Journal of Science and Technology
ISSN: 2456-5660 Volume 7, Special Issue 03 (MAY 2022)

www.jst.org.in *DOI:https://doi.org/10.46243/jst.2022.v7.i03.pp60-68*

Synthesis, Characterization and Antimicrobial Evaluation of a new Macrocyclic Ligand and Its Co (II), Ni (II,) Cu (II) and Zn (II)Complexes

Sopan A. Najan[1], Babasaheb S. Zine[2], Sunil G.Shankarwar [3]

[1]*(Department of Chemistry, Arts, Commerce and Science College, Sonai Tal. Newasa, Dist. Ahmednagar, Maharashtra, India.)*

[2](Department of Chemistry, Bhagwan College, Ashti, Maharashtra, India*)*

[3](Department of Chemistry, Dr. B. A. Marathwada University, Aurangabad, Maharashtra, India*)*

Corresponding Author: Email:najansa7@gmail.com

To Cite this Article

Sopan A. Najan, Babasaheb S. Zine Sunil G.Shankarwar *"***Synthesis, Characterization and Antimicrobial Evaluation of a new Macrocyclic Ligand and Its Co (II), Ni (II,) Cu (II) and Zn (II)Complexes***", Journal of Science and Technology, Vol. 07, Special Issue 03, May 2022.*

Article Info

Received: 17-04-2022 Revised: 8-05-2022 Accepted: 10-05-2022 Published: 21-05-2022

Abstract:*Coordination complexes derived from macrocyclic ligand metal complexes of Co (II), Ni (II,) Cu (II) and Zn (II) have been synthesized. The Schiff base ligand was synthesized by condensation of 1-(5-bromo -2-hydroxyphenyl) -3- (furan -2-yl) propane -1,3-dione with o-phenylenediamine. The metal complexes ML (H_2O)nare reported and characterised by conductivity, UV- visible, FTIR, H^1NMR, TGA-DTA and XRD analysis. All the complexes were found to be non-electrolytic in nature. The ligand acts as a hexadentate and coordinates through four nitrogen atoms of azomethine groups. The antibacterial and antifungal activities of the ligand and its metal complexes, has been screened in vitro against Gentamycin, Ampicillin, Chloramphenicol, Ciprofloxacin, Norfloxacin, Nystatin and Griseofulvin used as standard drug. All these complexes show higher biological activities than standard drugs.*

Key Word*:1, 3 β- diketone o-phenylenediamine, spectral characteristic, metal nitrate, biological activity.*

Introduction

Coordination chemistry of macrocyclic ligand containing a heteroatom is important complexing agents due to their antimicrobial characteristics.The stability of macrocyclic metal complexes depends upon a number of factors such as number and type of donor atoms present in the ligand and their relative positions within the macrocyclic skeleton, as well as the number and size of the chelate ring formed on complex[1]. The marocyclic complexes are interested because there is flexibility in the preparation and study of different parameters such as ring size, the nature of donor atoms and effect of electrons on the macrocyclic ring[2].The metal complexes of Schiff bases derived from heterocyclic compounds have been the center of attraction for many researchers in recent years[3]. The various studies revel azomethine linkage (C = N) in Schiff base[4], macrocyclic ligands and their metal complexes have a wide range of biological activities[5]. Many reports have shown that some drugs have greater activity when overseen as metal complex as that as free organic compound[6]. Schiff base complexes derived from heterocyclic compounds have acquired more attention in the field of bioinorganic chemistry because of their biological activities such as antibacterial, antifungal, anticancer[7], antioxidant[8], anti-inflammatory, analgesic[9,10], antiviral activities[11], antitumor activity[12] and anticonvulsant[13]. The present investigation deals with synthesis and characterization of complexes of Co(II), Ni(II,) Cu(II) and Zn(II) by Schiff base ligand derived from 1-(5-bromo -2- hydroxyphenyl) -3- (furan -2-yl) propane -1,3-dione and o-phenylenediamine using various techniques.

Experimental

www.jst.org.in *DOI:https://doi.org/10.46243/jst.2022.v7.i03.pp60-68*

All the AR grade quality chemicals obtained from Merck chemicals were used. 1-(5-bromo -2- hydroxyphenyl) -3-(furan -2-yl) propane -1, 3-dione, o-phenylenediamine and metal nitrates of Co (II), Ni(II) Cu (II), and Zn(II). The solvents like ethanol, methanol, DMSO; DMF etc. were purified by ordinary methods.

Physical Measurements:

UV-VIS. spectra study was recorded in the region 200–900 nm for 1mM solutions in DMF at 25 ^{o}C using a Shimadzu 160 spectrophotometer. Molar conductance measurement was conducted using 10 mM solutions of the complexes in DMF on Elico – CM82 Conductivity Bridge at room temperature. Magnetic susceptibility measurement was carried out on a Gouy balance at room temperature. FT-IR spectra study was recorded in KBr medium on a Shimadzu spectrophotometer in wave number region 4000-400 cm^{-1}.^{1}HNMR and ^{13}CNMR spectra were acquired in $CDCl_3$ solution using a Brucker 500 MHz spectrometer with tetramethyl silane (TMS) as an internal standard. The magnetic susceptibility measurements were determined on a Gouy balance at room temperature using Hg [Co (SCN) $_4$] as the calibrant.

Synthesis of ligand:

A warm ethanolic solution of 30 ml of 1- (5 – bromo – 2 – hydroxyphenyl) - 3 - (furan - 2 - yl) propane - 1, 3 - dione (6.18 g 20 mmol) and a warm ethanolic solution 30 ml of o-phenylenediamine (2.16 g 20 mmol) were mixed slowly with constant stirring. This mixture was refluxed at 90 ^{o}C for 14-15 h in presence of hydrochloric acid. On cooling a solid yellow precipitate are obtained which was filtered, washed with cold ethanol and dried under vacuum over P_4O_{10} and it was recrystallized from ethanol[14,15] (yield- 60%). mp. 201 ^{o}C,

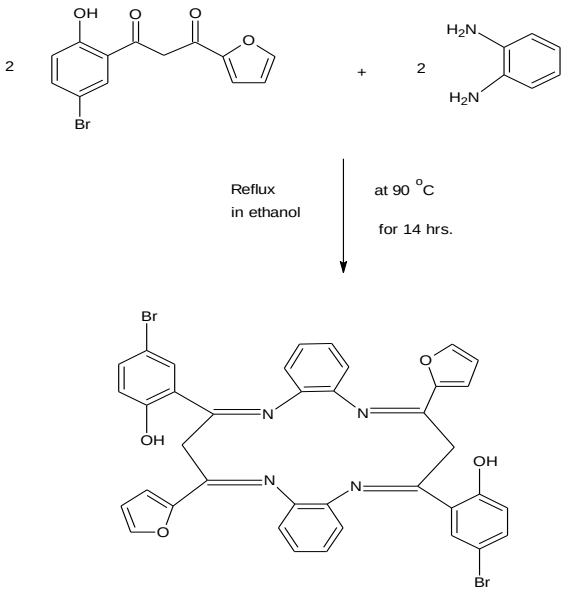

Figure 1: Synthesis of Schiff base ligand

Spectral Data of Ligand:

IR (KBr, cm^{-1}): 3267 *ν*(OH), 1670 *ν*(C=N), 536 *ν*(C-Br). ^{1}H NMR (in $CDCl_3$) in figure 2 shows δ 1.25 -1.62 ppm (m, 6H) is due to the proton at the furan ring[16], δ 2.62 ppm (s, 4H, - CH_2)[2,17,26], δ 6.62 ppm - 8.34 ppm corresponding to aromatic and phenyl ring protons (m, 14H Ar-H), δ 12.16 ppm (s, 2H, Ar-OH) [18-23]. ^{13}C-NMR spectrum in figure 3 displayed a peak at δ(157.07) ppm which is due to the C=N(azomethine group)[21,22]. The multiplet peaks at δ (111.14-147.3) ppm are due to (Ar-H) aromatic region. The signals at δ(12.74) ppm are assigned to the CH_2 in the ligand[21,23]. ESI MS (m/z) = 762 [M^{+}].

www.jst.org.in DOI:https://doi.org/10.46243/jst.2022.v7.i03.pp60-68

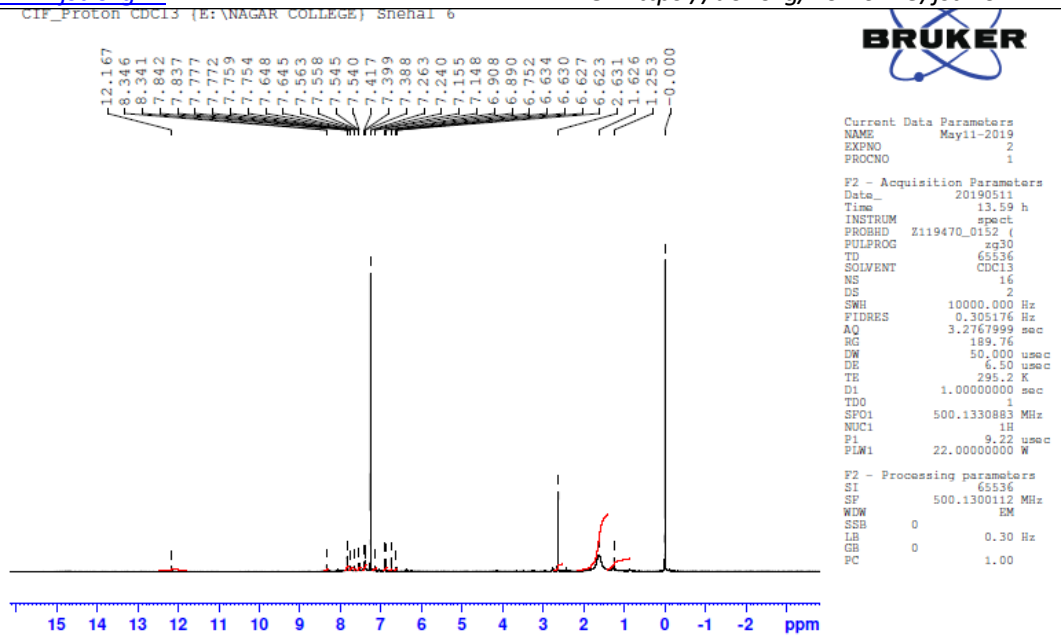

Figure 2: ^{1}H –NMR spectrum of ligand

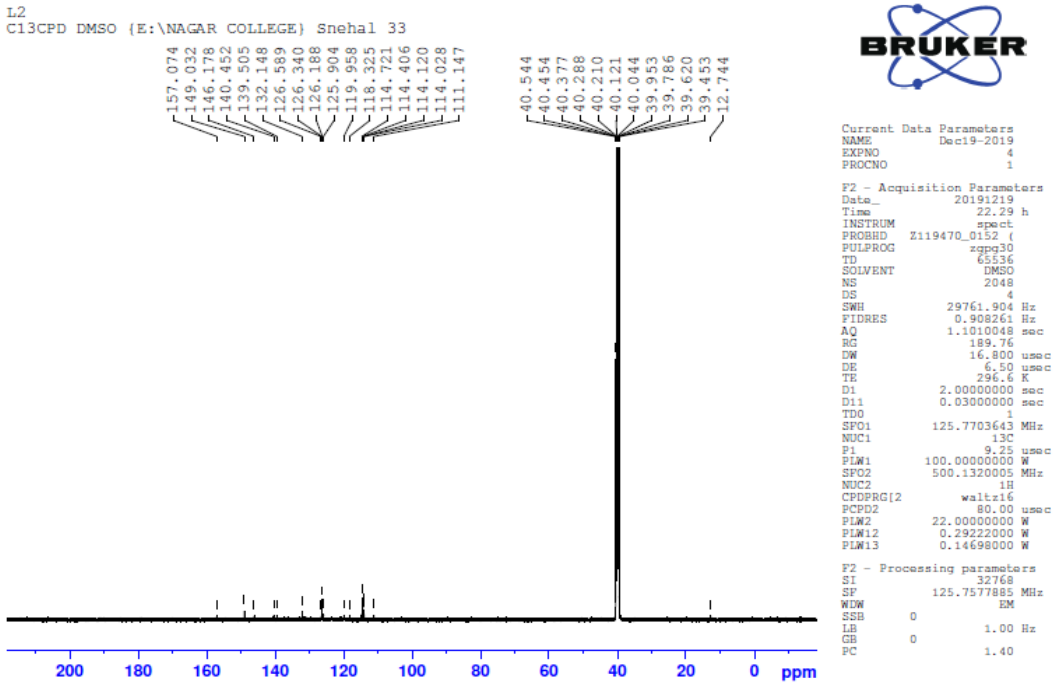

Figure 3: ^{13}C –NMR spectrum of ligand

Synthesis of Complexes:

The various complexes were prepared by warm ethanolic (20 ml) solution of the ligand (0.762 g 10 mmol) and a warm ethanolic (20 ml) solution of corresponding (10 mmol) metal nitrate of Co $(NO_3)_2$ $2H_2O$, Ni$(NO_3)_2$ $2H_2O$,

$Cu(NO_3)_2\,2H_2O$ and $Zn(NO_3)_2$ were mixed together with constant stirring. The pH of the mixture was adjusted in the range of 7-8 by adding 10% alcoholic ammonia solution. The reaction mixture was refluxed for 7-8 h at 90 °C on cooling a solid yellow precipitate are obtained which was filtered, washed with cold ethanol and dried under vacuum over P_4O_{10} and it was recrystallized from ethanol[14,15](yield- 58-60%).

Co(II) Complex

Yield 58% Elemental Analysis: $C_{38}H_{38}Br_2N_4O_{10}$ Co Calculated C=46.47%, H=3.46%, N=5.70 %, Co=5.90% ; Found C=47.96%, H=3.65%, N=9.06 %, Co=6.14% , IR (KBr, cm^{-1}): 3287 *ν*(OH), 1656 *ν*(C=N), 536 *ν*(C-Br), 418 *ν*(M-N), molar conductance (λv) = 12.42 mhos cm^2.

Ni(II) Complex

Yield 60% Elemental Analysis: $C_{38}H_{38}Br_2N_4O_{10}$ Ni Calculated C=45.98%, H=3.06%, N=5.64 %, Ni=5.80% ; Found C=47.10%, H=2.87%, N=7.98 %, Ni=6.20% IR (KBr, cm^{-1}): 3580 *ν*(OH), 1655 *ν*(C=N), 536 *ν*(C-Br), 418 *ν*(M-N), molar conductance (λv) 11.25 mhos cm^2.

Cu(II) Complex

Yield 59% Elemental Analysis: $C_{38}H_{32}Br_2N_4O_7$ Cu Calculated C=46.25%, H=3.04%, N=5.88%, Cu= 6.39 % ; Found C=45.20%, H=2.84%, N=9.14 % Cu= 7.26 % IR (KBr, cm^{-1}): 3276 *ν*(OH), 1655 *ν*(C=N), 536 *ν*(C-Br), 428 *ν*(M-N), molar conductance (λv) 12.50 mhos cm^2.

Zn(II) Complex

Yield 58% Elemental Analysis: $C_{38}H_{26}Br_2N_4O_4$ Zn Calculated C=47.90%, H=2.73%, N=8.82 %, Zn=6.83% ; Found C=48.20%, H=3.14%, N=9.20 % , Zn=7.82% IR (KBr, cm^{-1}): 3367 *ν*(OH), 1657 *ν*(C=N), 536 *ν*(C-Br), 418 *ν*(M-N), molar conductance (λv) 12.32 mhos cm^2.

I. Result and Discussion

The UV-visible spectra (1mM) of the ligand and its metal complexes are measured by using spectrophotometerat room temperature is shown in Table 1. Co(II), Ni(II) and Cu(II) complexes showed magnetic moment 3.80 2.64 and 1.92 B.M. corresponding to 3, 2 and 1 unpaired electrons, while Zn(II) complex was diamagnetic as expected for square planer geometry pairedelectrons system[24,25].

Table 1: Magnetic measurements and electronic spectra of metal complexes

Compound	**Solution spectra**		**Assignments**	**μ_{eff} in B.M.**
	(λ) (nm) ν in cm^{-1}	**OD**		
L	(258) 38759.68 (261) 38314.17 (321) 31152.60	0.345 0.153 0.640	π → π* π → π* n → π*	----
CoL $2H_2O$	261 (38314) 280 (35714) 321 (31152)	0.345 0.153 0.640	π → π* π → π* n → π*	3.80
NiL $2H_2O$	261 (38314) 280 (35714) 321 (31152)	0.207 0.090 0.325	π → π* π → π* n → π*	2.64
CuL $2H_2O$	262 (38167) 280 (35714) 321 (31152)	0.298 0.292 0534	π → π* π → π* n → π*	1.92
ZnL $2H_2O$	261 (38314) 280 (35714) 322 (31055)	0.359 0.140 0.664	π → π* π → π* n → π*	Diamagnetic

OD = optical density (absorption)

FTIR spectra

The IR spectrum of the macrocyclic ligand (L) and its complexes shows a ν(C=N) peak at 1670 cm^{-1}[26] and the absence of ν(C=O) peak at 1700 cm^{-1} and ν(NH_2) peak at 3250 cm^{-1} is indicative of Schiff base condensation[27]. The IR spectrum of ligand appearance of a new strong absorption band at 1670 cm^{-1} attributable to the characteristic stretching frequencies of the imino linkage ν(C=N) which provides strong evidence for the presence of cyclic

product. On complete formation the ν(C=N) shifted towards lower side by 15-13cm^{-1} hence the ligand is tetra dentate, nitrogen donor coordinates through nitrogen of ν(C=N) group. The band in the 418- 426 cm^{-1} regions may be assigned to ν(M-N) vibration[28,29].The ν(OH) vibration of phenolic proton appears as a broad band in the region 3200-3600 cm^{-1} probably due to the overlapping of the symmetric and antisymmetric OH stretching vibration of lattice water[30]. The appearances of strong band in the range 1354-1394 cm^{-1} indicate the presence of ionic nitrate[31].

Antibacterial activity:

All the synthesized metal complexes were tested against pathogenic clinically isolated standard bacterial strains *E. coli* (MTCC 442), *P. aeruginosa* (MTCC 441), *S. aureus* (MTCC 96), and *S. Pyogenus* (MTCC 443) using broth dilution method shown in Table-2. Antibacterial activity of ligand and their metal complexes are shown in figure 4. This bar diagram shows comparative antibacterial activity against bacterial strain and standard drugs. All metal complexes show higher antibacterial activity as compare to the ligand[5]. Gentamycine, Ampicillin, Chloramplenicol, Ciprofloxacin and Norfloxacin were used as a reference drug for bacteria. The complexe of Co(II) and Cu(II) shows higher activity against S. Pyogenus. Zn(II) complex shows higher activity against *S. aureus* than Ampicillin. Co(II), Ni(II) and Cu(II) complexes shows moderate antibacterial activity against the *E. coli, P. aeruginosa, S. aureus and S. Pyogenus.*

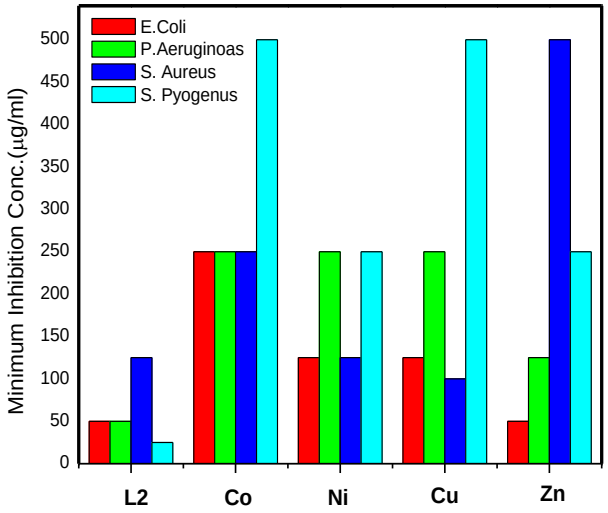

Figure 4: Minimum Inhibition Concentration (µg/ml) of Ligand and Their Metal Complexes

Antifungal activity

All the synthesized metal complexes were tested against pathogenic clinically isolated standard bacterial strains *C. Albicans***(**MTCC 227), *A. Niger*, (MTCC 282), *A. Clavatus* and (MTCC 1323), using broth dilution method shown in Table-2. Antifungal activity of ligand and their metal complexes are shown in figure 5. This bar diagram shows comparative antifungal activity against fungal strain and standard drugs. All metal complexes show higher antifungal activity as compare to the ligand[5]. The Co(II), Ni(II) and Zn(II) metal complexes better effective against*A. Niger* and *C. Albicans***Cu**(II) also shows higher activity against *C. Albicans than Greseofulvin*. Cu(II) and Zn(II), metal complexes show moderate antifungal activity against *A. Niger, C. Albicans*. It is also observed that some moieties, such as an azomethine linkage or a heteroaromatic nucleus, introduced into such compounds shows more biological activities that may be responsible for the increase in the hydrophobic character and liposolubility of the molecules in crossing the cell membrane of the microorganism, thereby increasing the biological utilization ratio and activity of these complexes [28,29].

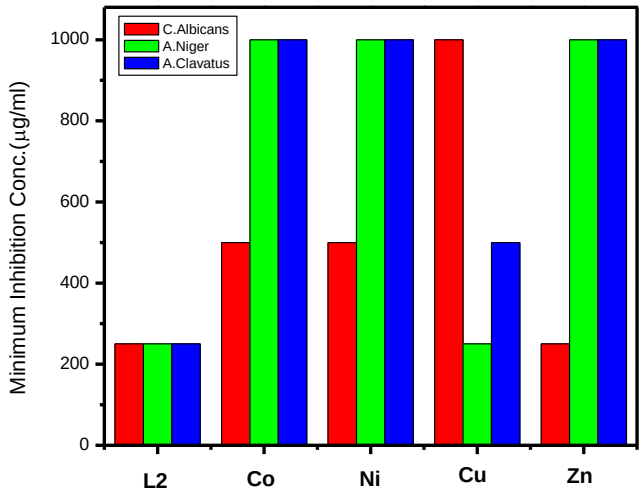

Figure 5: Minimum Inhibition Concentration (µg/ml) of Ligand and Their Metal Complexes.

Table 2: Antibacterial and antifungal activity of compounds

Sr. No	Code No	Antibacterial activityMIC (µg/ml)				Antifungal activity MIC (µg/ml)		
		E.Coli	***P. Aeruginoas***	***S. Aureus***	***S.Pyogenus***	***C. Albicans***	***A.Niger***	***A.Clavatus***
		MTCC 42	**MTCC 441**	**MTCC 96**	**MTCC 443**	**MTCC 227**	**MTCC 282**	**MTCC 1323**
1	L_2	50	50	50	25	250	250	250
2	CoL $2H_2O$	250	250	250	500	500	1000	1000
3	NiL $2H_2O$	125	250	250	250	500	1000	1000
4	CuL $2H_2O$	125	250	250	500	1000	250	500
5	ZnL $2H_2O$	50	125	125	250	250	1000	1000
6	Gentamycin	0.05	1	1	0.5	--	--	--
7	Ampicillin	100	100	100	100	--	--	--
8	Chloramphenicol	50	50	50	50	--	--	--
9	Ciprofloxacin	25	25	25	50	--	--	--
10	Norfloxacin	10	10	10	10	--	--	--
11	Nystatin	--	--	--	--	100	100	100
12	Greseofulvin	--	--	--	--	500	100	100

MIC = Minimum Inhibition Concentration

II. Conclusion

In this paper, we describe the synthesis and characterization of hexadentate macrocyclic ligand and it's Co(II), Ni(II), Cu(II) and Zn(II) complexes. Based on conductance, electronic visible and biological activity all these complexes exhibit coordination number six. The FTIR spectral data suggest that ligand behaves as a tetradentate ligand with N_4 donor atoms towards central metal ion. Some of these metal complexes show higher microbial activity than the Schiff base ligand and standard drugs because naturally transition metals are biologically active.

www.jst.org.in *DOI:https://doi.org/10.46243/jst.2022.v7.i03.pp60-68*

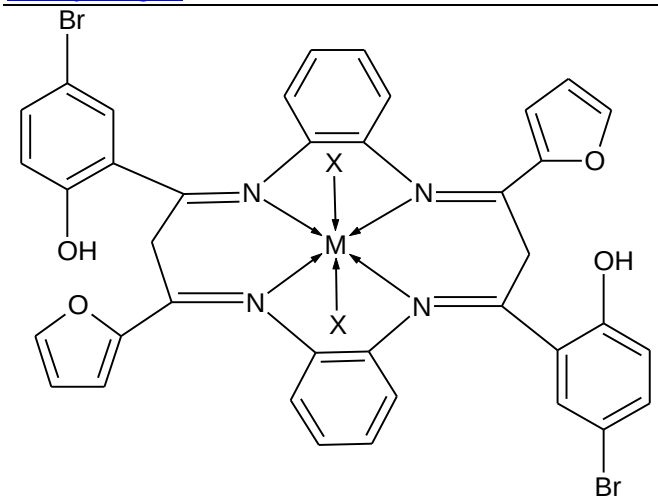

Figure 6: Proposed structure of complexWhere M= Co(II), Ni(II), Cu(II) and Zn(II)X= $2H_2O$

III. Acknowledgement

The authors are thanks to the Head, Post Graduate Teaching Department of Chemistry, Dr. Babasaheb Ambedkar Marathwada University Aurangabad. The authors also thankful to the Managemnt of Mula Education Society Sonai, Principal Arts, Commerce and Science college Sonai and Principal New Arts, Commerce and Science college Ahmednagar for providing necessary research facilities.

References

[1] Jayaseelan, P., Prasad, S. Synthesis, spectral characterization, electrochemical and anti-microbial activities of new binuclear Schiff base metal complexes derived from 3, 3' diaminobenzedine. Eur. J. Chem. 2, (4): 480-484, (2011).

[2] Shakir, M., Bano N., Rauf, A., Kazmi, S. and Alam, M. Synthesis and characterization of pharmacologically active 18-membered tetraamide macrocyclic complexes of Mn(II), Co(II), Ni(II), Cu(II), and Zn(II): *In-vitro* antimicrobial, anticancer screening, DNA interaction and docking studies *Inorg. Nano-Met. Chem.* 47, 576, (2017).

[3] Munde, A., Jagdale A., Jadhav, S., Chondhekar, T. Synthesis, characterization and thermal study of some transition metal complexes of an asymmetrical tetradentate Schiff base ligand. J. Serb. Chem. Soc.75, (3): 349-359, (2010).

[4] Tyagi, M., Chandra, S., Akhatar, J., Chand, D. "Modern spectroscopic techniquein the characterization of bio sensitive macrocyclic Schiff base ligand and its complexes.Inhibitory activity against plant pathogenic fungi". Spectrochimica Acta. Part A Molecularand Bimolecular Spectroscopy. (118): 1056-1060, (2014).

[5] Shankarwar, S. Shelke, V. Chondhekar, T. Synthesis, spectral, thermal and antimicrobial studies of transition metal complexes of 14- membered tetraaza [N_4] macrocyclic ligand. Spectrochimica Acta. Part A Molecular and Bimolecular Spectroscopy, (145): 188-193, (2015).

[6] Chaudhary, N. K. In vitro antibacterial studies of some transition metal complex of Schiff base derived from 2-aminophenol and furan-2-carbaldehyde. Archives of Applied Science Research, 5, (6): 227-231, (2013).

[7] Fahmi1, N., Upadhyay, M., Sharma, N. and Belwal, S. Synthesis, characterization and biochemical behaviour of macrocyclic complexes of Zn(II) and Co(II) metals. Journal of Chemical ResearchVol. 44, (5-6) 336 –342, (2020).

[8] Esmaiel, S., Sayed, Ali, N. T. and Mohsen, S. Synthesis, characterization, theoretical and biological studies of a new macrocyclicSchiff base with Co(II), Ni(II), Cu(II) and Zn(II) complexes J. Chil. Chem. Soc., 62, N-4, (2017).

[9] Shakir, M., Bano, N., Rauf, M., and Owais, MPharmacologically significant tetraaza macrocyclic metalcomplexes derived from isatin and 3,4-diaminobenzophenone: Synthesis, spectral studies and comparative *in vitro* biological assessment *J. Chem. Sci.* Vol. 129, No. 12, , pp. 1905–1920, (2017).

[10] Mishra, R. M., Pandey, S., Saxena, R. "Homozygous hemoglobin D with alpha thalassemia: case report," The Open Hematology Journal, Vol. (2): 1–4, (2011).

[11] Lawrence, K. Leo, Angelo, A.N. Paul. Synthesis, characterization and antibacterial activity of chiral 1, 1' – (4, 6 – dihydroxy – 1, 3 -phenylene) bisethanone based tetraaza macrocyclic Co (II), Ni (II), Cu (II) and Zn (II) metal complexes. International Journal of Research and Analytical Reviews Volume 6, Issue (1), 195-205, (2019).

[12] El-Boraey, HA, El-Salamony, MA and Hathout AA. J. Incl. Phenom Macrocycl Chem. 86: 153. (2016).

[13] Ajit, K. C., Pandeya, S. N., "Synthesis and anticonvulsant activity (chemoshock) of Schiff and Mannich bases of isatin derivatives with 2-amino pyridine (mechanism of action)," International Journal of Pharm. Tech. Research, Vol. 4, No. (2): 590–598, (2012).

[14] Manchanda, D., Sidhu, A., Gumber, Kaur K. Synthesis and antifungal potential of some transition metal complexes of tridentate N_2 - Benzylidenepyridine-2, 6-Diamine. Int. J. of Chemical Studies, 5, (2): 455-459, (2017).

[15] Sakhare, M., Lande, M., Arbad, B. Synthesis, characterization and antimicrobial studies on La(III), Ce(III) and Pr(III) complexes with a tetraaza macrocyclic Ligand, Advances in Applied Science Research. 4, (1): 94-100, (2013).

[16] Jisha, M. J., Isac, C. Sobana, R. Synthesis and characterization of Schiff base complexes of Cu(II), Ni(II), Co(II) complexes of Schiff base derived from furan 3- carboxaldehyde and 3- amino pyridine International Journal of Scientific and Research Publications, Vol. 7, Issue (10): 10-19, (2017).

[17] Chandra, S. Tyagi, M. and Agrwal, S., Synthesis, and characterization of tetraaza macrocyclic ligand and its Cobalt(II), Nickel(II,) Copper(II) complexes, J. of Serb. Chem. Soc. 75. (7): 935-941, (2010).

[18] Kalsi, P. S. Spectroscopy of Organic Compounds, New Age International (P) Ltd., New Delhi, India, (1999).

[19] Vijayalakshmi, M., Synthesis and spectral characterization of Schiff base transition metal complexes, DNA cleavage and antibacterial activity studies,Rasayan J. of Chem. 11, (2): 857 – 864, (2018).

[20] Gunvanthrao, N. Hire, B. Mruthyunjayaswamy, M. Metal (II) complexes of ONO donor Schiff base ligand as a new class of bioactive compounds containing indole core: synthesis and characterization. Int. J. Pharmcy and Pharm. Sci, 8, (1): 197-204, (2016).

[21] Waddai, F.Y., Karim, E. K.,Hussen, S. A., Synthesis, spectral characterization and antimicrobial activity of some transition metal complexes with new Schiff base ligand. Oriental Journal of Chemistry. Vol. 34 No. 1, (2018).

[22] Palanimurugan, A. Kulandaisamy, A. Synthesis and biological activities of 14- membered macrocyclic Schiff base metal complexes. Asian Journal of Chemistry, Vol. 30, No. (6): 1262-1268, (2018).

[23] Arumugam, A.P., Guhanathan, S. Elango, G. Co(II), Ni(II) and Cu(II) complexes with Schiff base ligand synthesis characterization antimicrobial molecular docking studies. (2017).

[24] Munde, A., Jagdale A., Jadhav, S., Chondhekar, T. Synthesis, characterization and thermal study of some transition metal complexes of an asymmetrical tetradentate Schiff base ligand. J. Serb. Chem. Soc.75, (3): 349-359, (2010).

[25] Patil, A., Donde, K., Raut S. Synthesis, characterization and biological activity of mixed ligand Co(II) complexes of Schiff base 2-amino-4-nitrophenol-n-salicylidene with some amino acids. Journal of Chemical and Pharmaceutical Research, 4: 1413 - 1425. (2012).

[26] Singh, D. P., Grover, V., Jain, K. Synthesis and characterization of divalent metal complexes of the macrocyclic ligand derived from istin and 1,2 diaminobenzene, Journal of the Serbian Chemical Society.76(3), 385-393, (2011).

[27] Nakamoto, K. Infrared Spectra of Inorganic and Coordination Spectroscopy, 1st Edn., Elsever, Amesterdam, . (1968).

[28] Nakamoto, K.. Infrared Spectra of Inorganic and Coordination Compounds, Wiley Interscience, New York, (1970).

[29] Goel, V. Malhotra, S. R. Macrocyclic Schiff base complexes-preparation, characterization and biological activity. Der Pharma. Chemica, 9, (2): 60 – 66, (2017).

[30] Panchbhai, M. A., Bhave, N. S., Synthesis and characterization Cobalt(II), Nickel(II) and Copper(II) complexes of 14-membered macrocyclic ligand. Asian Journal of Chemistry, Vol. 21, No.(8): 6057-6067, (2009).

[31] Sakhare, M.A., Dhokte, A.O., Bagal, M.R., Arbad, B. R. Spectral and antimicrobial studies on Nd(III), Sm(III) and Gd(III) complexes with a tetraaza macrocyclic ligand, American Int. Journal of Research in Formal, Applied and Natural Sciences, 47-52, (2013).