The Pharma Innovation Journal 2022; 11(5): 1780-1784

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 1780-1784

www.thepharmajournal.com
Received: 07-02-2022
Accepted: 15-03-2022

Nishant Chauhan
Associate Professor, Department of Chemistry, R.B.S College, Agra, Dr. B.R. Ambedkar University, Agra, Uttar Pradesh, India

Nagendra Singh
Research Scholar, Department of Chemistry, Narain (P.G) College, Shikohabad, Dr. B.R. Ambedkar University, Agra, Uttar Pradesh, India

Corresponding Author:
Nishant Chauhan
Associate Professor, Department of Chemistry, R.B.S College, Agra, Dr. B.R. Ambedkar University, Agra, Uttar Pradesh, India

Analytical study on binary and mixed ligand complexes of transition metal ion

Nishant Chauhan and Nagendra Singh

Abstract
Binary and ternary complex formation equilibria of M(II) with SAH-hydrazone ligand (2-((2-phthalazin-1-yl)hydrazono)methyl)phenol) in nearness of phenylalanine (Phe) as an agent case of amino acids have been examined utilizing the pH-metric titrations. The relative concentrations (M: L: X=1:2:2, 1:2:4, 1:4:2) and stabilities of the ternary species are contrasted and those of binary species. The AM-B type complexes were shaped, where Aspartic corrosive utilized as essential ligand and Cytosine optional ligand, delineated as An and B separately arrange with metal M (II) were exclusively controlled by the basicity of the carboxyl or amine gathering. Moreover, the impact of temperature on protonation of ligands and formation of blended ligand complexes (M-SAHPhe) was investigated. The thermodynamics were calculated and talked about.

Keywords: Complex, stabilities, aqueous, thermodynamics, ligand

Introduction

Coordination of heavy metal assumes an imperative job in the bioaccumulation and detoxification of the metal poisonousness that featured the zone of chelation treatment, which is an intravenous treatment, intended to tie heavy metals in the body so as to treat heavy metals harmfulness. It has been accounted for by a few examinations that a great many potential ligand have process ability to tie with metals particles to get their stability of metal complexes. Amino corrosive with at least one than one coordination site alongside various useful gathering has a huge job in metal chelation as detoxification and remediation of metal contaminations. Aminopolycarboxylate chelating ligand (APCs) like ethylenediaminedisuccinic acid (EDDS), ethylenediaminetetraacetic corrosive (EDTA) and nitrilotriacetic corrosive (NTA) can possibly irritate the common speciation of metals and impact metal bioavailability. There were numerous examinations have been uncovered the significance of chelation on metal bioavailability, plant uptake, harmfulness, transport, adsorption, circulation and destiny, on the other hand, chelating specialists are additionally influenced by the nearness of metals bringing about various reactivities of metal-chelates. The cadmium is considered as poisonous component even low level its introduction is promptly disseminated to the tissues of fundamental focused on organ like liver and kidney create intense or incessant maladies. At the point when Cd took an interest in bilirubin combination it restrains the compounds movement and furthermore builds pee Ca2+ excretion which can cause serious bone pathology. Studies in people with acrodermatitis enteropathica, a genetic disorder with zinc malabsorption bringing about serious lack, have given a lot of knowledge into the utilitarian results of zinc insufficiency and it additionally found that Nickel assumes various jobs in the science of microorganisms and plants.

Metallic complexes including hydrazones and amino acids bearing the significance of both amino acids and hydrazones and has happened to enormous organic significance. Likewise, estimations of stability constants of the complex formation of organically dynamic ligands with metal particles notwithstanding counts of the concentration of every specie at any pH are significant for the entire comprehension of the physiochemical way of such mixes, require assurance of their protonation constants. Furthermore, protonation constants are of principal significance in pharmaceutical investigations especially for the revelation and assessment of novel aggravates that could be compelling medications. In continuation of our already work and to expand the examination space of examination on the coordination science of hydrazones and amino acids, we report here the arrangement balance investigations of the blended ligand complexes including some transition metal particles (Cu2+, Co2+, Ni2+ and Mn2+), (SAH) as the essential ligand (L1) and Lphenylalanine (2ry ligand) are done

potentiometrically in 60% (v/v) DMSO-water blend at I = 0.1 mol dm-3 (NaCl). The thermodynamic parameters were calculated and talked about.

Metal ligand complexes are comprised of am focal metal particle and ligands notwithstanding the dissolvable atoms required to make up the coordination circle of the metal particle such metal particle ligand complexes are very basic in organic and explanatory frameworks. Therefore comprehension of the importance of metal particles in organic frameworks may unwind the secrets encompassing the protein-substrate connections and the control mechanisms that decide the coordination and coordination tendency of the metal particles bound at the dynamic destinations of numerous catalysts in compound metal particle substrate responses. Aside from this, the formation of blended ligand complexes is additionally significant in understanding the conduct of toxins in common waters, considering the high partiality of particle for benefactor iotas like oxygen and nitrogen and so on. Enalapril is a prodrug that contains an ester bunch that is hydrolyzed by esterases to enalaprilat an angiotensin-changing over chemical inhibitor. Enalapril shows next to no hydrolysis in human plasma yet fast hydrolysis in rodent plasma. Enalapril is utilized to treat hypertension, suggestive cardiovascular breakdown, and asymptomatic left ventricular brokenness. It has been demonstrated to ensure the capacity of the kidneys in hypertension, cardiovascular breakdown, and diabetes, and might be utilized in the absence of hypertension for its kidney defensive impacts.

Literature Review

Rawda M. Okasha (2019) [1] An effective oligomerization of ternary metal complexes, cobalt (II), nickel (II), copper (II), zinc (II), chromium (III) and ferric sulfate (III) with nitrilotriacetic corrosive (NTA) as an essential ligand and glutamic corrosive as an optional ligand, has been illustrated. The formation of oligomers emerged from the nearness of the sulfate moiety, which works as a crossed over bidentate ligand that organizes with other metal moieties. The epic oligomers showed octahedral structures, which reinforced together through the sulfate moiety. In silico expectations were led to measure the bioactivity, physico-synthetic and pharmacokinetic properties. The organic exercises of these oligomers just as their tumor inhibitory conduct have been investigated. This work additionally presents a simple and novel technique for setting up these materials in nanosize, utilizing Cetyltrimethylammonium bromide (CTAB) and polyvinyl liquor (PVA) as topping ligands. The size and state of the nanomaterials have been affirmed utilizing the transmission electron magnifying instrument (TEM) and the examining electron magnifying lens (SEM).

Ahmed A. El-Sherif (2012) [2] Thermodynamic parameters for protonation of 1,4-bis(3-aminopropyl)- piperazine (BAPP) and its metal complexation with some divalent metal particles were resolved in watery arrangement at consistent ionic quality (0.1 M NaNO3) utilizing a potentiometric procedure. The request for – ΔG0 and – ΔH0 was found to obey Co2+ < Ni2+ < Cu2+ > Zn2+, as per the Irving-Williams request. The formation equilibria of zinc (II) complexes and the ternary complexes Zn(BAPP)L, where L = amino corrosive, amides, or DNA constituents), have been investigated. Ternary complexes are framed by a concurrent mechanism. The concentration circulation of the complexes in arrangement was assessed as an element of pH. Stoichiometry and stability constants for the complexes shaped are accounted for and examined. The stability of ternary complexes was quantitatively contrasted and their relating binary complexes as far as the parameter Δlog K.

Mohamed S. A. Abdel-Mottaleb (2019) [3] Divalent transition metal complexes [MGlu-Arg (H2O)] H2O and [MGlu-Arg (H2O)] H2O, where MCo, Ni, Cu, and Zn, Glglutamic corrosive, and Arg L-arginine, are arranged and portrayed utilizing various methods. DFT and TD-DFT displaying approved and deciphered some trial results. Weight reduction method uncovers effective erosion hindrance activity of these complexes towards aluminum metal at various temperatures. Our outcomes point to erosion restraint through synthetic adsorption on the aluminum surface. Furthermore, a simple calcination of Co and Cu complexes at 550° C yields nanosized oxides of Co3O4, CoO, and CuO crystalline stages. (e complexes show remarkable natural exercises towards pathogenic microbes and organisms. Besides, *in vitro* anticancer action assessment of these complexes is accomplished against hepatocellular carcinoma (HepG-2). (e results are connected with sub-atomic descriptors, for example, synthetic potential and hardness acquired from the wilderness orbitals.

Srikanth Bathula (2019) [4] Chemical speciation of ternary complexes of L-arginine and L-aspartic corrosive with basic transition metal particles was examined pH metrically. The accompanying MLX, MLXH and ML2X ternary species are distinguished and announced in this paper. The presence of various ternary species is set up from displaying considers utilizing the PC program MINIQUAD75. The additional stability related with the ternary complexes is ascribed to variables, for example, charge balance, chelate impact, stacking cooperations and hydrogen holding. Pattern in variety of stability constants with the adjustment in the mole division of the surfactant in different micellar media is clarified based on electrostatic and non-electrostatic powers. Appropriation graphs comparable to pH and conceivable structures were introduced.

Singh Dharmveer (2014) [5] The Complexation of blended ligand formation of bio-ligands with heavy metals particle Cd (II), Ni (II), and Zn (II), were dictated by potentiometric pH titration in watery arrangement (I = 0.1 M, NaNO3, 35°±1 C).The AM-B type complexes were framed, where Aspartic corrosive utilized as essential ligand and Cytosine optional ligand, delineated as An and B separately facilitate with metal M (II) were exclusively controlled by the basicity of the carboxyl or amine gathering. The conceivable equilibria have been concluded based on speciation bends got through SCOGS PC program and species are additionally introduced and talked about. Ligand has a novel conduct to formation of chelates with metal particles it assume huge job in detoxification of metal by utilizing as a chelating operator. The investigation bargains the general equilibria, level of species organization, relative stability of blended ligand ternary complexes follow the Irving-Williams request Ni>Zn>Cd. The request for stability constants of blended ligand ternary frameworks were discovered A-Zn (II)- B>A-Ni (II)- B>A-Cd (II)- B. In the investigation of among three individual metal ternary complexes the dominancy of ternary complexes is followed at the pH run between 3.0 to 9.0, which roughly contributes 90% of pretty much all the species formation.

Research methodology

Rawda M. Okasha (2019) [1] An effective oligomerization of ternary metal complexes, cobalt (II), nickel (II), copper (II), zinc (II), chromium (III) and ferric sulfate (III) with nitrilotriacetic corrosive (NTA) as an essential ligand and glutamic corrosive as an optional ligand, has been illustrated. The formation of oligomers emerged from the nearness of the sulfate moiety, which works as a crossed over bidentate ligand that organizes with other metal moieties. The epic oligomers showed octahedral structures, which reinforced together through the sulfate moiety. In silico expectations were led to measure the bioactivity, physico-synthetic and pharmacokinetic properties. The organic exercises of these oligomers just as their tumor inhibitory conduct have been investigated. This work additionally presents a simple and novel technique for setting up these materials in nanosize, utilizing Cetyltrimethylammonium bromide (CTAB) and polyvinyl liquor (PVA) as topping ligands. The size and state of the nanomaterials have been affirmed utilizing the transmission electron magnifying instrument (TEM) and the examining electron magnifying lens (SEM).

Ahmed A. El-Sherif (2012) [2] Thermodynamic parameters for protonation of 1,4-bis(3-aminopropyl)- piperazine (BAPP) and its metal complexation with some divalent metal particles were resolved in watery arrangement at consistent ionic quality (0.1 M NaNO3) utilizing a potentiometric procedure. The request for – ΔG0 and – ΔH0 was found to obey Co2+ < Ni2+ < Cu2+ > Zn2+, as per the Irving-Williams request. The formation equilibria of zinc (II) complexes and the ternary complexes Zn(BAPP)L, where L = amino corrosive, amides, or DNA constituents), have been investigated. Ternary complexes are framed by a concurrent mechanism. The concentration circulation of the complexes in arrangement was assessed as an element of pH. Stoichiometry and stability constants for the complexes shaped are accounted for and examined. The stability of ternary complexes was quantitatively contrasted and their relating binary complexes as far as the parameter Δlog K.

Mohamed S. A. Abdel-Mottaleb (2019) [3] Divalent transition metal complexes [MGlu-Arg (H2O)]H2O and [MGlu-Arg (H2O)]H2O, where MCo, Ni, Cu, and Zn, Glglutamic corrosive, and Arg L-arginine, are arranged and portrayed utilizing various methods. DFT and TD-DFT displaying approved and deciphered some trial results. Weight reduction method uncovers effective erosion hindrance activity of these complexes towards aluminum metal at various temperatures. Our outcomes point to erosion restraint through synthetic adsorption on the aluminum surface. Furthermore, a simple calcination of Co and Cu complexes at 550 °C yields nanosized oxides of Co3O4, CoO, and CuO crystalline stages. (e complexes show remarkable natural exercises towards pathogenic microbes and organisms. Besides, *in vitro* anticancer action assessment of these complexes is accomplished against hepatocellular carcinoma (HepG-2). (e results are connected with sub-atomic descriptors, for example, synthetic potential and hardness acquired from the wilderness orbitals.

Srikanth Bathula (2019) [4] Chemical speciation of ternary complexes of L-arginine and L-aspartic corrosive with basic transition metal particles was examined pH metrically. The accompanying MLX, MLXH and ML2X ternary species are distinguished and announced in this paper. The presence of various ternary species is set up from displaying considers utilizing the PC program MINIQUAD75. The additional stability related with the ternary complexes is ascribed to variables, for example, charge balance, chelate impact, stacking cooperations and hydrogen holding. Pattern in variety of stability constants with the adjustment in the mole division of the surfactant in different micellar media is clarified based on electrostatic and non-electrostatic powers. Appropriation graphs comparable to pH and conceivable structures were introduced.

Singh Dharmveer (2014) [5] The Complexation of blended ligand formation of bio-ligands with heavy metals particle Cd (II), Ni (II), and Zn (II), were dictated by potentiometric pH titration in watery arrangement (I = 0.1 M, NaNO3, 35°±1 C).The AM-B type complexes were framed, where Aspartic corrosive utilized as essential ligand and Cytosine optional ligand, delineated as An and B separately facilitate with metal M (II) were exclusively controlled by the basicity of the carboxyl or amine gathering. The conceivable equilibria have been concluded based on speciation bends got through SCOGS PC program and species are additionally introduced and talked about. Ligand has a novel conduct to formation of chelates with metal particles it assume huge job in detoxification of metal by utilizing as a chelating operator. The investigation bargains the general equilibria, level of species organization, relative stability of blended ligand ternary complexes follow the Irving-Williams request Ni>Zn>Cd. The request for stability constants of blended ligand ternary frameworks were discovered A-Zn (II)- B>A-Ni (II)- B>A-Cd (II)- B. In the investigation of among three individual metal ternary complexes the dominancy of ternary complexes is followed at the pH run between 3.0 to 9.0, which roughly contributes 90% of pretty much all the species formation.

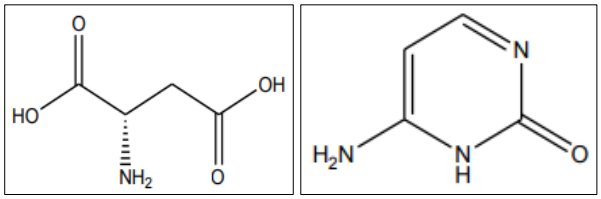


Fig 1: Structure of (a) Aspartic acid and (b) Cytosine

Aspartic corrosive is synthetically 2-Aminobutanedioic corrosive containing two terminal carboxylic gatherings and one - NH2 gathering. The two carboxylic gatherings separate framing two carboxylate anions which take an interest in chelate formation to the metal site alongside – NH2 gathering, in this way Aspartic corrosive carries on as a tridentate ligand. Due to having novel constituents among the amino corrosive, aspartic corrosive assume significant jobs as general acids in compound dynamic habitats, just as in keeping up the solubility and ionic character of proteins.

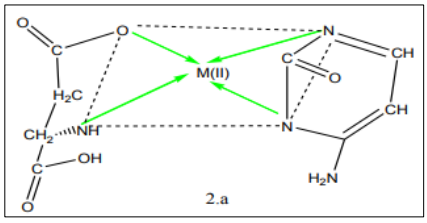


Fig 2: Proposed structure of ternary Aspartic acid-M (II)-Cytosine (1:1:1) complexes, where M (II) =tetra coordinated metal ions

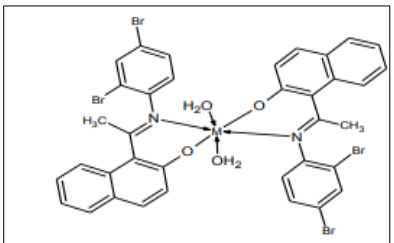
Proton-ligand stability constants of secondary ligand (Y)

From the titration bends of arrangements (I) and (ii), ñA values at different pH were calculated. The proton ligand formation bend was acquired by plotting the estimations of ñA versus pH-meter readings. From the diagram the estimations of log H K1 and log H K2 were assessed considerably basic strategy (A). The estimations of log H K1 and log H K2 were likewise assessed utilizing graphical technique (B) by plotting the chart of log [ñA/(1-ñA)] against pH and log [(2-ñA)/(ñA-1)] against pH, individually. The qualities acquired by technique An and B are in concurrence with one another, the normal estimations of log H K1 and log H K2 has been seen as 8.68 and 2.15 individually.

Metal-ligand stability constants of the Binary (M-Y) complexes

The metal ligand stability constants of binary complexes were assessed expecting the polynuclear complexes and hydrolyzed items were not shaped. The metal-ligand binary restricting proposed structure is appeared in figure 3. An assessment of titration bends demonstrate that complex formation takes place in the arrangement on the accompanying grounds: (I) The metal titration bend of arrangement (iii) shows uprooting with deference ligand (Y) titration bend of arrangement (ii) along the volume hub. This demonstrates the partiality of the ligand to metal particles which discharge proton and produce volume distinction. (II) The shading change of ligand showed up within the sight of metal particle shows the formation of new species because of coordination. (III) The hydrolysis of the metal particle was stifled because of the complex formation and precipitation didn't show up during the titrations.

From the titration bends of arrangements (ii) and (iii), ñ and pL values were calculated. The formation bends were gotten by plotting the estimations of ñ versus pL. From the diagram the estimations of log M KMY1 and log MY KMY2 were assessed considerably essential technique (An) and in the comparative way the estimations of log M KMY1 and log MY KMY2 were assessed utilizing graphical strategy (B) by plotting the chart of log [ñ/(1-ñ)] against pL and log [(2-ñ)/(ñ-1)] against pL individually. The qualities got by strategy An and B are in concurrence with one another, the normal estimations of log M KMY1 and log MY KMY2 alongside metal-ligand stability constants the log β estimations of the binary complexes are given in Table 1. The varieties of ñ was seen as between 0.0-2.0 for the binary (M-Y) complexes of Co(II), Ni(II), Cu(II) and Zn(II) metal particles, which demonstrate that the structure of the complexes were 1:2 in arrangement. The log M KMY1 values for the binary complexes of the metal particles are in the accompanying request: Cu(II) > Ni(II) > Co(II) > Zn(II).



M = Co(II), Ni(II), Cu(II) and Zn(II).

Fig 3: The metal-ligand binary binding proposed structure

Results and Discussion

The proton ligand stability constants (pKa) and metal ligand stability constants (LogK) of binary complexes were dictated by utilizing Irving and Rossotti strategies for the examination with these of ternary frameworks. It is appeared in Table 1.

Table 1: Stability constants of ethambutol HCl and amino acids metal complexes

Ligands	K_1^H	K_2^H	Cu(II)		Zinc(II)	
			$LogK_1$	$LogK_2$	$LogK_1$	$LogK_2$
Ethambutol HCl	6.48	-	5.17	4.86	3.67	3.12
Serine(R_1)	2.13	9.06	7.88	-	8.68	4.66
Valine(R_2)	2.26	9.49	8.12	-	8.23	4.44
Methionine(R_3)	2.06	8.66	8.31	-	4.63	-
Glutamic acid(R_4)	2.18	4.20	7.87	-	8.23	4.58

The deviation of metal titration bends from ligand bend shows the formation of binary complex. The most elevated estimations of n^- (normal number of ligands bound per metal molecule) are around 2.0 demonstrates the formation of 1:1 and 1:2 binary complexes. The request for stability of binary complexes of transition metal particles with drug(L) follows the normal order [Cu (II)>Zn (II)] of Irving and Williams arrangement which has been accounted for by a few of researchers. In instance of amino acids copper complexes shows low stability than zinc complexes. The low estimations of stability constants recommend the ionic cooperations.

Table 2: Stability constants of ternary complexes of Cu (II) with ethambutol-HCl (L) and amino acids and their relative parameters

Amino Acids	β_{111}	β_{20}	β_{02}	K_L	K_R	K_r	ΔlogK
Serine(R_1)	11.18	10.03	7.88	6.01	3.30	1.25	-1.87
Valine(R_2)	12.22	10.03	8.12	7.05	4.10	1.35	-1.07
Methionine(R_3)	12.22	10.03	8.31	7.05	3.91	1.33	-1.26
Glutamic acid(R_4)	12.85	10.03	7.87	7.68	4.98	1.44	-0.19

The comparison of β111 with β20 and β 02 of these frameworks uncovers the particular formation of ternary complexes over the binary frameworks. The low estimations of KL and KR show the greater stability of ternary complexes concerning binary complexes of essential and auxiliary ligands. The positive estimations of Kr likewise bolster the additional stability of blended ligand complexes which might be ascribed to the connections outside the coordinated circle, for example, formation of hydrogen holding between coordinated ligands, charge balance, chelate impact and electrostatic collaborations between non coordinated charge gatherings of ligands. The negative estimations of ΔLogK proposes the formation of ternary complexes however less steady having destabilized nature of complexes which has been accounted for in N and O contributors. The positive estimation of ΔlogK at times is ascribed to the additional stability of ternary complexes.

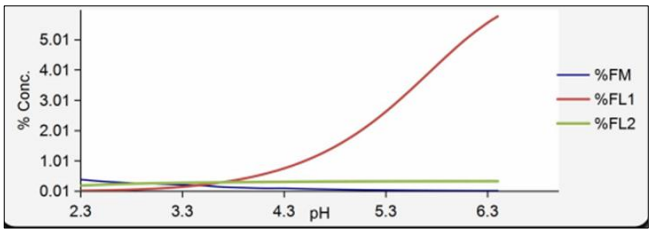


Fig 4: Species distribution curve of Cu(II)LR4system (pH versus % conc. of free metal and free ligands)

The species conveyance bend of different potential types of Cu(II)LR4 system(Figure:4) unmistakably demonstrates the formation of ternary complexes(CuLR) which is about 91.46% at pH 6.4. It additionally shows that less measure of formation of CuL binary species. The rate concentration of CuR2 (C6) diminishes (96% to 8.14% from 2.30pH to 6.40pH) because of the formation of blended ligand complexes as:

$$CuR_2 + CuL \leftrightarrow CuLR + CuR$$

Conclusion

Complex formation equilibria of M(II), with SAH and phenyl alanine was investigated 60% DMSO-40% H2O blend was considered. It is trusted that the acquired information from protonation of the investigated SAH-hydrazone and Phe and their complex formation equilibria in 60% DMSO-40% H2O blend will be a noteworthy commitment to workers doing unthinking examinations in organic media. More positive Δ log10K and increasingly positive log10X values demonstrated the remarked stabilities of the blended ligand complexes in comparison to the binary complexes. The positive estimations of ΔS values affirming that the complex formation is entropically great. Registered sub-atomic and spectroscopic (IR, UVVis, and EPR) properties approved the trial results. (e utilized computational techniques are equipped for giving great basic depictions to the TM complexes. Predictable with the exploratory properties, the advanced structures of the complexes [Cu(II) Glu-Arg] and [Co(II) Glu-Arg (H2O)2] uncover that balance condition of Cu(II) shows marginally misshaped square planar shape, though Co(II)- complex has a mutilated octahedral (where Co(II) focal particle is of C4v-neighborhood balance). Ghastly properties of [Ni(II) Glu-Arg (H2O)2] and [Zn•Glu•Arg•(H2O)2] complexes demonstrate that they have comparable structure as Co(II) complex. The ternary complexes are progressively agreeable for "metal vehicle" as a result of their additional stability. The examination additionally gives knowledge into the metal accessibility/metal vehicle in bio-fluids and furthermore attempted to comprehend job of metal chelation for detoxification and remediation of heavy metal contaminations.

References

1. Rawda Okasha M. Design of Novel Oligomeric Mixed Ligand Complexes: Preparation, Biological Applications and the First Example of Their Nanosized Scale, Int. J Mol. Sci. 2019;20:743.
2. Ahmed El-Sherif A. Thermodynamic Investigation and Mixed Ligand Complex Formation of 1,4-Bis-(3-aminopropyl)-piperazine and Biorelevant Ligands, Hindawi Publishing Corporation Bioinorganic Chemistry and Applications. 2012, 10pp.
3. Mahmoud M, Mashaly ZH, Abd-Elwahab, Faheim AA. Mixed-Ligand Complexes of a Schiff Base, 8-Hydroxyquinoline and Oxalic Acid with Cu(II), Ni(II), Zn(II), and Fe(III) Ions: Pyrolytic Products and Biological Activities, Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry. 2019;34(2):233-268.
4. Bathula Srikanth, Kotra Krishna. Mixed Ligand Complexes of Transition Metal Ions with Selective Bio-Ligands in Surfactant-Water Mixtures, 2019, 8.
5. Singh Dharmveer, Chandra Harish, Shankar Vijay, Krishna V. Mixed Ligand Ternary Complexes of Some Transition Metals with Aspartic Acid as Primary Ligand and Cytosine as Secondary Ligand: Equilibrium Study, Chemical Speciation and Stability Constant. International Journal of Research in Chemistry and Environment. 2014;4:48-53.
6. Bartaria D, Chandra P, Singh M, Krishna V. A Comparative Study on the interaction of some metal ions with Glutamic Acid and L- Cysteine as Primary Ligands and Thymine as a Secondary Ligand using Potentiometry in Aqueous Medium, Int. J Res. Chem. Environ. 2012;2(4):45.
7. Tripathi NK, Krishna V. Speciation of Nickel (II) and Cobalt (II) Quaternary Complexes of L-Aspartic acid and Uracil, Ultra Chem. 2013;9(1):83.
8. Neelakantan MA, Sundaram M, Thalamuthu S, Nair MS. Thermal and redox behavior and Ni(II), Cu(II) and Zn(II) complexes containing Pyridoxine and Imidazole moieties, J. Coord. Chem. 2010;63:1969.
9. Sajadi SAA. Metal ion-binding properties of LGlutamic acid and L-aspartic acid, a comparative investigation, Nat. sci. 2010;2(2):85.
10. Bartaria D, Chandra P, Krishna V. A Study on Speciation and Coordination Tendency of Glutamic Acid and Uracil for Ternary Complexation towards some toxic metal ions, Che. Sci. Rev. Lett. 2013;1(4):201.