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## Co(II) AND Cu(II) COMPLEXES OF SCHIFF BASE LIGANDS: SYNTHESIS, SPECTRAL CHARACTERIZATION, THERMAL ANALYSIS AND ANTIMICROBIAL ACTIVITY

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#### **ABSTRACT:**

The Schiff's base ligand, LH<sub>2</sub> [N-(4-(((2,4 dihydroxyphenyl) (phenyl)methylene) amino) phenyl) pyridine-2-sulfonamide] was prepared by the condensation of sulphapyridine with 2,4 dihydroxybenzophenone in ethanol. New complexes of with metal ions Cu(II) and Co(II) were synthesized. Elemental, spectroscopic and thermal analyses as well as conductivity and magnetic susceptibility measurements are used to elucidate the structure of the newly prepared metal complexes. The metal complexes exhibited square planar geometrical arrangements; the molar conductivity data reveal the non-electrolytic nature of complexes. The thermogravimetry (TG) of the Cu(II) and Co(II) complexes were carried out in the range of 30–500 °C. The Co(II) and Cu(II) complexes were decomposed in four stages while ligand decomposed in single stage. Also, decomposition of the synthesized complexes is related to the Schiff's base characteristics. The thermal decomposition of the studied reactions was first order. The kinetic parameters for the decomposition steps in Cu(II) and Co(II) complexes thermograms have been calculated using Freeman-Carroll and Sharp-Wentworth methods. The synthesized ligand, in comparison to their metal complexes also were screened for antibacterial activity in vitro against Gram positive and Gram negative bacteria viz. Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa and Klebsiella pneumoniae using standard agar cup plate or well diffusion method. The activity data show that Schiff base and its metal complexes showed significant antimicrobial activity

KEYWORDS- Sulphapyridine, 2,4 Dihydroxybenzophenone, Metal complexes, Schiff base

#### **INTRODUCTION:**

Sulfa drugs appeal significant interest due to their therapeutic relevance, particularly in the treatment of infections caused by a variety of bacteria. Recently, the rise in research focused on the development of new pharmaceuticals has been driven by the emergence of resistant strains of microorganisms. Consequently, a number of sulfonamide derivatives have been synthesized, characterized, and assessed for their potential as antibacterial agents. A wide array of compounds is currently employed to combat bacterial infections. Various pharmacological

agents with distinct biological activities are derived from the original sulfonamide structure and are widely utilized in clinical settings.

Furthermore, schiff bases derived from sulfonamides have gathered interest due to their applications in anticancer<sup>ii</sup>, antiviral<sup>iii</sup>, antifungal, antibacterial, herbicidal<sup>iv</sup>, and antitubercular activities <sup>v-vii</sup>.

Sulfonamide-based ligands have the capacity to form chelates with various metals, including vanadium, chromium, cobalt, manganese, nickel, copper, and zinc. While metal-based compounds generally exhibit superior biological activity compared to ligands, the mechanisms underlying their resistance remain inadequately understood. The incorporation of transition metal ions into schiff base sulfonamide derivative ligands plays a crucial role in enhancing their biological efficacy, thereby expanding their potential as antimicrobial and anticancer agents. The selection of the specific metal ion, its oxidation state, and the design of the ligand are essential determinants of the effectiveness and specificity of these metal complexes in biological systems<sup>viii-x</sup>.

In this context, synthesis and characterization of some transition metal complexes with (N-(4-(((2,4 dihydroxyphenyl) (phenyl)methylene) amino) phenyl) pyridine-2-sulfonamide and biological activity of its complexes have been discussed in the present investigation.

# EXPERIMENTAL:

## MATERIALS AND METHODS

All the solvents used were of analytical reagent grade purchased from SD Fine and Merck. Pure sample of sulphapyridine was obtained from Shah Scientific Pvt. Ltd. Mumbai. Solvents were purified and dried before use by literature method<sup>xi</sup>. The ligand used in the present work is not commercially available; hence, it was synthesized in the laboratory.

Microanalyses of carbon, hydrogen and nitrogen of the ligands were carried out on a Perkin Elmer CHN 2400 elemental analyzer. <sup>1</sup>H-NMR spectra of the ligands were recorded in DMSO- $d_6$  solution on Bruker Advance 400 NMR Spectrometer. The electronic spectra of the ligands were recorded on a Shimadzu UV/Vis spectrophotometer in the region 200-1000 nm. The Fourier-transform infrared (FTIR) spectra of ligands were recorded as KBr pellets using Shimadzu spectrometer (IRAffinity-1S). Mass spectra of synthesized compounds were carried out on Thermo scientific TSQ 8000 Gas Chromatograph- Mass Spectrometer. The thermal analysis was performed with a Perkin Elmer (TGS-2 model) thermal analyzer at a heating rate of 10°C min<sup>-1</sup> in the temperature range 40-500°C. ESR spectra of complexes at room temperature and liquid nitrogen temperature were carried by using JES-FA 200 ESR spectrometer.

## **GENERAL PROCEDURE**

## FOR THE PREPARATION OF N-(4-(((2,4 DIHYDROXYPHENYL) (PHENYL)METHYLENE) AMINO) PHENYL) PYRIDINE-2-SULFONAMIDE (SCHEME-1)

Equimolar (0.01m) solutions of 2,4 dihydroxybenzophenone (2.14g) and sulphapyridine (2.49g) were separately dissolved in ethanol and refluxed for three hours. The volume of reaction mixture was reduced to one third and cooled at  $0^{0}$ C. The solid residue was filtered off and recrystallized by ethanol. The purity of the compound was checked by thin layer chromatography (TLC). Yield- 80%, M. P.145<sup>o</sup>C



(Scheme-1)

### PREPARATION OF METAL COMPLEXES

The complexes are generally synthesized by refluxing respective metal salt with ligand in ethanolic medium for desired time. The metal salts used for the preparation of complexes were cobalt(II) acetate tetrahydrate  $[Co(OAc)_2.4H_2O]$  and Copper(II) acetate monohydrate  $[Cu(OAc)_2.H_2O]$ .

### FOR THE PREPARATION OF Co(II)COMPLEXES

Cobalt(II) acetate tetrahydrate  $[Co(OAc)_2.4H_2O]$  (0.02 mol, 4.75g) and ligands (0.02mol) were dissolved separately in absolute alcohol. Both the solutions were filtered and mixed in hot conditions. Few drops of 1N KOH were added to the reaction mixture and then the reaction was refluxed for about 8-10 hours. The colored solid obtained were filtered off, washed several times with small amount of ethanol followed by petroleum ether and finally dried over fused calcium chloride.

### FOR THE PREPARATION OF Cu(II) COMPLEXES

Copper(II) acetate tetrahydrate [Cu(OAc)<sub>2</sub>.H<sub>2</sub>O] (0.02 mol, 3.99 g) and ligands (0.02 mol) were dissolved separately in absolute alcohol. Both the solutions were filtered and mixed in hot conditions. Few drops of 1N KOH were added to the reaction mixture and then the reaction was refluxed for about 10-12 hours. The colored solid obtained were filtered off, washed several times with small amount of ethanol followed by petroleum ether and finally dried over fused calcium chloride.

Compound	Formula wt	~ .	Found (Calc.) %			
Compound	rormula wi.	Color	С	Η	Ν	Μ
$C_{20}H_{18}N_2O_4S$	382.10	Orange	62.81	4.74	7.33	
		_	(62.66)	(4.79)	(7.26)	
[Co(LH) OAc (H <sub>2</sub> O)].H <sub>2</sub> O	598.49	Pale brown	52.18	4.21	7.02	9.85
			(52.29)	(4.34)	(7.15)	(9.98)
[Cu(LH) OAc (H <sub>2</sub> O)].H <sub>2</sub> O	603.11	Brown	51.78	4.18	6.97	10.54
			(51.89)	(4.31)	(7.14)	(10.71)

Table 1: Elemental analysis, color and formula weight of the compound

#### **RESULTS AND DISCUSSION**

The newly synthesized ligands are characterized by elemental analysis, IR, <sup>1</sup>H NMR, mass and repeated M. P. determination studies. The C, H and N analyses of the ligand satisfactorily coincide with its proposed molecular formula. In order to find out the binding modes (donor sites) towards the metal ion, the Infrared Spectra of the ligands were recorded. The absorption band of donor atom either disappeared or showed increase/ decrease in absorption frequencies due to formation of the complex.

#### <sup>1</sup>H-NMR SPECTRA OF THE LIGAND

<sup>1</sup>H-NMR Spectra of the ligands were recorded in DMSO by using TMS as an internal standard to identify the number of protons and its electronic environment. The observed chemical shifts ( $\delta$  in ppm) indicate the presence of functional groups in compounds. Tables3 indicate the recorded NMR values for the ligand.



Table 2:1H-NMR signals obtained for Ligand LH2



## **IR Spectra**

The IR spectra of metal complexes of ligand LH<sub>2</sub> are shown in Figure 3.58-3.64 and IR group frequencies of diagnostic importance bands are collected in Table 3.11. The broad band that appeared in the spectra of the ligand and their metal complexes in the range 3309-3363 cm<sup>-1</sup> is assigned to the stretching vibration of  $v(N-H)^{xii-xiii}$ . The IR spectral band of the free ligand and its metal complexes indicates that the band at 3232 cm<sup>-1</sup> due to intramolecular hydrogen bonded v(OH) group in the free ligand spectrum disappeared in spectra of all the complexes suggesting the coordination of ligand through phenolic oxygen via deprotonation<sup>xiv</sup>. Further the bands at 1620 cm<sup>-1</sup> (azomethine C=N) shifted its position to lower frequency on complexation<sup>xv</sup>. The bands at 1350 cm<sup>-1</sup> and 1122 cm<sup>-1</sup> in the ligand are assigned to  $v_{as}(SO_2)$  and  $v_s(SO_2)^{xvi-xix}$ . These bands remain almost at the same position in the complexes suggesting that the sulfonyl oxygen is not taking part in coordination. The v(M-O) and v(M-N) bands have been assigned in the region 524-543 cm<sup>-1</sup> and 445-453 cm<sup>-1</sup> respectively<sup>xx</sup>. The coordination of water in Co(II) and Cu(II) complexes is indicated by appearance of bands at 3414- 3460 cm<sup>-1</sup>, 1540-1544 cm<sup>-1</sup>, 837-840 cm<sup>-1</sup>, 767-771 cm<sup>-1</sup> assignable to v(OH),  $\delta(OH)$ ,  $\rho_r(H_2O)$ ,  $\rho_w(H_2O)$  mode respectively<sup>xxi-xxii</sup>.

Sr. No	Compound	v(O-H) hydroge	v(NH v(C=		v(SO <sub>2</sub> )		v(M -O)	v(M -N)	v(H2O)
•	Compound	n bonded	)	N)	asy	sym			
1	LH <sub>2</sub>	3232	3402	1620	135 0	112 2			
2	[Co(LH)OAc (H <sub>2</sub> O)]. H <sub>2</sub> O		3309	1604	135 9	111 1	543	453	3414,154 4, 837,771
3	[Cu(LH)OAc(H <sub>2</sub> O)]. H <sub>2</sub> O		3363	1606	132 7	112 6	524	445	3460,154 0, 840,767

 Table 3: Infrared spectral data (cm<sup>-1</sup>) of ligand LH<sub>2</sub> and its complexes

## Electronic spectra and magnetic moment:

The electronic absorption spectra of metal complexes were recorded in DMSO. UV spectrum of Co(II) complex exhibits absorption bands at 425 nm and 610 nm, which may be assigned to  ${}^{2}A_{1g} \rightarrow {}^{2}B_{1g}$  and  ${}^{2}A_{1g} \rightarrow {}^{2}E_{g}$  transition respectively. These bands clearly suggest square planar geometry for Co(II) complex<sup>xxiii</sup>. Electronic spectra of Cu(II) complex display bands at 440, 554, 675 and 910 nm which are assigned to transition LMCT,  ${}^{2}B_{1g} \rightarrow {}^{2}A_{1g}$ ,  ${}^{2}B_{1g} \rightarrow {}^{2}B_{2g}$  and  ${}^{2}B_{1g} \rightarrow E_{g}$  respectively. These are consistent with square planar geometry for Cu(II) complex are given in Table 3.

 Table 4: Electronic spectral data of the complexes

Complex	Absorption region (nm)	Band assignment	µ <sub>eff</sub> B. M.	Λ <sub>M</sub> Ω <sup>-</sup> <sup>1</sup> cm <sup>2</sup> mol <sup>-1</sup>	Geometry
[Co(LH)OAc (H <sub>2</sub> O)]. H <sub>2</sub> O	425	$^{2}A_{1g} \rightarrow ^{2}B_{1g}$	2.26	7.00	Square
	610	$^{2}A_{1g}\rightarrow ^{2}E_{g}$	2.20	7.90	planar
[Co(LH)OAc (H <sub>2</sub> O)]. H <sub>2</sub> O	440	LMCT		0 50	Square
	554	$^{2}B_{1g} \rightarrow ^{2}A_{1g}$	0.80		
	675	$^{2}B_{1g} \rightarrow ^{2}B_{2g}$ 0.80		8.38	planar
	910	$^{2}B_{1g} \rightarrow E_{g}$			

# Thermal analysis

An analysis of TG curves of LH<sub>2</sub> and its complexes reveals a four-stage decomposition pattern for Co(II) and Cu(II) complexes and one stage decomposition pattern for ligand. All the complexes are stable upto 60-70<sup>o</sup>C. The TG curve of Co(II) and Cu(II)complexes are stable upto  $60^{\circ}$ C. Decomposition of one lattice water was observed for Co(II) and Cu(II)complexes at 120<sup>o</sup>C with % weight loss obs/calcd: Co(II): 3.06/3.01,Cu(II): 3.03/2.98. The further weight loss was observed for Co(II) and Cu(II) complexes from 120-220<sup>o</sup>C indicates the presence one coordinate water molecule in Co(II) and Cu(II)complexes [% weight loss obs./calcd: Co(II): 3.06/3.01 and Cu(II): 3.03/2.98]. In all the complexes continuous and rapid weight loss has been observed above 220<sup>o</sup>C corresponding to thermal degradation of free part of the coordinated ligand along with the other groups present there in. A gradual weight loss above 340<sup>o</sup>C corresponds to the degradation of actual coordination part of the ligand. Finally, the horizontal level beyond 440<sup>o</sup>C suggests the formation of final decomposition products corresponding to respective metal CoO and Cu<sub>2</sub>O. The thermal decomposition data of the compounds is given in Table 5. The relative thermal stability on the basis of half decomposition temperature is found to be  $Co(II) > Cu(II) > LH_2$ .

Compounds	Half Decompositi on	Activation Energy Ea (kJ)		Order of Reaction	Entropy Change	Free Energy Change	
	Temp.( <sup>0</sup> C)	FC	SW	( <b>n</b> )	AS (J/mol/K)	аг (kJ/mol)	
LH <sub>2</sub>	220	24.38	24.55	0.95	-278.96	111.69	
[Co(LH) OAc (H <sub>2</sub> O)]. H <sub>2</sub> O	440	15.00	14.88	0.93	-232.766	87.86	
[Cu(LH) OAc (H <sub>2</sub> O)]. H <sub>2</sub> O	350	16.54	16.42	0.95	-323.274	117.72	

Table 5: Thermodynamic data of LH<sub>2</sub> and its complexes

## Mass spectra of the ligands

Mass spectrometry has been successfully used to determine the molecular ion peak for Schiff base ligand. The various fragmentation peaks obtained for ligand, Co(II), Cu(II) and Ni(II) complexes are in good agreement with proposed structure. Mass spectrum of Cu(II) LH<sub>2</sub> complex was shown in Figure 3.



Figure 2: Mass spectrum of Cu(II) LH<sub>2</sub> complex.

## ESR of Cu(II) complex

The X band ESR spectra of Cu(II) complex recorded in the solid state at room temperature (RT) and liquid nitrogen temperature (LNT) shown in Fig 5.9 and 5.10 respectively, their parameters  $g_{\parallel}$ ,  $g_{\perp}$ ,  $A_{\parallel}$  and  $A_{\perp}$  have been calculated and reported in Table 5.4. At RT, At LNT, the Cu(II) complex shows one intense band due to tumbling motion of the molecules whereas

at LNT, spectrum shows four well-resolved peaks in the low field region. The observed g values of the complex indicate that the unpaired electron is present in  $d_{x^2-y^2}$  orbital as it follows the trend (g<sub>||</sub> = 2.1113 > g<sup>⊥</sup> = 2.0142 > 2.0023). The parameters of complex coincide well with related systems which suggest that the complex has square planar geometry.

Table 6: g and A value of powder ESR spectra of Cu(II) complex of ligand LH<sub>2</sub> at RT and LNT

Complex		Spectral I	Spectral Parameters						
compiex		g	g⊥	/g/	A	A⊥	/A/		
Cu(II)	RT	2.1113	2.0142	2.0465					
	LNT	2.1286	2.0185	2.0552	56	23	35		



## Figure 3: ESR spectrum of Cu(II) LH<sub>2</sub> complex at RT. Antimicrobial Activity

Ligand  $L^4H_2$  found to be active against all bacterial species where it showed high activity towards *K. pneumoniae* and moderate activity towards *S. aureus, E. coli* and *P. aeroginosa*. Ligand and all metal complexes were bactericidal towards *E. coli*. All metal complexes showed good to moderate activity against *S. aureus* except Fe(III) and VO(IV). Bacteriocidal activity of ligand decreased on complexation with metal ions for bacteria *K. pneumoniae*. Results of studies of antibacterial effect of ligand (LH<sub>2</sub>) and its complexes are summarized in Table 7.

S. N.	Ligand and its complexes	E. coli (mm)	S. aureus (mm)	P. aeroginosa (mm)	K. pneumoniae (mm)
1	LH <sub>2</sub>	S <sub>18</sub>	S <sub>20</sub>	S <sub>16</sub>	S <sub>27</sub>
2	[Co(LH) OAc (H <sub>2</sub> O)]. H <sub>2</sub> O	<b>S</b> <sub>13</sub>	R	S <sub>14</sub>	R
3	[Cu(LH) OAc (H <sub>2</sub> O)]. H <sub>2</sub> O	S <sub>13</sub>	S <sub>14</sub>	R	<b>S</b> <sub>16</sub>

 Table 7: Antimicrobial activity of ligand (LH2) and their complexes

## **CONCLUSION:**

The present article includes the synthesis and characterization of new Schiff base ligand and its Co(II) and Cu(II) complexes. Characterization of compounds includes IR, UV-Vis, mass, <sup>1</sup>HNMR, ESR and TGA. Electronic spectrum suggests square geometry for all synthesized complexes. It is observed that ligand coordinates to metal ion through hydroxyl oxygen, and azomethine nitrogen and acts as a monobasic bidentate ligand (metal ligand ratio 1:1). The thermal study revealed that complexes are thermally stable. The relative thermal stabilities of

the complexes were in the order  $Co(II) > Cu(II) > LH_2$ . The mass spectra of ligands show molecular ion peaks in good agreement with the empirical formula suggested by elemental analysis. The activation energy calculated by the Freeman-Caroll and Sharp-Wentworth methods are in good agreement with each other. The Schiff base ligand and its complexes have been tested in vitro to evaluate their antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* using welldiffusion method. It has been found that the Schiff base ligand and its complexes show significant antimicrobial activity.

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## **REFERENCES:**

- Alyar S.; Alyar H.; Ozmen U. O.; Aktas O.; Erdem K.; Biochemical properties of Schiff bases derived from FDA-approved sulfa drugs: Synthesis, ADME/molecular docking studies, and anticancer activity; Journal of Molecular Structure; 2023, 1293, 136-167.
- Yang J.; Zhou S.; Ji l.; Zhang C.; Yu S.; Li Z.; Meng X.; Synthesis and structure– activity relationship of 4-azaheterocycle benzenesulfonamide derivatives as new microtubule-targeting agents; Bioinorganic and Medicinal Chemistry Letters; 2014, 24 (21), 50555-5058.
- Ravula M. R.; Kavitha P.; Synthesis, characterization and antimicrobial activity of Schiff base ligand and Metal complexes; Indian Journal of Chemistry; 2024, 63 (3), 281-285.
- <sup>iv</sup> Thangadurai T. D.; Gowri M.; Natarajan K.; Synthesis and Characterization of ruthenium(III) Complexes Containing Monobasic Bidentate Schiff Bases and their Biological Activities, Synth. React. Inorg. Met.-Org. Chem., 2002, **32**, 329.
- v Dayan S.; Cetin A.; Arslan N. B.; Ozpozan N.K.; Ozdemir N.; Dayan O.; Palladium(II) Complexes Bearing Bidentate Pyridyl-Sulfonamide Ligands: Synthesis and Catalytic Applications, Polyhedron, 2015, 85, 748-753.
- <sup>vi</sup> Khalil S. M. E.; Seleem H. S.; El-Shetary B. A.; Shebl M.; Mono and Bi-nuclear Metal Complexes of Schiff-Base Hydrazone (ONN) Derived from o-Hydroxyacetophenone and 2- amino-4-hydrazino-6-methyl Pyrimidine, Journal of Coordination Chemistry, 2002, 55 (8), 883–899.
- vii Tuna S.; Canpolat E.; Kaya M; Complexes of Cobalt(II), Nickel(II) and Copper(II) with 3- Hydroxysalicyliden-p-aminoacetophenoneoxime, Polish Journal of Chemistry, 2006, 80(2): 227-234.
- viii Guo Z.; Xing R.; Liu S.; Zhong Z.; Ji X.; Wang L.; Li P.; Antifungal properties of Schiff bases of chitosan, N-substituted chitosan and quaternized chitosan, Carbohydrate Research, 2007, **342** (10), 1329-1332.
- ix Zafar W.; Sumra S. H.; Hassan A. U.; Chohan Z. H.; A review on 'sulfonamides': their chemistry and pharmacological potentials for designing therapeutic drugs in medical science, 2023, **76**, 546-580

- El-Gaby M.; Ammar Y.A.; El-Qaliei M. I. H.; Ali A.M.; Hussein M.F.; Faraghally F.A.; Sulfonamides: synthesis and the recent applications in medicinal chemistry, Egypt. J. Chem., 2020, 63, 5289-5327,
- Halli M. B.; Patil V. B.; Synthesis, Characterization and DNA cleavage studies of Co(II), Ni(II), Cu(II), Cd(II) and Hg(II) complexes with benzofuran-2-carbohrdrazide Schiff bases; Indian J. Chem.; 2011, Vol. 50A, 664-669.
- xii Edrees M. M.; Farghaly T. A.; Synthesis and Antitumor activity of benzo[6",7"]cyclohepta [1",2":4',5']pyrido[2',3'-d][1,2,4]triazolo[4,3-a]pyrimidin-5-ones, Arabian Journal of Chemistry, 2017, **10**, 1613-1618.
- xiii Yadava A. K.; Yadav H. S.; Singh S.; Yadav U. S.; Rao D. P.; Syntheses and Spectroscopic Studies on Macrocyclic Complexes of Dioxomolybdenum(VI) with Furil as Precursor, Journal of Chemistry, 2013, **9** (2), 497-503.
- xiv Conpolat E.; Synthesis and Characterization of Dioxouranium (VI) Complexes of Schiff Bases (Mixed-Ligads Part 1), BEU Journal of Science, 2014, **3** (1), 74-80.
- xv Nair M. S.; Arish D.; Johnson; Synthesis, characterization and biological studies on some metal complexes with Schiff base ligand containing pyrazolone moiety, Journal of Saudi Chemical Society, 2016, 20, 591-598
- xvi Gomati V.; Selvameena R.; Synthesis, Physico Chemical and Antimicrobial Studies on Schiff Base Complexes of Sulfa Drug with Metals of Life, Indian Journal of Applied Research, 2013, 3 (4), 51-53.
- xvii Hariprasath K.; Sudheer Babu I.; Synthesis and pharmacological screening of schiff's base metal complexes of sulphanilamide, Asian Journal of Pharmaceutical and Medicinal Chemistry, 2014, 2 (3), 119-126.
- xviii Ahmad Sabry A. K., Rabie S. F., Alaa E. D. M. and Hady A., Synthesis, Characterization and Antimicrobial Activity of Schiff Base (E)-N-(4-(2-Hydroxybenzylideneamino) Phenylsulfonyl) Acetamide Metal Complexes American Journal of Analytical Chemistry, 2016, 7 (3), 233.
- xix Sathiyaraj S.; Ayyannan G.; Jaya Balakrishnan; Synthesis, spectral, DNA binding and cleavage properties of ruthenium(II) Schiff base complexes containing PPh3/AsPh3 as co-ligands Journal of Serbian Chemical Society, 2014, 79 (2), 151-165
- Shakir M.; Nasman O. S. M.; Varkey S. P.; Binuclear N<sub>6</sub> 22-membered macrocyclic transition metal complexes: synthesis and characterization, Polyhedron, 1996, 15 (2), 309-314.
- Garg R., Fahmi N. and Singh R. V., Synthesis, Spectral and Antimicrobial Aspects of Biologically Relevant Coordination Compounds of Dioxomolybdenum(VI) and Oxovanadium(V), Russian Journal of Coordination Chemistry, 2008, 34 (3), 198-203.
- <sup>xxiii</sup> Chandra S.; Kumar R.; Synthesis and spectral studies on mononuclear complexes of chromium(III) and manganese(II) with 12-membered tetradentate N<sub>2</sub>O<sub>2</sub>, N<sub>2</sub>S<sub>2</sub> and N<sub>4</sub> donor macrocyclic ligands, Transition Metal Chemistry, 2004, **29** (3), 269-275.
- xxiii Osowole A. A.; Balogun S. A.; Spectral, magnetic, thermal and antibacterial properties of some metal (II) complexes of arninoindanyl Schiff base, European Journal of Applied Sciences, 2012, 4(1), 6-13.

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