthesized Schiff base ligand L and their metal complexes were further analyzed against gram negative [*E. Coli.* (MTCC No: 452)] and gram positive [*Bacillus* sp (MTCC No: 297)] bacterial strains through Kirby's method [18]. All microbial strains were cultivated and maintained in standard laboratory conditions throughout the experiment. Schiff base ligand and metal complexes were also tested ($100\text{ }\mu\text{g/mL}$) against positive control (Ampicillin, $10\text{ }\mu\text{g/mL}$) (Figure 1 & 2)



Scheme 1. Synthesis of 2-acetylthiophene semicarbazone (L)



Scheme 2. Synthesis of metal complexes $[\text{M}(\text{L})_2]\text{Cl}_2$



Figure 1. Zone of inhibition against *Escherichia coli* genus



Figure 2. Zone of inhibition against *Bacillus sp* genus

Statistical analysis

Values of antibacterial assay were expressed as mean \pm standard deviation (SD) and analyzed by using one-way ANOVA method followed by Tukey's test. The value of $p < 0.05$ was considered as statistically significant.

Results and Discussion

The Schiff base ligand and their metal complexes were characterized by various analytical methods such as FT-IR, UV-Vis., NMR and C, H, N, S elemental analysis. Pre-confirmatory test for the synthesis of ligand was done through UV-Vis. and IR spectra. The composition of the compound was confirmed by ^1H NMR, and CHN analysis [15,19].

2-acetylthiophene semicarbazone (L)

CHNS Analytical calculation for $\text{C}_7\text{H}_9\text{N}_3\text{O}_2\text{S}$ (%): C, 45.89; H, 4.95; N, 22.94; O, 8.73 and Observed values (%): C, 45.68; H, 5.08; N, 22.82; O, 8.54.

The UV spectra of the ligand L shows 3 bands (λ_{max}) at 210, 297 and 329 nm. The first two bands at 210 and 297 nm were attributed to $\pi \rightarrow \pi^*$ transitions of the aromatic ring, and ketonic moieties, respectively [20]. The other band at 329 nm was due to $n \rightarrow \pi^*$ associated with the azomethine linkage [21,22].

FT-IR spectra for the ligand L is given in Figure 3. Infrared spectra of the ligands shows the IR bands at 3471 cm^{-1} and 3147 cm^{-1} were assigned to symmetric or asymmetric $\nu(\text{NH}_2)$ stretching and $\nu(\text{N-H})$ vibration of free NH_2

groups [23,24]. The spectrum also shows bands at 1592 and 1702 cm^{-1} due to the $\nu(\text{C=N})$ & $\delta(\text{C=O})$ groups respectively [25-30].

The ^1H NMR spectra of the ligand (Figure 3) are given as (ppm) δ 9.13 (s, >NH); δ 5.98 (s, $\text{H}_2\text{N-CO}$); δ 2.18 (s, $\text{H}_3\text{C-C}$); δ 6.91-7.21 (m, Ar-H) [31].

Metal complexes of 2-acetylthiophene semicarbazone

The UV spectra of metal complexes containing ligand shows λ_{max} at 317, 320 and 312 nm for $[\text{Zr}(\text{L})_4]\text{Cl}_2$, $[\text{Pb}(\text{L})_2]\text{Cl}_2$ and $[\text{U}(\text{L})_3]\text{Cl}_2$ complexes respectively which is due to $n \rightarrow \pi^*$. The shifts in λ_{max} value in metal complexes were observed due to the coordination of metal ions with ligand. In FT-IR spectra of metal complexes (Figure 4-6), the position of vibration band due to azomethene moiety ($>\text{C=N}$) at 1592 cm^{-1} shifted towards lower side, i.e. 1485 cm^{-1} , 1495 cm^{-1} , 1465 cm^{-1} and ($>\text{C=O}$) at 1702 cm^{-1} is shifted towards lower side at 1593 cm^{-1} for Pb^{2+} , Zr^{4+} and U^{6+} complexes respectively [26-28]. This indicates that the coordination took place through the nitrogen atom of imine groups and the oxygen atom of the cationic group ($>\text{C=O}$) [32-34]. Thus the ligand coordinates through sulphur and oxygen with central metal ion in complexes.

In the ^1H - NMR spectrums, signals due to -NH and $-\text{NH}_2$ in ligand shifted after complexation with metal ions. This indicates the participation of nitrogen and ketonic oxygen in bonding with metal (Figure 4-6).

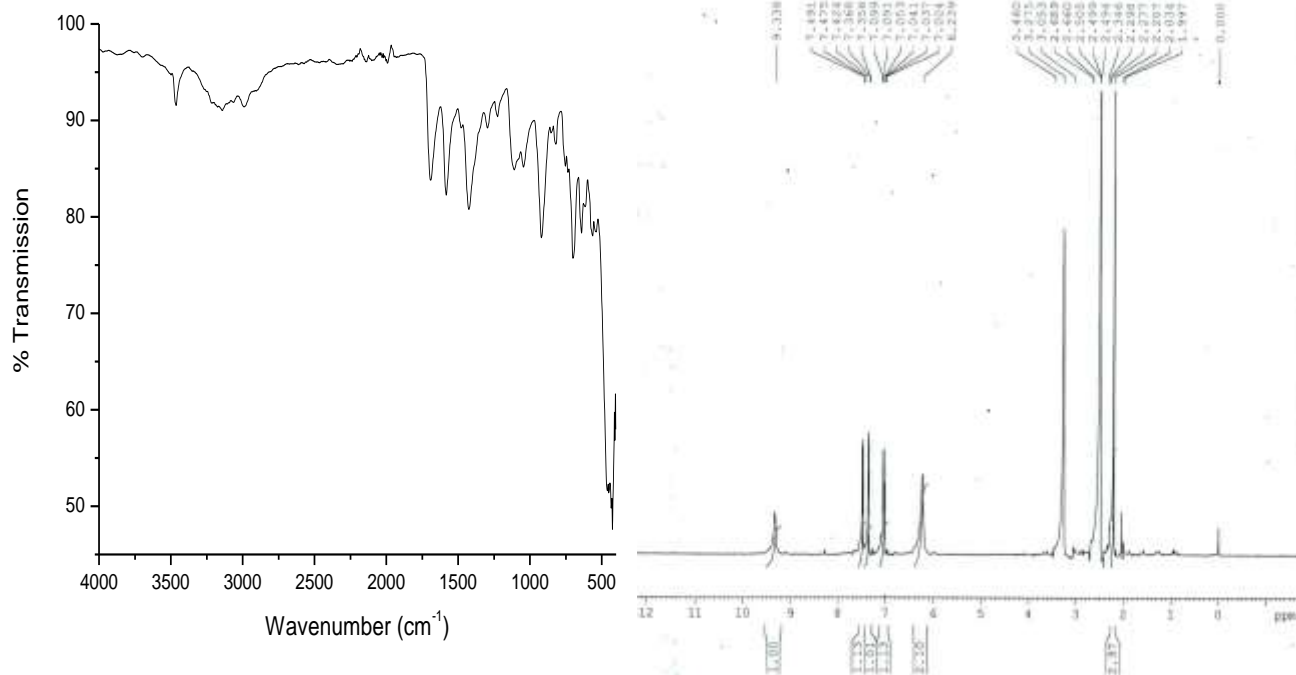


Figure 5. FT-IR and ¹H NMR spectrum of Zirconium (IV) complex with ligand L

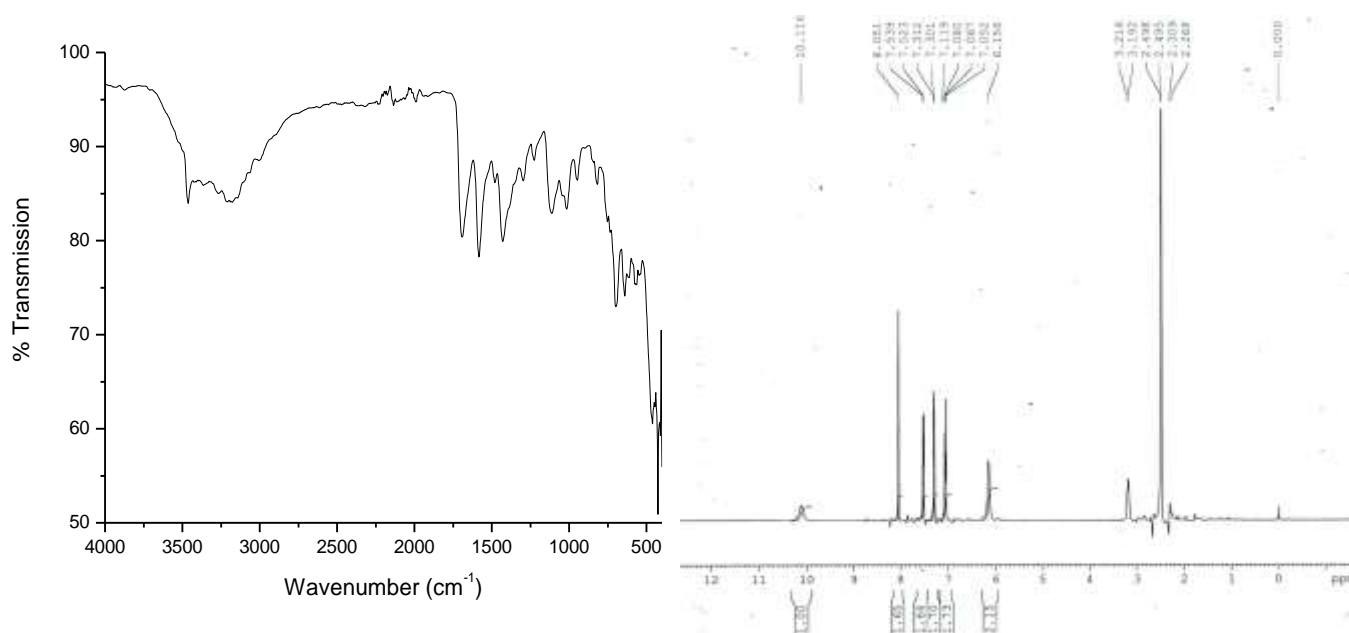


Figure 6. FT-IR and ¹H NMR spectrum of Uranium (VI) complex with ligand L

Table 1. % Inhibition of ligand and its complexes against *E. Coli.* and *Bacillus sp.*

Ent ry	Treatment	Zone of Inhibition (Diameter in mm)		
		Concentration (in µg)	Escherichia coli	Bacillus sp
1.	Normal control	-	1.3 ± 0.4	1.4 ± 0.2
2.	Ampicillin	10	14.22 ± 0.7 ^a	13.23 ± 0.7 ^a
3.	L	100	5.5 ± 0.3 ^a	2.2 ± 0.6 ^a
4.	[Zr(L) ₄]Cl ₂	100	11.14 ± 0.2 ^a	10.23 ± 0.5 ^a
5.	[U(L) ₃]Cl ₂	100	2.03 ± 0.3 ^a	4.8 ± 0.8 ^a
6.	[Pb(L) ₂]Cl ₂	100	12.02 ± 0.3	11.05 ± 0.3 ^a

^aAll data has represented as mean ± SD. a = p < 0.05 vs normal control, b = p < 0.05 vs standard concentration (10 µg) of ampicillin in respective bacterial strain.

Assessment of antibacterial assay

The synthesized ligand and metal complexes shows significant antibacterial activity [19] at the concentration of 100 µg/ mL (Table 1). The antibacterial activity analysis of all compounds has shown in Figure 12 & 13 and results revealed that the Zirconium [Zr(L)₄]Cl₂ and lead [Pb(L)₂]Cl₂ metal complexes has shown excellent antibacterial activity having a zone of inhibition as 11.14 ± 0.2 & 10.23 ± 0.5 mm and 12.02 ± 0.3 & 11.05 ± 0.3 mm against *E. Coli.* and *Bacillus* species respectively.

CONCLUSION

In the present work we have successfully synthesized 2- acetylthiophene semicarbazone ligand and three new Zr(IV), Pb(II) and U(VI) based metal complexes. The ligand and metal complexes have been characterized by various analytical and spectral techniques. Results of analytical studies confirmed the synthesis of metal complexes. The antibacterial activity studies of the synthesized compounds, screening against *E. Coli.* and *Bacillus sp* proved that the Zr and Pb complexes exhibit significant antibacterial activity over other compounds.

Acknowledgments

The authors are thankful to the University Grant Commission, New Delhi, for providing financial assistance and the Management, K. R. Mangalam University for providing research facilities. We also express our sincere thanks to IIT Delhi and University of Delhi, for recording FT-IR and NMR spectra.

Declarations of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

REFERENCES

- [1] D.T. Sakhare, T.K. Chondhekar, S.G. Shankarwar, A.G. Shankarwar, Synthesis, characterization of some transition metal complexes of bidentate schiff base and their antifungal and antimicrobial studies, *Adv. Appl. Sci. Res.*, 6 (2015) 10-16.
- [2] K.K. Alisher, T.S. Khamza, Y.S. Ikbol, Quantum-chemical study of geometric and energy characteristics of some bases of shiff gossipol, *Prog. Chem. Biochem. Res.*, 2 (2019) 1-5.

- [3] M. Aghazadeh, Tertiary cyclic amides in Vilsmeier type reaction with indoles, *Prog. Chem. Biochem. Res.*, 2 (2019) 34-39.
- [4] K.G. Abraham, M.V. Lokhande, S. Bhusare, Synthesis and characterization of Mn (II), Co (II), Ni (II), Cu (II) and Zn (II) complexes with 4-[(E)-[(2-chlorophenyl) imino] methyl] benzene-1, 2-diamine, *Biol. Phy. Sci.*, 2 (2011) 137.
- [5] A. Nagajothi, A. Kiruthika, S. Chitra, K. Parameswari, Synthesis and characterization of tetradentate Co (II) schiff base complexes: antimicrobial and DNA cleavage studies, *Int. J. Res. Pharm. Biomed. Sci.*, 3 (2012) 1768-1778.
- [6] Y.K. Gupta, S.C. Agarwal, S.P. Madnawat, R. Narain, Synthesis, characterization and antimicrobial studies of some transition metal complexes of schiff bases, *Res. J. Chem. Sci.*, 2 (2012) 68-71.
- [7] A. Xavier, N. Srividhya, Synthesis and study of schiff base ligands, *J. Appl. Chem.*, 7 (2014) 6-5.
- [8] S.T. Gebreyesus, M.A. Khan, An overview on metal complexes of selected schiff-bases with their electrochemical and sensor aspects, *J. Chem. Chemical Sci.*, 5 (2015) 19-27.
- [9] M.A. Ashraf, K. Mahmood, A. Wajid, Synthesis, characterization and biological activity of schiff bases, *Int. Proc. Chem. Biol. Envir. Eng.*, 10 (2011) 1-7.
- [10] A. Prakash, D. Adhikari, Application of schiff bases and their metal complexes-a review, *Int. J. ChemTech Res.*, 3 (2011) 891-896.
- [11] K. Kiranmai, Y. Prashanthi, N.J.P. Subhashini, **Shivaraj**, Synthesis, characterization and biological activity of metal complexes of 3-amino-5-methyl isoxazole schiff bases, *J. Chem. Pharm. Res.*, 2 (2010) 375-384.
- [12] N.V. Harohally, C. Cherita, P. Bhatt, K.A. Anu Appaiah, Antiaflatoxic and antimicrobial activities of schiff bases of 2-hydroxy-4-methoxybenzaldehyde, cinnamaldehyde, and similar aldehydes, *J. Agr. Food Chem.*, 65 (2017) 8773-8778.
- [13] R. Arshad, I.H. Bukhari, F. Anum, Z. Aftab, Z. Noreen, Synthesis, spectral and biological studies of transition metal complexes of schiff base derived from ofloxacin, *Int. J. Adv. Res. Biol. Sci.*, 3 (2016) 99-108.
- [14] V.G. Deshpande, S. Shah, M.M. Deshpande, S.I. Habib, P.A. Kulkarni, Synthesis and antimicrobial evaluation of schiff bases derived from 2-amino-4, 6-dimethyl benzothiazole with 2-hydroxy-naphthalene-1-carbaldehyde, 3-methyl-thiophene-2-carbaldehyde and their metal complexes, *Int. J. Pharm.Chem. Sci.*, 2 (2013) 801-807.
- [15] C. Mohan, K. Sharma, S. Chandra, Cd (II) ion-selective electrode based on 2-acetylthiophene semicarbazone in polymeric membrane, *Anal. Bioanal. Electrochem.*, 9 (2017) 35-46.
- [16] N.L. Mary, G. Parameswaran, Kinetics and mechanism of thermal decomposition of schiff base complexes of lanthanum and cerium by TG studies, *Syn. React. Inorg. Metal-Org. Chem.*, 23 (1993) 1209-1227.
- [17] N.L. Mary, G. Parameswaran, Physicochemical studies and thermal decomposition kinetics of cobalt (II) and nickel (II) complexes of acetylacetoneaminofluorene, *Croatica Chemica Acta*, 66 (1993) 355-362.
- [18] V. Kumar, A.K. Sharma, S.K. Rajput, M. Pal, N. Dhiman, Pharmacognostic pharmacological evaluation of *Eulaliopsis binata* plant extracts by measuring in vitro/in vivo safety profile and anti-microbial potential, *Toxic. Res.*, 7 (2018) 454-464.
- [19] C. Mohan, V. Kumar, S. Kumari, Synthesis, characterization, and antibacterial activity of Schiff bases derived from thiosemicarbazide, 2-acetyl thiophene and thiophene-2 aldehyde, *Int. Res. J. Pharm.*, 9 (2018) 153-158.
- [20] G. Eisenmann, The electrochemistry of cation selective glass electrodes in advances in analytical chemistry and instrumentation, John Wiley and Sons, New York (1965).

- [21] G. Eisenmann, Glass electrodes for hydrogen and other cations: Principles and Practice, Marcel Dekker Inc., New York (1967).
- [22] H.J.C. Tendeloo, A new and easy method for the potentiometric determination of calcium concentrations in solutions, *J. Biol. Chem.*, 113 (1936) 197-204.
- [23] J.M. Ramosa, R.M. Viana, C.A. Tellez, Infrared spectrum, DFT: pBP86/DN** and NCA vibrational calculations of 2-methylthiosemicarbazide copper(II) nitrate [Cu(2MeTSC)2(NO3)2], *Spectrochim. Acta A*, 65 (2006) 433-438.
- [24] R.C. Maurya, D.D. Mishra, Synthesis and characterization of some novel mixed-ligand cyanonitrosyl {CrNO}-5 heterocomplexes of chromium (I) with potentially tridentate benzothiazole derivatives, *Syn. React. Inorg. Metal-Org. Chem.*, 22 (1992) 1227-1237.
- [25] S. Jayasree, K.K. Aravindakshan, Synthesis, characterization and antitumour studies of metal chelates of acetoacetanilide thiosemicarbazone, *Trans. Metal Chem.*, 18 (1993) 85-88.
- [26] S. Chandra, U. Kumar, Spectral studies of coordination compounds of cobalt (II) with thiosemicarbazone of heterocyclic ketone, *Spectrochim. Acta A*, 62 (2005) 940-944.
- [27] S. Chandra, L.K. Gupta, EPR, IR and electronic spectral studies on Mn(II), Co(II), Ni(II) and Cu(II) complexes with a new 22-membered azamacrocyclic [N4] ligand, *Spectrochim. Acta A*, 60 (2004) 1751-1761.
- [28] E. Keskioglu, A.B. Gunduzalp, S. Cete, F. Hamucru, B. Erk, Cr(III), Fe(III) and Co(III) complexes of tetradentate (ONNO) schiff base ligands: synthesis, characterization, properties and biological activity, *Spectrochim. Acta A*, 70 (2008) 634-660.
- [29] S. Chandra, L.K. Gupta, U. Banzal, Spectroscopic approach in the characterization of the copper (II) complexes of isatin-3, 2'-quinolyl-hydrazones and their adducts, *Spectrochim. Acta A*, 65 (2006) 463-466.
- [30] A Castineiras, R. Carballo, T. Perez, Synthesis and structural characterization of complexes of Zn(II), Cd(II) and Hg(II) halides with 2-formylpyrrole thiosemicarbazone and 2-acetylpyrrole thiosemicarbazone, *Polyhedron*, 20 (2001) 441-448.
- [31] S. Mundwiler, L. Candrea, P. Häfliger, K. Ortner, R. Alberto, Preparation of NO-carrier-added technetium-99m complexes via metal-assisted cleavage from a solid phase, *Bioconjug. Chem.*, 15 (2004) 195-202.
- [32] M. Joseph, V. Suni, M.R.K. Prathapachandra, M. Nethaji, A. Kishore, S.G. Bhat, Structural, spectral and antimicrobial studies of copper (II) complexes of 2-benzoylpyridine N(4)-cyclohexylthiosemicarbazone, *Polyhedron*, 23 (2004) 3069-3080.
- [33] D. Gambino, L. Otero, M. Vieitesa, M. Boiani, Vibrational spectra of palladium 5-nitrofuryl thiosemicarbazone complexes: experimental and theoretical study, *Spectrochim. Acta A*, 68 (2007) 341-348.
- [34] M.F. Belicchi, G.F. Gasparri, E. Leporati, C. Pelizzi, P. Tarasconi, Thiosemicarbazones as co-ordinating agents: solution chemistry and x-ray structure of pyridoxal thiosemicarbazone trihydrate and spectroscopic properties of its metal complexes, *J. Chem. Soc., Dal. Trans.*, 11 (1986) 2455-246.

HOW TO CITE THIS ARTICLE

Chandra Mohan, Vinod Kuma, Neeraj Kumari, Sarla Kumari, Jatin Yadav, Tarun Gandass, Sonam Yadav, Synthesis, Characterization and Antibacterial Activity of Semicarbazide Based Schiff Bases and their Pb(II), Zr(IV) and U(VI) Complexes, *Ad. J. Chem. B*, 2 (2020) 187-196.

DOI: 10.22034/ajcb.2020.113663

URL: http://www.ajchem-b.com/article_113663.html

