ejpmr, 2018,5(4), 106-113

SJIF Impact Factor 4.897

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Research Article

ISSN 2394-3211

EJPMR

MIXED LIGAND COMPLEXES OF Ni(II) AND Cd(II) WITH PHTHALIC ACID OR SUCCINIC ACID AND HETEROCYCLIC AMINES: SYNTHESIS AND CHARACTERIZATION WITH ANTIMICROBIAL STUDY

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Article Received on 07/02/2018 **Article Revised on 28/02/2018** **Article Accepted on 20/03/2018**

ABSTRACT

Mixed ligand complexes of Ni(II) and Cd(II) with phthalic acid or succinic acid and heterocyclic amines have been synthesized. The synthesized complexes were characterized by using elemental analysis, conductometric, magnetic moment measurements, electronic spectra and FTIR spectral studies. The complexes were found to be colored, non-electrolytic in nature. The results showed that the Ni(II) complexes were octahedral, while Cd(II) complexes were tetrahedral structure. Antibacterial and antifungal activities of synthesized mixed ligand complexes were studied.

KEYWORDS: Mixed ligand complexes, FTIR, Electronic spectra, Antimicrobial activity.

INTRODUCTION

Last many decades, coordination compounds play a vital role in the research field of chemistry. Biologically active ligands are very much important for coordination compound.[1-3] Mixed ligands complexes also play an important role in magneto chemistry, analytical chemistry and photochemistry.[4] These complexes are given more important information about the explanation of enzymatic processes of biological applicability.[5,6] Also, these complexes are very much biologically active against pathogenic microorganisms.[7,8] Antimicrobial activities of Ni(II) and Cd(II) ions have been described.[9,10] The preparation of one, two or three-dimensional linkages[11-13] with metal centers[14-16] succinate $(C_4H_4O_4)^{2-}$ anions plays an important role because it used as a polydentate ligands. Phthalic acid, which is a bridging ligand containing two carboxylic groups in ortho position form coordination compound with a different metal.[17]

O and N donor atoms containing d-group metal complexes have biologically active.[18-21] Recently, one of the challenging areas of antibacterial investigation is to an improvement of new complexes to contract with resistant bacteria.[22,23] The production of new metal-based compounds of antibacterial and antifungal is the part of metallo-organic chemistry.[24,25] Organic compounds with Pyridine ring play a vital role in numerous biological reactions.[26]

Here, we present the synthesis strategy, the characterization with antimicrobial activity of mixed ligand complexes of Ni(II) and Cd(II) via phthalic acid or succinic acid (primary ligand) and heterocyclic amines (secondary ligand). **"Fig. 1"** denotes the corresponding structure of used four ligands. Also, we broadly studied the antibacterial and antifungal activities of obtained complexes against different kind of common reference bacteria and fungi.

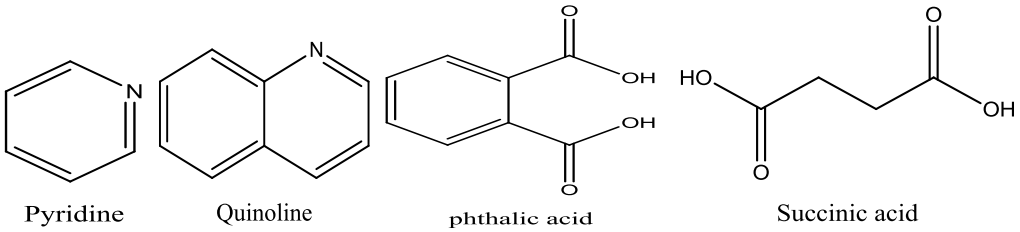

Fig. 1: Structures of the ligands.

MATERIALS AND METHODS

2.1 Reagents and chemicals

Nickel chloride, $NiCl_2.6H_2O$ (Thomas & Baker, ≥97%), Cadmium chloride, $CdCl_2$. H_2O (May & Baker, England). Succinic acid and Quinoline (BDH, England, 98%), Phthalic acid and Pyridine (Thomas & Baker, India). Solvents were purified and dried according to standard procedures.

2.2. General method for the preparation of the complexes

An ethanolic solution of Ni(II) or Cd(II) chloride (1 mM) and deprotonated phthalic acid or succinic acid (1 mM) was mixed as the first ligand with constant stirring but no precipitate was observed. Ethanolic solution was used to dissolve the reactants.[27] Then 25 mL an ethanolic KOH solution of secondary ligand (pyridine or quinoline) in calculated ratio was added to the resulting mixture and heat on a magnetic regulator hot plate with constant stirring. The volume of the solution was reduced to one half and allowed to cool. The precipitate was filtered, washed several times with ethanol and then dried in desiccators over anhydrous $CaCl_2$.

2.3. Physical measurements

The synthesized metal complexes were examined in an electro thermal melting point apparatus model SMP30 for the purpose of melting or decomposition temperature. Above 390°C temperature was impossible to measure the melting points. The magnetic moment data was investigated with the help of SHERWOOD SCIENTIFIC Magnetic Susceptibility Balance. SHIMADZU FTIR-8400 (Japan) spectrophotometer in the range of 4000-400 cm^{-1} we used for FT-IR. The absorbances of all complexes were detected on SHIMADZU spectrophotometer model UV-1800.

2.4. Antibacterial and antifungal screening

The complexes were investigated against the tested four bacterial species among them two are gram-positive (*Bacillus cereus* and *Staphylococcus aureus*) and two are gram-negative (*Escherichia coli* and *Shigella sonnei*). We also observed three fungal species where two are human pathogens (*Candida albicans and Saccharomyces cerevisiae*) and one is planted pathogens (*Aspergillus niger*). Biological activities are tested with the help of reference antibacterial (ciprofloxacin) and antifungal (fluconazole) agents respectively. The paper disc diffusion method[28-33] was used to test the antibacterial and antifungal activity of the complexes whose concentration 40 µg/ 0.01 mL in DMSO solution. On the agar medium inoculated, the well was made with microorganisms. By using micropipette the well was filled with the test solution and the plate was incubated at 37°C for 16 h for bacteria and fungi. The test solution diffused and the growth of the inoculated microorganisms was influenced during this incubated period. The zone of inhibition developed on the plate was measured.

RESULTS AND DISCUSSION

3.1. Physical properties and elemental analysis

The physical properties and analytical data of the Ni(II) and Cd(II) complexes are tabulated in **Table 1**. At room temperature, the molar conductance's of 1×10^{-03} M solution of the complexes in DMSO were investigated. The molar conductance values ranged from 39.7 to 68.3 ohm^{-1} cm^2 mol^{-1} indicates that the compounds are non-electrolytic in nature.[34,35] The elemental analysis data (obtained and calculated) of all the prepared complexes have presented in **Table 2**. It can be observed from this **Table 2** that the values of Metal, C, H, N, and O are consistent with their proposed molecular formula.

Table 1: Physical properties and analytical data of the complexes.

No.	Complex	Color	Decomposition temp. ($\pm5^0$C)	Molar conductance (ohm^{-1} cm^2 mol^{-1})	μ_{eff} (B.M.)
1	$[Ni(DPA)(Py)_4]$	Lemon	290	62.9	2.97
2	$[Ni(DPA)(Q)_4]$	Ash	381	68.3	3.13
3	$[Ni(Suc)(Py)_4]$	Lemon	270	55.8	2.95
4	$[Ni(Suc)(Q)_4]$	Light Brown	200	66.9	3.15
5	$[Cd(DPA)(Py)_2]$	White	206	64.1	Dia
6	$[Cd(DPA)(Q)_2]$	Off White	214	54.6	Dia
7	$[Cd(Succ)(Py)_2]$	White	213	39.7	Dia

Where,
Py = Pyridine, Q = Quinoline
DPA = Deprotonated phthalic acid, Succ = Deprotonated Succinic acid

Table 2: Elemental analysis data of the complexes.

No.	Complex	Molecular Weight		% Metal	% C	% H	% N	% O
1	$[Ni(DPA)(Py)_4]$	Calculate	539.20	10.88	62.83	4.49	10.39	11.87
		Found	539.24	10.92	62.86	4.55	10.43	11.92
2	$[Ni(DPA)(Q)_4]$	Calculate	739.44	7.94	72.00	4.36	7.58	8.66
		Found	739.51	7.97	72.04	4.40	7.63	8.69
3	$[Ni(Suc)(Py)_4]$	Calculate	491.52	11.94	59.08	4.92	11.40	13.02
		Found	491.57	11.97	59.18	4.95	11.46	13.08
4	$[Ni(Suc)(Q)_4]$	Calculate	691.76	8.48	69.97	4.67	8.10	9.25
		Found	691.79	8.53	70.03	4.72	8.14	9.29
5	$[Cd(DPA)(Py)_2]$	Calculate	434.72	25.85	50.10	3.25	6.44	14.72
		Found	434.76	25.87	50.14	3.28	6.47	14.75
6	$[Cd(DPA)(Py)_4]$	Calculate	534.85	21.02	58.38	3.39	5.24	11.96
		Found	534.87	21.05	58.42	3.44	5.26	11.99
7	$[Cd(Suc)(Py)_2]$	Calculate	387.04	29.04	43.77	3.66	7.24	16.54
		Found	387.08	29.08	43.80	3.71	7.29	16.58

3.2. Magnetic moment and electronic spectra

Table 1, represents the observed effective moment (μeff) values of the Ni(II) and Cd(II) complexes at room temperature. From the value of effective magnetic moments, $\mu_{eff,}$ it can be concluded that the Ni(II) complexes are paramagnetic whereas Cd complexes are diamagnetic.[36-38] The electronic spectra of all complexes were noted at room temperature with the concentration of DMSO solution was 10^{-3} M. The electronic spectra of $[Ni(DPA)(Py)_4]$, $[Ni(DPA)(Q)_4]$, $[Ni(Succ)(Py)_4]$, and $[Ni(Succ)(Q)_4]$ complexes were shown 353, 357, 355, and 350 nm respectively, and these are suggestive of octahedral geometry around Ni(II) ion.[39-41] In Cd (II) complexes, d^{10} orbital is completely filled that's why it does not show any d-d electronic transition but exhibit charge transfer spectra.[42] The $[Cd(DPA)(Py)_2]$, $[Cd(DPA)(Q)_2]$, and $[Cd(Suc)(Py)_2]$ complexes were shown 282, 281, and 283 nm due to the L→M charge transfer transition that corresponds to tetrahedral structure.[38,43] All data of electronic spectra of Ni(II) and Cd(II) complexes as shown in **Table 3** and **"Fig. 2".**

Table 3: Data for the determination of UV-visible spectral bands.

No.	Complex	λ_{max} (nm)
1	$[Ni(DPA)(Py)_4]$	353
2	$[Ni(DPA)(Q)_4]$	357
3	$[Ni(Succ)(Py)_4]$	355
4	$[Ni(Succ)(Q)_4]$	350
5	$[Cd(DPA)(Py)_2]$	282
6	$[Cd(DPA)(Q)_2]$	281
7	$[Cd(Suc)(Py)_2]$	283

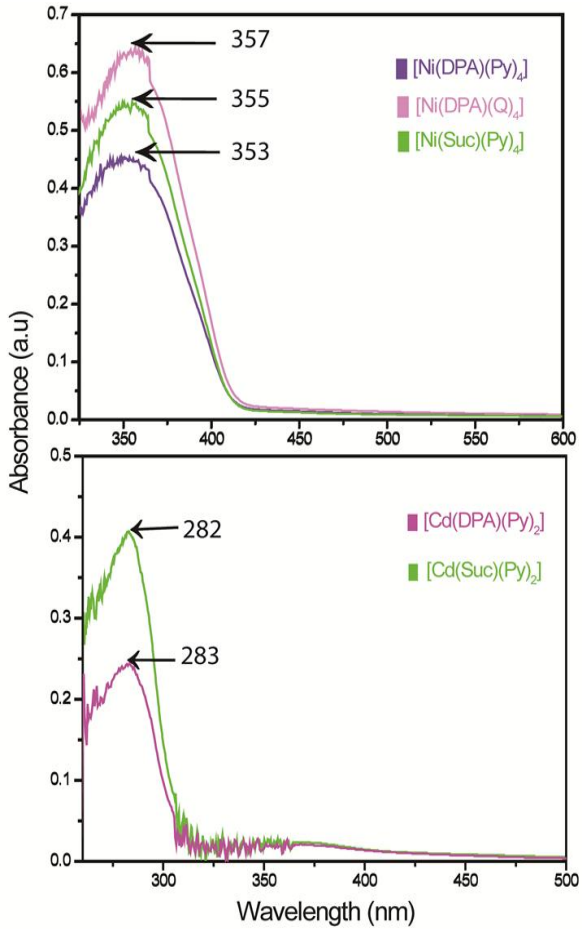

Fig. 2: UV/VIS absorption spectra achieved from the complexes of [Ni(DPA)(Py)$_4$], [Ni(DPA)(Q)$_4$], [Ni(Suc)(Py)$_4$], [Cd(DPA)(Py)$_2$], and [Cd(Succ)(Py)$_2$].

3.3. FTIR studies

FTIR spectra of the Ni(II) and Cd(II) complexes were represented in **Table 4** and **"Fig. 3"**. The complexes display bands in the regions (1550-1675) and (1150-1395) cm^{-1} due to υ(C=O) and υ(C-O) respectively, significantly lower than that of free ligand indicating the coordination of metal ion through its carboxylate anion. The band observed in the (1395-1395) cm^{-1} region due to υ(C=N) vibrations. The in-plane and out-of-plane ring deformation modes of heterocyclic amines observed at 680 and 620 cm^{-1} respectively undergo a positive shift in mixed ligand complexes confirming their coordination through nitrogen. The low intensity in the ranges 360-495 and 500-580cm^{-1} can be allotted to stretching vibrations υ(M-N) and υ(M-O), respectively.[44,45]

Table 4: Data for the determination of IR Spectroscopy in cm^{-1}

No.	Complex	υ(C=O)	υ(C-O)	υ(C=N)	υ(M-O)	υ(M-N)
1	[Ni(DPA)(Py)$_4$]	1656.40	1306.25	1530.18	501.13	490.28
2	[Ni(DPA)(Q)$_4$]	1585.28	1359.75	1463.21	532.90	488.57
3	[Ni(Suc)(Py)$_4$]	1567.66	1296.78	1398.88	519.28	361.05
4	[Ni(Suc)(Q)$_4$]	1668.95	1390.40	1440.02	521.14	483.45
5	[Cd(DPA)(Py)$_4$]	1656.40	1298.96	1423.12	509.40	415.34
6	[Cd(DPA)(Py)$_2$]	1554.50	1154.14	1414.96	533.83	445.08
7	[Cd(Suc)(Py)$_2$]	1672.80	1387.56	1504.87	574.54	423.43

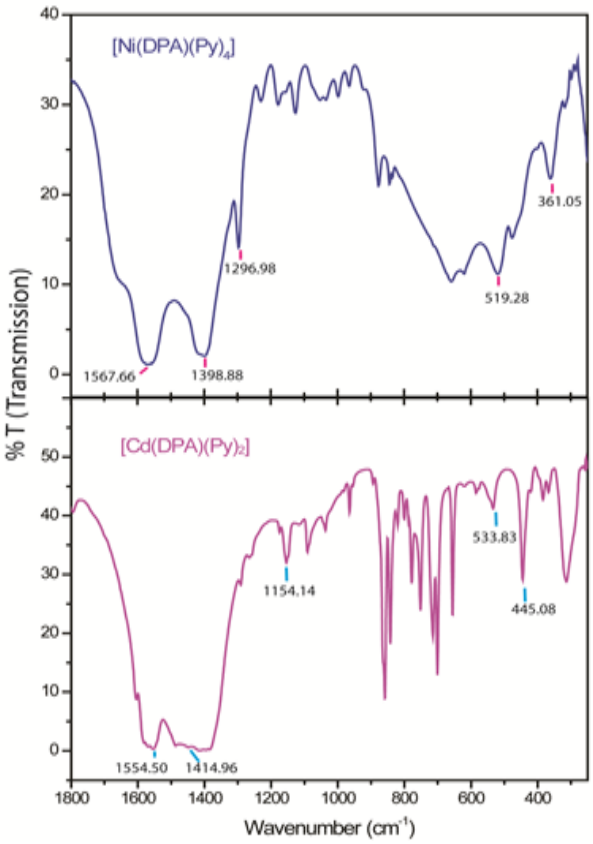

Fig. 3: FTIR spectra of the complexes [Ni(DPA)(Py)$_4$], and [Cd(DPA)(Py)$_2$].

3.4. Antibacterial and antifungal screening

Metal complexes show a significant character in regulating biological activities. The antimicrobial activity is subjected to the cell membrane of the microorganisms and nature of metal ions.[46] The uses of metals for stopping or decreasing growth of bacterial and fungal in medical treatment have been reported.[47] The antibacterial and antifungal potentiality of all the tested compounds against the four chosen bacteria and three fungi were presented in **Table 5**, **Table 6** and **"Fig. 4"**, **"Fig. 5"** respectively. The zone of inhibition (mm) around the discs was measured. Results are spoken as the zone of inhibition. The results of the antibacterial and antifungal screening have shown that all the compounds display broad spectra against the reference bacteria and fungi.

Table 5: Antibacterial activity of the synthesized complexes

Complex	Zone of inhibition, diameter in mm			
	Bacillus cereus	***Staphyllococeus aureus***	***Escherichia coli***	***Shigella sonnei***
[Ni(DPA)(Py)$_4$]	20	14	14	10
[Ni(Succ)(Py)$_4$]	6	6	10	14
[Cd(DPA)(Py)$_2$]	7	7	15	10
[Cd(Succ)(Py)$_2$]	22	22	20	18
Ciprofloxacin	30	40	30	40

Table 6: Antifungal activity of the synthesized complexes.

Complex	Zone of inhibition, diameter in mm		
	Candida albicans	***Aspergllus niger***	***Saccharromyces cerevaceae***
[Ni(DPA)(Py)$_4$]	12	14	10
[Ni(Succ)(Py)$_4$]	12	14	12
[Cd(DPA)(Py)$_2$]	25	25	22
[Cd(Succ)(Py)$_2$]	16	20	18
Fluconazole	12	12	12

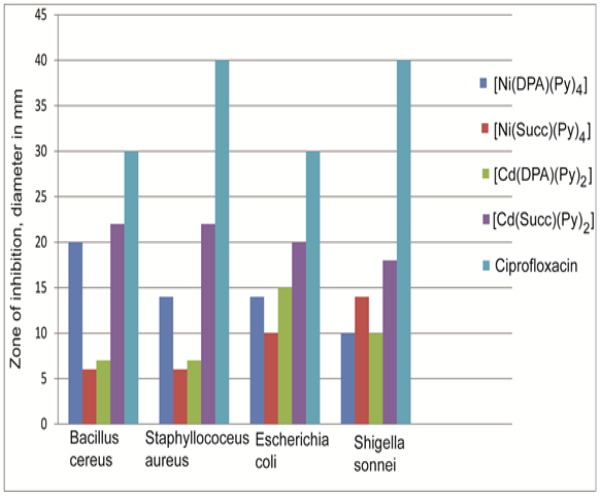

Fig. 4: Antibacterial activity of the synthesized complexes.

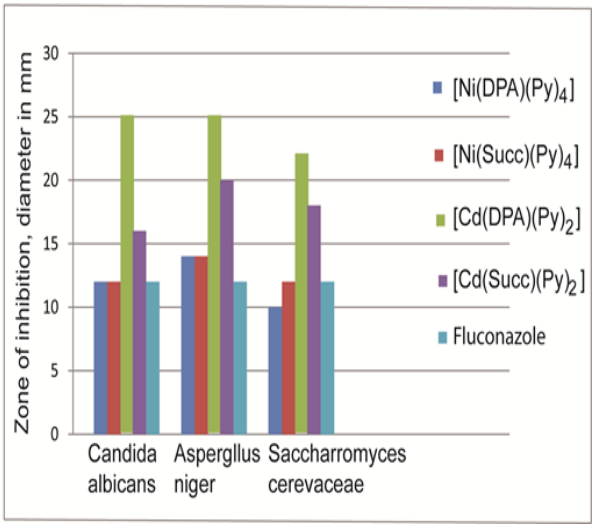

Fig. 5: Antifungal activity of the synthesized complexes.

CONCLUSION

On the basis of all the above experimental measurement, we have offered octahedral geometry for Ni(II) compound but tetrahedral geometry for Cd(II) compound. The proposed structures of $[Ni(DPA)(Py)_4]$, and $[Cd(DPA)(Py)_2]$ have revealed in **"Fig. 6"** and **"Fig. 7"**. All the prepared complexes detected good antimicrobial activity. The tested mixed-ligand complexes displayed higher activities against fungi compared to bacteria.

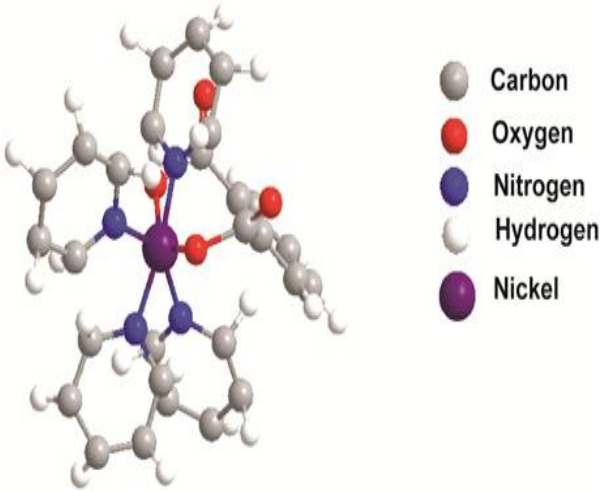

Fig. 6: Probable 3-D structure of the complex $[Ni(DPA)(Py)_4]$.

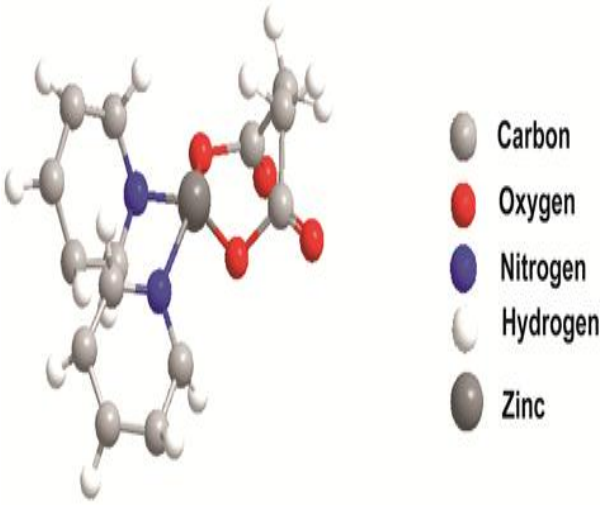

Fig. 7: Probable 3-D structure of the complex $[Cd(DPA)(Py)_2]$.

ACKNOWLEDGEMENTS

The authors are grateul to the Department of Chemistry, Faculty of Science, University of Rajshahi, Rajshahi, Bangladesh. Also, Department of Chemistry, Faculty of Civil Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh.

REFERENCES

1. Naik AD, Annigeri SM, Gangadharmath UB, Ravankar VK, Mahale VB, Reddy VK. Anchoring mercapto-triazoles on dicarbonyl backbone to assemble novel binucleating, acyclic SNONS compartmental ligands. Ind J Chem., 2002; 41A: 2046–2053.
2. Sen AK, Singh G, Singh K, Handa RN, Dubey SN, Squattirito PJ. Synthesis and characterization of some monofunctional bidentate Schiff bases derived from cinnamaldehyde ands-triazoles, and their Co(II), Ni(II), Cu(II) and Zn(II) complexes. Proc Ind Acad Sci., 1998; 110: 75–81.

3. Sen AK, Singh G, Singh K, Noren RK, Handa RN, Dubey SN. Synthesis and characterization of some monofunctional bidentate Schiff bases derived from furfuraldehyde and their cobalt(II), nickel(II) and copper(II) complexes. Ind J Chem., 1997; 36A: 891–894.
4. International tables for X-ray crystallography. IV, Kynoch Press, Birmingham, 1974.
5. Mukerjee GN, Sahu HK. Multimetal multiligand complexes. Part-II. Equilibrium study on the formation and stability of mixed-metal, mixed-ligand complexes of cobalt-, nickel-, copper-and zinc (II) with aspartate and benzimidazole in aqueous solution. J Ind Chem Soc., 2000; 77: 209–212.
6. Yamauchi O, Odani A. Structure-stability relationship in ternary copper(II) complexes involving aromatic amines and tyrosine or related amino acids. Intramolecular aromatic ring stacking and its regulation through tyrosine phosphorylation. J Am Chem Soc., 1985; 107: 5938–5945.
7. Thakkar NV, Thakkar JR. Synthesis and characterization of chiral mixed ligand Co(II) complexes of isonitrosopropiophenone and amino acids. Syn. React. Inorg Met Org Chem., 2000; 30: 1871–1887.
8. Shivankar VS, Takkar NV. Synthesis, characterization and antimicrobial activity of some mixed ligand Co (II) and Ni (II) complexes. Acta Pol Pham Drug Res, 2003; 60: 45–50.
9. Hanif MA, Zahid AASM, Akter J, Islam MS, Haque MM, Banu LA, Hahn JR. Synthesis, characterization and antimicrobial activity of Ni(II) and Zn(II) complexes with amino acids and heterocyclic amine. Der Chem Sin, 2016; 7: 75–82.
10. Ali MA, Haroon CM, Nazimuddin M, Majumder SMMH, Tarafder MTH, Khair MA. Synthesis, characterization and biological activities of some new nickel(II), copper(II), zinc(II) and cadmium(II) complexes of quadridentate SNNS ligands. Transit Met Chem., 1992; 17: 133–136.
11. Livage C, Egger C, Ferey G. Hybrid Open Networks (MIL 16): Synthesis, crystal structure, and ferrimagnetism of $Co_4(OH)_2(H_2O)_2(C_4H_4O_4)_3 \cdot 2H_2O$, A new layered cobalt(II) carboxylate with 14-membered ring channels. Chem Mater, 1999; 11: 1546–1550.
12. Livage C, Egger C, Nogues M, Ferey G. Hybrid open frameworks (MIL-n). Part 5 Synthesis and crystal structure of MIL-9: a new three-dimensional ferromagnetic cobalt(II) carboxylate with a two-dimensional array of edge-sharing Co octahedra with 12-membered rings. J Mater Chem., 1998; 8: 2743–2747.
13. Livage C, Egger C, Ferey G. Hydrothermal versus nonhydrothermal synthesis for the preparation of organic-inorganic solids: the example of cobalt(II) succinate. Chem Mater, 2001; 13: 410–414.
14. Vaidhyanathan R, Natarajan S, Rao CNR. Three-dimensional yttrium oxalates possessing large channels. J Chem Mater, 2001; 13: 185–191.
15. Zhang J, Li ZJ, Wen YH, Kang Y, Cheng JK, et al. Synthesis and crystal structures of two metal succinates modified by bipyridines. Z Anorg Allg Chem., 2004; 630: 2731–2735.
16. Prasad PA, Neeraj S, Natarajan S, Rao CNR. Synthesis and structure of the first open-framework cadmium oxalate possessing channels. Chem Commun, 2000; 14: 1251–1252.
17. Liu X, Xie C, Wang X, Shen G, Shen D. A novel 2D polymeric structure of Cu–Na complex, in which phthalate gives seven coordination sites. Inor Chem Commun, 2003; 6: 1433–1435.
18. Cao Y, Yi C, Liu H, Li H, Li Q, Yuan Z, Wei G. Syntheses, crystal structures and in vitro anticancer activities of oxovanadium(IV) complexes of amino acid Schiff base and 1,10-phenanthroline ligands. Transit Met Chem., 2016; 41: 531–538.
19. Sedighipoor M, Kianfar AH, Mahmood WAK, Azarian MH. Epoxidation of alkenes by an oxidovanadium(IV) tetradentate Schiff base complex as an efficient catalyst with tert-butyl hydroperoxide. Inorg Chim Acta, 2017; 457: 116–121.
20. Kawashima A, Shu S, Takeda R, Kawamura A, Sato T, Moriwaki H, Wang J, Izawa K, Acena JL, Soloshonok VA, Liu H. Advanced asymmetric synthesis of (1R,2S)-1-amino-2-vinylcyclopropanecarboxylic acid by alkylation/cyclization of newly designed axially chiral Ni(II) complex of glycine Schiff base. Amino Acids, 2016; 48: 973–986.
21. Hosseini-Yazdi SA, Mirzaahmadi A, Khandar AA, EignerV, Dusek M, Lotfipour F, Mahdavi M, Soltani S, Dehghan G. Synthesis, characterization and in vitro biological activities of new water-soluble copper(II), zinc(II), and nickel(II) complexes with sulfonato-substituted Schiffbase ligand. Inorg Chim Acta, 2017; 458: 171–180.
22. Wright PM, Seiple IB, Myers AG. The evolving role of chemical synthesis in antibacterial drug discovery. Angew Chem Inter Ed, 2014; 53: 8840–8869.
23. Dogruer D, Urlu S, Onkol S, Ozcelik B, Sahin MF. Synthesis of some pyridazine derivatives carrying urea, thiourea, and sulfonamide moieties and their antimicrobial activity. Turk J Chem., 2010; 34: 57–65.
24. Scozzafava A, Supuran CT. Carbonic anhydrase and matrix metalloproteinase inhibitors: sulfonylated amino acid hydroxamates with MMP inhibitory properties act as efficient inhibitors of CA isozymes I, II, and IV, and *N*-hydroxysulfonamides inhibit both these zinc enzymes[1]. J Med Chem., 2000; 43: 3677–3687.
25. Rice SA, Givskov M, Steinberg P, Kjelleberg S. Bacterial signals and antagonists: the interaction

between bacteria and higher organisms. J Mol Microbiol Biotechnol, 1999; 1: 23–31.
26. EMG Abd. Thermodynamic and structural studies of complexes of manganese (II), cobalt (II), nickel (II) and copper(II) with aminofuropyridine carboxamide. J Serb Chem Soc, 2003; 68: 463–470.
27. Akter J, Hanif MA, Islam MS, Haque MM, Lee SH, Banu LA. Synthesis, characterization and antimicrobial activity of mixed ligand complexes of Mn(II) and Zn(II) with phthalic acid or succinic acid and heterocyclic amines. Der Chemica Sinica, 2017; 8: 166–174.
28. Chohan ZH, Farooq MA, Iqbal MS. Synthesis, characterization and biological properties of anions of bivalent transition metal [Co(II) and Ni(II)] complexes with acylhydrazine derived ono donor Schiff bases. Metal-Based Drugs, 2000; 7: 133–139.
29. Priya NP, Arunachalam S, Manimaran A, Muthipriya D, Ishanan CJ. Mononuclear Ru(III) Schiff base complexes: synthesis, spectral, redox, catalytic and biological activity studies. Spectrochim Acta A, 2009; 72: 670–676.
30. Barry AL. Principles and practice of Microbiology. Lea and Febgen, Philadelphia, 1976.
31. Buer AW, Kirby WMM, Sherris JC, Turck M. Antibiotic susceptibility testing by a standardized single disk method. Am J Clin Pathol, 1966; 44: 493–496.
32. Gnanamanickam SS, Smith DA. Selective toxicity of isoflavonoidphytoalenins to Gram positive bacteria, Phytoalenins to Gram positive bacteria. Phytopathology, 1980; 70: 894–896.
33. Chohan ZH. Symmetric 1,1'-dimethylferrocene-derived amino acids: their synthesis, characterization, ligational and biological properties with Cu(II), Co(II) and Ni(II) ions. Metal-Based Drugs, 2000; 7: 177–183.
34. Natarajan R, Antonysamy K, Chinnathangavel T. Redox and antimicrobial studies of transition metal (II) tetradentate Schiff base complexes. Transit Metal Chem, 2003; 28: 29–36.
35. Mohamed GG, Gamel NEAEL. Synthesis, investigation and spectroscopic characterization of piroxicam ternary complexes of Fe(II), Fe(III), Co(II), Ni(II), Cu(II) and Zn(II) with glycine and dl-phenylalanine. Spectrochim Acta Part A., 2004; 60: 3141–3154.
36. JfIRGENSEN CHRK. Comparative crystal field studies of some ligands and the lowest singlet state of paramagnetic nickel (II) complexes. Acta Chem Scand, 1955; 9: 1362–1377.
37. Ho FLH and Reilley CN. Conformational studies of chelated ethylenediamines by nuclear magnetic resonance. Paramagnetic nickel(II) complexes of N-alkylethylenediamines. Anal Chem., 1969; 41: 1835–1841.
38. Golcu A, Tumer M, Demirelli H, Wheatley RA. Cd(II) and Cu(II) complexes of polydentate Schiff base ligands: synthesis, characterization, properties and biological activity. Inorg Chim Acta., 2005; 358: 1785–1797.
39. Mohamed TA, Shaaban IA, Farag RS, Zoghaib WM, Afifi MS. Synthesis, antimicrobial activity, structural and spectral characterization and DFT calculations of Co(II),Ni(II), Cu(II) and Pd(II) complexes of 4-amino-5-pyrimidinecarbonitrile. Spectrochim. Acta A., 2015; 135: 417–427.
40. Mohamed GG, Soliman MH. Synthesis, spectroscopic and thermal characterization of sulpiride complexes of iron, manganese, copper, cobalt, nickel, and zinc salts. Antibacterial and antifungal activity. Spectrochim Acta A, 2010; 76: 341–347.
41. Mohamed GG, Zayed EM, Hindy AMM. Coordination behavior of new bis Schiff base ligand derived from 2-furan carboxaldehyde and propane-1,3 diamine. Spectroscopic, thermal, anticancer and antibacterial activity studies. Spectrochim Acta A, 2015; 145: 76–84.
42. Nair MS, Arish D, Joseyphus RS. Synthesis, characterization, antifungal, antibacterial and DNA cleavage studies of some heterocyclic Schiff base metal complexes. J Saudi Chem Soc., 2012; 16: 83–88.
43. Mohamed GG, El-Gamel NEA, Teixidor F. Complexes of 2-(2-benzimidazolylazo)-4 acetamidophenol, a phenoldiazenyl-containing ligand. Could this be a moiety suitable for Zn and Cd extraction? Polyhedron, 2001; 20: 2689–2696.
44. Gu¨lcan M, So¨nmez M. Synthesis and characterization of Cu(II), Ni(II), Co(II), Mn(II), and Cd(II) transition metal complexes of tridentate schiff base derived from o-vanillin and N-aminopyrimidine-2-thione. Phosphorus Sulfur Silicon, 2011; 186: 1962–1971.
45. Alan I, Kriza A, Badea M, Stanica N, Olar R. Synthesis and characterisation of Co(II), Ni(II), Zn(II) and Cd(II) complexes with 5-bromo-N, N0-bis-(salicylidene)-o-tolidine. J Therm Anal Calorim, 2013; 111: 483–490.
46. Joseyphus RS, Nair MS. Synthesis, characterization and biological studies of some Co(II), Ni(II) and Cu(II) complexes derived from indole-3-carboxaldehyde and glycylglycine as Schiff base ligand. Arabian J Chem., 2010; 3: 195–204.
47. Kateřina M, Petr P, Zuzana R, Ondřej K. Antibacterial and antifungal activities of silver, copper and zinc montmorillonites. Appl Clay Sci., 2011; 53: 642–645.