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POTENTIOMETRIC STUDY ON STABILITY OF BINARY AND TERNARY COMPLEXES OF NICOTINAMIDE IN AQUEOUS SOLUTION WITH COPPER (II) METAL ION

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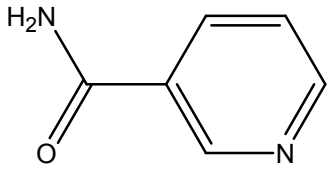
ABSTRACT
Formation of binary and ternary complexes of Cu (II) metal ion with nicotinamide (NA) as a secondary ligand and some biologically important aliphatic carboxylic acids (glycine, alanine, valine, cysteine and penicillamine) as primary ligands was studied by the potentiometric technique at 25±0.1°C and 0.1M ($NaClO_4$) ionic strength. The ternary complex formation was found to take place in a stepwise manner. The stability constants of these binary and ternary systems were calculated. .

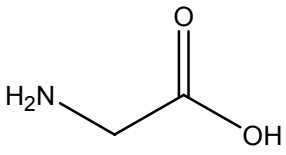
KEYWORDS: nicotinamide (NA), glycine, alanine, valine, cysteine and penicillamine, Copper (II), stability constant, potentiometric titration.

INTRODUCTION

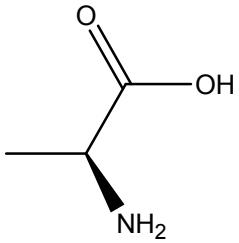
The widespread occurrence and use of copper in biological systems is a result of its ability to chemically interact with organic and inorganic substances. This has sponsored widespread examination and discussion of copper chemistry in medicine and biology. Copper-containing superoxide dismutase is an important anti-inflammatory agent. The ability of copper to combine with organics has made it widely used in chemistry, to examine some of the fundamental chemical concepts, to determine the nature of organometallic compounds (and the organisms that produce them), to synthesize potentially useful agents and to assist in purification of noxious chemicals/fuels. Because of its reactive nature, copper is also used in a wide range of chemical purifications and reactions. Nicotinamide (3-pyridine carboxamide) is a pyridine derivative which is important bioligand for human health. Nicotinamide (NA) is very prevalent in plants and human tissues. The NA is not free in body. It may exist in at least two nucleotide structures such as nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). In the recent decade, the synthesis and structure of new series of bimetallic complexes with NA has been studied by various methods because of biological importance of NA [1-2]. In the present investigation the formation and stability of binary and ternary Cu(II) complexes[3] containing nicotinamide (N.O) donor ligands[4] and with glycine, alanine, valine, cysteine and penicillamine (N,O^-) donor ligands (fig.1) are reported at 25±0.1^{0}C in 0.1 M ($NaClO_4$). The effect of the substituent[5], on the dissociation constants, and on the stability & formation of the binary and ternary complexes have been evaluated by comparing the relevant data for systems containing determined under identical experimental conditions.



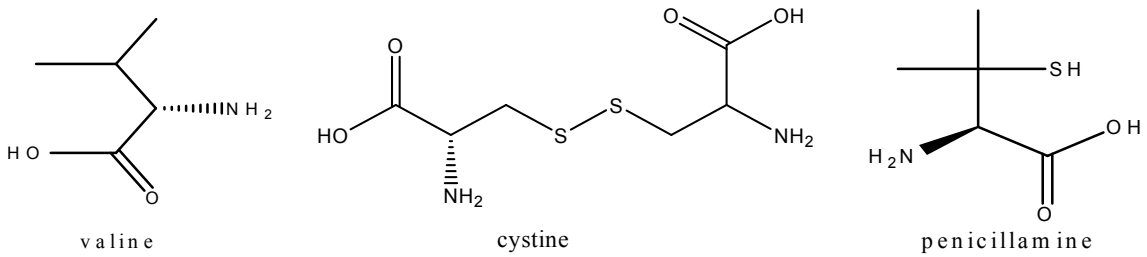
Nicotinamide



glycine



alanine



FIGURES 1. Structure of the compounds

Experimental

Materials and solution

Nicotinamide is 3-pyridine carboxamide was of analytical grade and NaOH, $NaClO_4$, $HClO_4$ and copper salt were of Analar grade. The solutions used in the potentiometric titrations were prepared in double distilled water. The NaOH (0.041M) solution was standardized against oxalic acid solution (0.1M) and the standard alkali solution was again used for standardization of $HClO_4$. The copper salt solution was standardized using EDTA titrations [6]. The ligand (NA) is soluble in double distilled water. The pH meter was calibrated before each titration with standard buffer solutions of 4.00, 7.00, and 9.2. The pH-meter (ELICO, L1-120) was used with a combined glass electrode assembly.

Potentiometric Procedure:

In the study of binary and ternary chelates by the potentiometric titration technique. The following sets were prepared in the standard:

(1)Free $HClO_4$
(2)Free $HClO_4$ +Ligand (L_P)
(3) Free $HClO_4$ +Ligand (L_P) +Metal ion
(4)Free $HClO_4$ +Ligand (L_S)
(5) Free $HClO_4$ +Ligand (L_S) +Metal ion (M)
(6) Free $HClO_4$ +Ligand (L_P) +Ligand (L_S) +Metal ion (M)

Against standard sodium hydroxide, the ionic strength of solutions was maintained constant by adding appropriate amount of (0.1M) Sodium perchlorate solution. The titrations were carried out at room temperature in inert atmosphere by bubbling oxygen free nitrogen gas through an assembly containing the electrode to keep out CO_2 .by noting the pH of precipitation for ML_P, ML_S and ML_PL_S titration, the formation of mixed ligand complexes can be concluded.

Calculations

The protonation constants of the ligand were calculated from the potentiometric pH titrations data of solutions according to Irving and Rossetti's method [7]. For this purpose, the average proton-ligand formation number ($\bar{n}_a$) at various pH for the ligand was determined according to the literature [8]. The value of pK_a was read directly from $\bar{n}_a = f(pH)$ graph at $\bar{n}_a = 0.5$. For the calculation of stability constants of binary complexes (using the potentiometric titration data of the solutions and according to Irving and Rossotti's method [7], the metal-ligand (M-NA and M-2NA) formation number($\bar{n}$) at various pH for the ligand was determined according to the literature [8]. Then pL values were calculated with using the equation from the literature [8].Having thus obtained corresponding values of $\bar{n}$ and pL, the formation curve of the metal-ligand system is drawn and the stability constant is read directly at $\bar{n} = 0.5$, 1.5. The calculation of the stability constant of ternary complex by the stepwise equilibria in solution would be confirmed when the mixed ligand curve could be superimposed over the binary ML_Por ML_Stitration curve. The method of Thomson and Loraas [9] for calculation of stepwise stability constants is widely used. The stabilities of the mixed –ligand complexes can be calculated by the replacement of M=L_P=L_S by ML_Por ML_S in the following expression.

i) For monobasic acid as secondary ligand

$$K^{ML_P}_{ML_PL_S} = \frac{T_M - AX}{A^2X} \quad (1)$$

Where $$A = \frac{T_{LS} - T_{OH} - [H^+] + [OH^-]}{[H^+]/K_1}$$

And $$X = \frac{[H^+]}{K_1} + 1$$

ii) For dibasic acids as secondary ligand

$$K^{ML_S}_{ML_SL_P} = \frac{T_M - AX}{A^2.X} \quad (2)$$

Where $$A = \frac{2T_R - T_{OH} - [OH^-] + [H^+]}{\frac{[H^+]}{K_1} + \frac{2[H^+]^2}{K_1K_2}}$$

And $$X = 1 + \frac{[H^+]}{K_1} + \frac{[H^+]^2}{K_1K_2}$$

RESULTS AND DISCUSSION

The dissociation constant of NA, glycine, alanine, valine, cysteine and penicillamine of the associated proton pKa [10]. The first proton association constant of neutral, HL, was determined potentiomtrically in aqueous solutions, under the experimental conditions (t=25±0.1°C, μ=0.1 M $NaClO_4$). Proton ionization was assigned to the O at the position assuming the negative charge. The protonation constant of NA agree well with that given previously by Tuba Sismanoglu [11]. The second dissociation of the proton from the N group of glycine, alanine, valine, cysteine and penicillamine takes place at higher buffer region (pH) and hence the corresponding dissociation constant could not be

calculated by this method. The equilibria involved in the formation of 1:3 metal – ligand binary complexes may be represented as follows:

$$M + L \rightleftharpoons ML \quad , \quad K_{ML}^{M}$$

$$ML + L \rightleftharpoons ML_2 \quad , \quad K_{ML2}^{ML}$$

The stability constants of 1:3 binary complexes of inosine with Cu (II) metal ion have been determined. The constant determined by us for Cu (NA) in 1:3 complexes agrees well with that given previously by Valentin A. Sharnin et al [12]. The formation of a ternary complex is ascertained by comparison of the mixed-ligand titration curve with the composite curve obtained by graphical addition of the NA titration data to that of the (1:3) MII -carboxylic acid titration curve. The Cu (II) – carboxylic and amino group– NA system is taken as representative. The mixed-ligand system was found to deviate considerably from the resultant composite curve indicating the formation of a ternary complex. Therefore, it is assumed that in the presence of both ligands, the carboxylic and amino groups are ligated to the metal ion, and then followed by ligation of NA, i.e. the ternary complex formation could be considered in stepwise equilibria (Eqs. (3) and (4)):

$$M + Lp \rightleftharpoons MLp \qquad (3)$$

$$MLp + Ls \rightleftharpoons MLpLs \qquad (4)$$

$$K_{MLpLs}^{MLp} = \frac{[MLpLs]}{[MLp][Ls]} \qquad (5)$$

Where Lp= carboxylic and amino groups and Ls= neutral ligand nicotinamide.

In the ternary systems studied in table2, the values of K_{MLpLs}^{MLp} were found to lie in the sequence: glycine \ penicillamine \alanine \ valine \ cysteine. The higher stability of glycine complex than another one may be due to the formation of neutral complexes (MLpLs). In which the electrostatic repulsions are very minimal. The behavior of metals towards N, O donor ligands reflected in the stability constant values of ternary complexes. The stereochemistry of metal chelates ring differs from that of carbon ring system in the sense that all the atoms in the chelates ring are not of the same size and some of the bond angles normally vary from 109^0 or 120^0 C as a result of the directed valences of metal ion. Clashing groups of two coordinated ligands result in the distortion of bond angles and a decrease in stability. A steric effect [13], affects the mode of packing of ligands round a central metal ion, and imposes a particular geometric arrangement like planar, tetrahedral or octahedral to the complex.

TABLE1. Protonation constants of ligands

Ligands	pK_1^H	pK_2^H
nicotinamide	3.48	
glycine	2.34	9.60
alanine	2.34	9.69
valine	2.32	9.62
cysteine	1.96	8.18
penicillamine	1.8	10.7

TABLE2. Parameter based on some relationship between formations of mixed ligand complexes of Cu (II) with nicotinamide (drugs) and some (N, O-) compounds

Ligand	$LogK_{MAL}$
Nicotinamide- glycine	10.54
Nicotinamide- alanine	10.45
Nicotinamide- valine	10.34
Nicotinamide- cysteine	10.05
Nicotinamide- penicillamine	10.46

CONCLUSION

The present work describes the complex formation equilibria was investigated to ascertain the composition and stability constants of the complexes. The effect of ligand properties on the stability of the complexes was investigated. The ligand and complexes may have interesting biological activity. This would require specially designed research conducted by specialized biologists.

REFERENCES

S.B.Sharma, V.P.Singh, M.K.Singh, J.Indian Chem.Soc., 1986, 63,794.

P.P.Singh, D.Singh, S.A.Khan, J.Indian Chem.Soc., 1986, 63, 951.

P. Venkataiah, M. Srinivas Mohan and Y. Laxmi Kumari, Proc. Indian Acad. Sci. (Chem. Sci.), 104(4), 1992, 533-534.

C. R. Krishnamoorthy, S. Sunil and K. Ramalingam, Polyhedron, 4(8), 1451-1456.1985.

D. L. Leussing and E. M. Hanna, J. Am. Chem. Soc. 88, 693, 1966.

G.H.Jeffery, J.Bassett, J.Mendham, R.C.Denney, Vogel, s textbook of quantitative chemical analysis, 5nd Edition, longman group UK limited 1978, 1989.

H.M.Irving, H.S.Rossotti, J.Chem.Soc. 1954, 2904.

A.S.Bastug, T.Sismanoglu, S.Pura, Chimica Acta Turcica, 1998, 26,117.

Thomson, L.C. and Loraas J.A., Inorg. Chem. 1,490 (1962).
R.B. Simpson, Association constants of methylmercuric and mercuric ions with nucleosides, J. Am. Chem. Soc. 86 (1964) 2059.

Tuba Sismanoglu, Chinese Chemical Letters, 14(11), 1207 – 1210, 2003.

Valentin A. Sharnin, Svetlana V. Dushina, Maxim A. Zevakin, Alexandra S. Gushchina, Konstantin V. Grazhdan, Inorganica Chimica Acta 362 (2009) 437–442.

Akane Akashi, Yoko Matsuya and Hisashi Nagasawa, Biomaterials, 13 (11), 1992.