DETERMINATION OF STABILITY CONSTANT OF CU (II)-NICOTINATE COMPLEX BY pH-METRIC STUDIES

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Abstract

Nicotinic acid (pyridine-3-carboxylic acid), Niacin forms complexes with many metals. It may behave as mono, bi and tri dentate ligand but mostly co-ordinates as monodentate ligand.

Complex formation of Niacin with different metals is a pH dependent reaction. In this study potentiometric results were used for the calculation of stability constant. These results show that complexes of Nicotinic acid and Cu, forms (like ML, ML_2) at different pH. The stability constant was also calculated at different temperature (35 ^{0}C, 40 ^{0}C, 45 ^{0}C, 50 ^{0}C). pH-metric titration was also done by different mole ratios and results shows that best ratio is 1:2. Thermodynamic values ΔH, ΔS and ΔG were determined by stability constant (at different temperature), these values suggests that ML_2 of Cu (II)-Nicotinate complexes are more stable than ML_1 Cu (II)-Nicotinate complex.

Introduction

Ligand Niacin, pyridine-3-carboxylic acid and Nicotinic acid is one of five vitamins which are essential for the growth. By deficiency of this, a disease "Pellagra" occurred which has symptoms of diarrhea, dermatitis, dementia and hyper pigmentation, thickening of the skin, inflammation of the mouth and tongue, digestive disturbance. It found in cow milk, cheese, eggs, beef, beef liver, pork, corn, breakfast cearls, wheat flour, corn flakes, rice, soybean, yeast etc. By the deficiency of this disease "Pellagra" occurred.

There are forty to eighty essential human nutrients and Nicotinic acid included in these. Nicotinic acid is also counted one of these vitamins whose deficiency causes Pandemic Disease. Nicotinic acid is also helpful for reducing the cholesterol level in body. It has been used from several years for this purpose. It can enhance blood flow and prevent gastric congestion. It also decreases total lipids.

Nicotinic acid exists in two types Nicotinic acid and Nicotinamide. These two types are not interchangeable but both forms could be changed to NAD and NADP. Deficiency of Nicotinic acid mostly causes "Characinoid Syndrome" Pellagra (Ravi.2008) and other disease are also concern with Alzheimer's disease and age related cognitive, Cataracts, Convulsions, Depression, Diabetes, Rheumatoid arthritis, Smelling disorder, Taste disorders Vertigo.

Copper also found in many enzymes like Cytochrome-c oxidase, Superoxide dismutase, Tyrosinase, uricase, Spermine oxidase etc. Copper complexes exhibits antiflammotry, anticancer, antiulcer, anticonvulsant, antimutagenic, ant diabetic, analgesic, radioprotective and antimicrobial activity. Due to this reason Copper salts mostly used in pesticides, fungicides, algaecides, pigments and pharmaceutical industries (Dudova *et al.,* 2001). Copper is one of the biologically active metals. In biological system it combines with protein for transportation of electron and oxygen (Lippard and Berg, 1994). Copper has different oxidation states Cu (II) and Cu (I), due to this behavior it also engage as catalytic co-factor in many biological systems. Several studies revealed that Copper also involved in different body functions like cellular respiration, Iron metabolism, free radical detoxification and synthesis of neurotransmitter. This shows that Copper is compulsory metal for proper functioning of body organs (Aaseth *et al* 2007), (Araya *et al.,* 2006), (Decker and Terwilliger, 2000) and (Srivastava *et al.,* 2005).

Niacin has been using for complexation with transition metals (like Cu^{+2},Co^{+2},Ni^{+2}, Mn^{+2}, Au^{+2}, Na^{+1}, $Mg^{+2}$and Fe^{+2} etc.) from last years (Allan *et al.,* 1979), (Singh and Rio 1981), (Ahuja *et al.,* 1977,1978). Due to importance of Copper (metal) and Nicotinic acid (ligand) in Biology and pharmaceutical industries, in present work stability constant of Cu (II)-Nicotinate complex was determined by pH-metric Titration with different ratios and different temperatures.

The stability constant gives valuable Knowledge (about interaction of reactants) which is utilized for calculating the concentration of complexes. Stability constant has significance in field of chemistry, biology and medicine.

Materials and Methods

All reagents which used were of A.R grade and used without more purification. Solutions were prepared in deionized distilled water. Equimolar ($5x10^{-3}$ M) solutions of (metal) $CuSO_4.5H_2O$ and (ligand) Nicotinic acid

$C_6H_5NO_2$ were prepared. All stock solutions were prepared in deionized distilled water. NaOH solution was of $5x10^{-3}$ M, and standardized by oxalic acid of similar strength.

A Potentiometric study was done by using Orion pH meter model SA-720. pH 4, 7 and 10 buffer tablet (BDH chemicals) were used for calibrating pH meter .

(a)pH-metric Titration by different ratios: For potentiometric titration Nicotinic acid (ligand) solution ($5x10^{-3}$ M) and Cu (II) (metal) solution ($5x10^{-3}$ M) were mixed in different ratios for making complex solutions.
Different mole ratios were prepared, in this way like 1:1, 1:2, 1:3, 1:4 and 1:5 complex solutions by adding 5ml, 10ml, 15ml, 20 ml and 25 ml of Nicotinic acid (ligand) solution in 50 ml volumetric flasks. 5ml Cu (II) (metal) solution was added in each volumetric flask, and then made up the volume with distilled and deionized water.

(b)pH-metric Titration at different temperatures: 15 ml of Nicotinic acid (ligand) solution and 5 ml of Cu (II) (metal) solutions were taken in 50 ml volumetric flasks, and then made up with distilled water up to the mark. Same ratio of Nicotinic acid and metal was used for pH-metric titration at different temperatures. These complex solutions were titrated against standard solution of NaOH (0.005 M). Aliquots of standard NaOH was added to the complex solution by using pipetman model Gilson (made in France) and pH change was analyzed after each addition by using pH-meter.

Results and Discussion

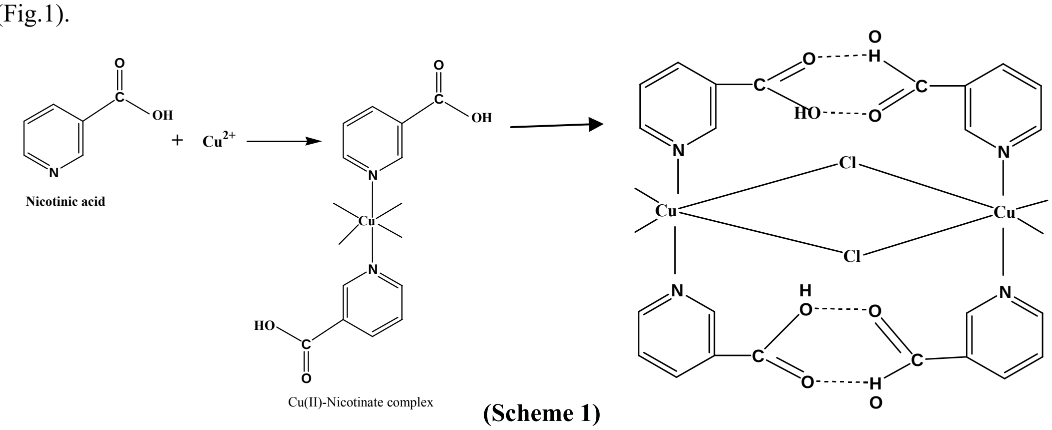
Mostly Nicotinate complexes are insoluble in many polar and nonpolar solvents due to polymeric nature. Therefore it could be concluded that polymeric octahedral structure of Cu (II)-Nicotinate complex was formed. In polymeric form, molecule of Nicotinic acid attached by Hydrogen with other Nicotinic acid by oxygen of Carboxylic group. In this way Hydrogen bonding developed which supported the formation of chain like structure (Allan *et al.,* 1979). Supposed octahedral structure of these compounds is mentioned in (Fig.2).

Potentiometric graph of this titration indicated that Cu (II) formed complexes in two ratios like ML_1 and ML_2. From literature it is found that maximum number of Ligand (Nicotinic acid) attached with metal is two , it means that Nicotinic acid behaved as a mono dentate ligand in many complexes (Allan *et al.,* 1979) and in present study (Nicotinic acid) also chelated as mono dentate ligand. In Nicotinic acid there is possibility of attack from two sides, first one is Nitrogen of Pyridine ring and second is Carboxylic group. Mostly Nicotinic acid attach with metal from Nitrogen (scheme 1).

Mostly Nicotinic acid transition metal complexes have very poor solubility in common organic solvents including DMF, DMSO, water and other solvents which indicate that these complexes are non electrolytes and polymers (Singh and Rio, 1981). Cu (II)-Nicotinate complex has reported to exert diverse bioactivities.

Concentration of different species (like M, ML, and ML_2) at equilibrium condition can be determined by specie distribution curve. Species distribution curves of Cu (II)-Nicotinate complex was plotted by taking values from pH-metric data against pH (Fig.3) and according to this curve, complexometric reaction (reaction between metal and ligand) was appeared fast. The concentration of metal-ligand complex is increasing with increase of pH. Maximum ML (96%) and ML_2 (97.5%) species were formed at pH 5-6 and 8-10.

The data of mole ratio of Nicotinic acid which is given in (Fig.1) explains the deprotonation of ligand latter by increasing mole ratio. In high molar ratio (1:5) more volume of NaOH was consumed in titration (for releasing proton from ligand) than low ratio(1:1) , this shows in 1:5 ratio complex proton is releasing latter than 1:4 , and in 1: 4 is latter than 1: 3 and so on which is mentioned in Table1.
The data of pH metric titration of ligand and metal complex shows that Nicotinic acid forms complexes with Cu^{+2} as ML at 4 -5 pH , ML_2 at 8 pH . pH changes in different ratios during pH-metric titration which have seen in (Fig.1).



(Scheme 1)

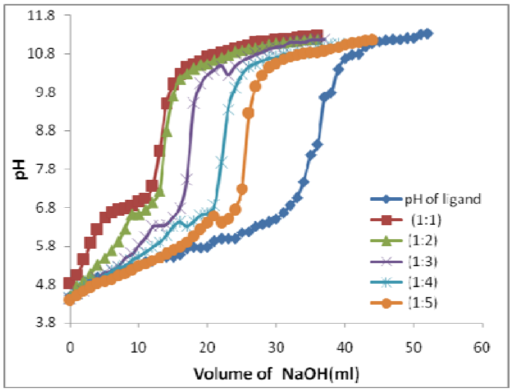


Fig.1. Over lay of Mole ratios of Cu (II)-Nicotinate complex.

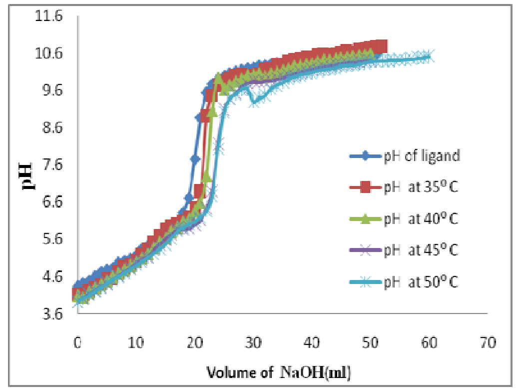


Fig.2. Overlay of Cu (II)- Nicotinate complex (1:3) at different temperatures.

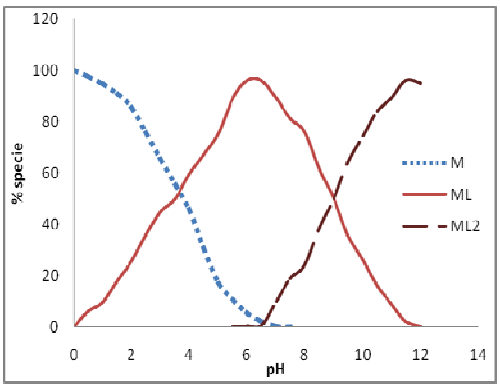


Fig.3. Specie Distribution Diagram of Cu (II)-Nicotinate Complex.

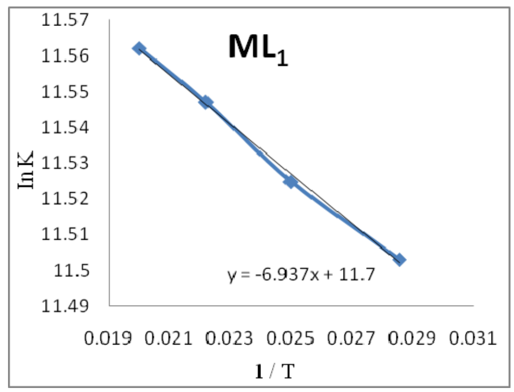


Fig.4. Plot of Ink vs. 1/T of ML_1 of Cu (II)-Nicotinate complex.

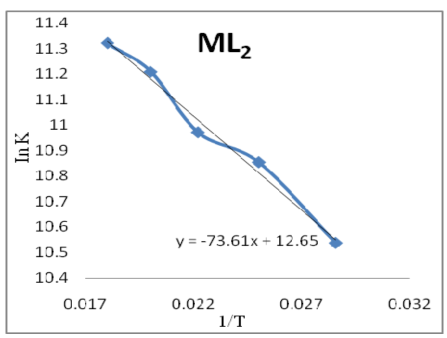


Fig.5. Plot of Ink vs. 1/T of ML_2 of Cu (II)-Nicotinate complex.

Table 1. pH values of Cu (II)-Nicotinate complex by different mole ratios.

	Cu (II)-Nicotinate complex										
	Complex	1:1		1:2		1:3		1:4		1:5	
		pH	ml of NaOH	pH	ml of NaOH	pH	ml of NaOH	pH	ml of NaOH	pH	ml of NaOH
1	ML	6.5	5	6.62	9	6.3	12	6.42	16	6.59	21
2	ML_2	7.04	11	7.24	13	6.78	16	6.64	20	6.74	24

Table 2. In K values of Cu (II)-Nicotinate complex at different temperatures.

$1/T\ ^0C$	In K	
	ML_1	ML_2
35	11.503	10.5361
40	11.525	10.853
45	11.547	10.97
50	11.562	11.208
55	11.547	11.32

Table 3.Thermodynamic values.

	ΔH J/mol	**ΔS** J/ deg mol	**ΔG** J/mol
ML_1	-0.83437	1.4072	-2.2416
ML_2	-8.85374	1.52152	-10.3752

The stability constant was calculated by using formula of Jannik Bjerrum developed the first general method for the determination of stability constants in 1941.

Bjerrum suggested that complexometric reaction is a type of acid-base equilibrium where is interaction of ligand, metal and Hydrogen ion,

$K = [ML]/ [M] [L]$ because

$HL \text{----------->} L^- + H^+$

$M + L^- \text{----------->} ML_1,\ K_1 = [ML] /[M][L]$

$ML + L^- \text{----------->} ML_2\ ,K_2 = [ML_2] / [ML][L]$

(Where HL=Nicotinic acid, L=Ligand, M=Metal, ML_1, ML_2=Complex, k= Stability constant)

The potentiometric titration of Cu (II)-Nicotinate complexes were carried out at different temperatures, but these results showed that there is very small change occurred with rise in temperature (Fig.3).

The potentiometric data is utilized for calculating stability constant of complexes at different temperatures. The stability constant values of Cu (II)-Nicotinate are mentioned in Table 2. The In K values of Cu (II)-Nicotinate complex at different temperatures are not too much higher, like other complexes which were synthesized in past. Nicotinic acid complexes show low stability constant values because Nicotinic acid is not a strong Ligand (Ahuja *et al.,* 1977; Youssef.2005).

According to these results In K values were increased with rise in temperature, which shows that high temperature favored the reaction. In K values of ML_2 is larger than ML_1The stability constant values were increased with increase in temperature. So, it can be considered that formation of these complexes is endothermic reaction. There is a link between stability constant and thermodynamic properties like ΔG°, ΔS° and ΔH° which is shown by the following equation.

$$\Delta G = - RT \ln K$$

$$\Delta G = - RT \ln K = \Delta H° - T\ \Delta S°$$

For the calculation of ΔH° and ΔS° slope and intercept values are used.

Slope and intercept was determined by graph which was plotted between In K on Y axis and 1/T on X axis (Fig.4, 5). These graphs gave negative slope and positive intercept .These graphs also showed first order kinetics. Slope value is -6.937, -73.61 and intercept is 11.7, 12.65 according to (Fig. 4, 5).

The potentiometric titration of Cu (II)-Nicotinate complexes were carried out at different temperatures, but these results showed that there is very small change occurred with rise in temperature (Fig.4). Thermodynamic values ΔH, ΔS and ΔG are mentioned in (Table 3). Thermodynamic data gives the following information:

(1) The ΔH value of ML_2 is more negative than ML_1, this shows that ML_2 complex of Cu Nicotinate is more stable than ML_1.

(2) Larger positive value of ΔS of ML_2 than ML_1 proves the stability of ML_2 complex of Cu Nicotinate.

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