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Full Length Research Paper

Potentiometric studies on essential metal (II) amino acid complexes

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Potentiometric Studies on complexes formed by essential metals (Cr, Mn, Fe, Co, Ni, Cu and Zn) and amino acids (alanine, arginine, asparagines, glycine, histidine, lysine, methionine, phenylamine, proline, threonine, tryptophan and valine) have been carried out. The dissociation constants of the amino acids $(pK_a)(K_1, K_2 \ and \ K_3)$, the stepwise formation constants $(K_1, K_2 \ and \ K_3)$ and the overall stability constants $(K_1 x K_2 x K_3 = \beta)$ of the metal (II) amino acid complexes were determined. The dissociation constants of the amino acids determined are; alanine (10.29), arginine (12.02), asparagine (9.39), glycine (9.87), histidine (7.01), lysine (9.28), methionine (9.68), phenylalanine (9.61), proline (10.53), threonine (10.31), tryptophan (9.77), and valine (10.28). The ratio of metal to amino acid determined for the complexes is 1:3, except for Cu (II) and Zn (II), which is 1:2. The Stepwise Stability Constants of the complexes were determined are found to decrease in the order $K_1 > K_2 > K_3$ for all the complexes. The value of overall stability constant (β) of each complex obtained is relatively high, indicating good stability for the complexes.

Key words: Potentiometry, metal ion-amino acid complexes, stability constant and dissociation constant.

INTRODUCTION

Amino acids are organic molecules containing amino group (- NH_2) and carboxylic acid group (- COOH) both attached to the same carbon atom called α – carbon. Amino acids were earlier discovered as constituents of natural products even before they were recognized as components of proteins, for example asparagine was discovered in 1806 in juice of asparagus plant and cystine in 1810 in urinary stones (Akpurieme, 2001). The first amino acid isolated from hydrolysis of protein was glycine, obtained in 1820 from gelatin by Braconnot as reported by Lehninger (1995). He also reported threonine as the most recently discovered amino acid isolated from hydrolyzates of fibrin by Rose in 1935 (Lehninger, 1995). The works of Hofmeister and of the Fischer (1902) offered explanation for the mode of combination of the amino acids in proteins. Amino acids such as tryptophan, lysine, methionine, phenylalanine, threonine, valine, leucine and isoleucine are the essential constituents of plants and animal tissues. They cannot be manufactured by the body, therefore must be supplemented with proper nutrition (Akpurieme, 2001). Since amino acids are the building blocks of proteins and also many other biologically occurring amino acids serve other functions in cells, it is then necessary to determine their dissociation constants and their stability constants for the formation of complexes with essential metals. The dissociation constant, pKa is used to explain the strength of the acids because it is a quantitative measure of the strength of the acids in all its reactions. The acid dissociation constant can be calculated from the pH of solution of the acid of known concentration. Thus it is possible to calculate the pH of a solution of the acid from the knowledge of its dissociation constant.

Weak acids dissociate partially in aqueous solution to produce an equilibrium mixture containing dissociated and un-dissociated molecules for a weak acid HA, presented as;

$$HA + H_2O \rightleftharpoons A^- + H_3O^+$$

And the equilibrium constant, Ka is given by the expression; $Ka = \frac{[H_3O^+][A^-]}{[HA]}$

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Studies on many amino acid metal complexes were carried out by various workers, for example Antonili *et al* (1980) studied the silver (1) complexes of some N-protected amino acids such as N-acetyl and benzoyl – glycine, alanine, valine and leucine and tryptophan. Battaglia (1981) reported the syunthesis of copper (II) complexes of alanine with hydrated bis alaninato being formed while Patel *et al.,* (2002) reported the crystal and molecular structure of isolated tris glycinato chromium (II) mono hydrated. Furthermore, Yamuchi and Odani (1996) reported the studies on copper (II), Zinc (II), and Iridium (II) complexes of some amino acids with positively charged side chain including arginine, lysine and ornithine.

Despite the numerous researches carried out on stability constant of metal amino acid complexes, exhaustive literature search revealed paucity of information on use of potentiometer for such studies. Therefore this paper reports some potentiometric studies on essential metal (II) amino acid complexes

MATERIALS AND METHODS

In solution preparation, all glassware's used were thoroughly washed with detergent and rinsed with distilled water before used. All weighing were carried out using electric metler balance model, Model AB 54.The pH measurements were carried out using Jenway pH meter model 3320. All the chemicals used in this work are of AnalaR grade purity; they were used without further purification

Determination of pKa of the Amino Acids

The determination was carried by first measuring the pH of the reaction mixture prepared by adding into 400 mL beaker containing magnetic stirring bar 90 mL of distilled water, 100 mL of 0.04M potassium trioxonitrate (V) and 10 mL of 0.08M of glycine respectively (Angelici, 1977).

The electrodes of the standardized pH meter was then introduced into the reaction mixture with stirring aliquots (0.5 mL) of standardized 0.1M NaOH were added from a burette into the reaction mixture. After each addition of the aliquot the corresponding stable pH reading was recorded. The same procedure was repeated for each of the remaining amino acids (Angelici, 1977).

Determination of Stability Constants of the Complexes

Into a 400 mL beaker 100 mL of 0.04M, KNO_3 10 mL of 0.02M HNO_3, 90 mL of distilled water and 1 millimole (0.001 mole) of nickel (II) chloride hexahydrate were added respectively. 0.05 mL of 0.1M Sodium glycinate was added and after each addition with stirring the corresponding pH reading was recorded. The addition of the sodium glycinate solution was continued until the full 10 mL was added. The sodium glycinate was prepared by exactly neutralizing a weighed solid glycine with a calculated amount of standardized 0.1M NaOH and diluting the solution with distilled water to a total volume of 20 mL out of which 10 mL was put into a cleaned and rinsed burette. The same procedure was repeated for other metal salts and each of the remaining amino acids (Angelici, 1977).

RESULTS AND DISCUSSION

The values of dissociation constants Ka are reported as pKa (Sovago et al., 1993; Yamuchi and Odani 1996; Berthon, 1995). The values of the dissociation constants of the amino acids studied were 9.87 (glycine), 12.02 (arginine), 9.39 (asparagines), 7.09 (Histidine), 10.28 (lysine), 9.68 (methionine), 9.61 (Phenylalanine), 10.31 (Threonine), 9.77 (Tryptophan) and 9.90 (Valine). These values of pKa are in agreement with those reported by Sovago et al (1993), Yamuchi and Odani (1996), and Berthon, (1995), Sovago et al (1993), Robert and Melvin (1982 – 1983) and Berthon, (1995).

The stepwise stability constants of the metal amino acid complexes studied were determined by a new graphical/computational method. The graph of log [A] versus n were plotted and analysed using a program 'ORIGIN 50'. The stepwise stability constants, the mean number of amino acid anions coordinated to each metal ion, were then obtained by interpolation as reported by Angelici (1977). The values of stepwise stability constants of the metal amino acids complexes determined are high (Tables 1 - 12) for each complex. This observation was made by Satya (2006), Cotton and Wilkinson (1980) the values were found to decrease in the order $K_1 > K_2 > K_3$, which is expected on the basis of electrostatic concept. The overall stability constant of each complex was determined as the product of the stepwise stability constant; $\beta = K_1 x K_2 x K_3$ (Angelici 1977; Cotton and Wilkinson 1980; Satya 2006).

The number of coordinated amino acid anions to a metal ion determined for copper and zinc is 1:2 (which indicates tetrahedral complexes), while for chromium, manganese, iron cobalt and nickel is 1:3, which have octahedral geometry. The coordination number two for copper and zinc complexes is due to Jahn Teller effect (Cotton and Wilkinson, 1980).

The stepwise stability constants $(\log K_1 \ and \ \log K_2)$ of all the tetrahedral complexes and those of octahedral complexes $(\log K_1, \ \log K_2 \ and \ \log K_3)$ are quite high,

Table 1. Stability constants of glycine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Glycine	[Cr(Gly)3]	9.87	9.89	9.78	29.54
(Gly)	[Mn(Gly)3]	9.14	9.12	8.99	27.25
	[Fe(Gly)3]	9.17	9.19	9.09	27.45
	[Co(Gly)3]	9.16	9.14	8.93	27.23
	[Ni(Gly)3]	9.17	9.10	8.95	27.22
	[Cu(Gly)3]	9.52	9.38		18.90
	[Zn(Gly)3]	8.92	8.89		17.81

Table 2. Stability constants of alanine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Alanine	[Cr(Ala)3]	10.13	10.05	10.05	30.23
(Ala)	[Mn(Ala)3]	9.49	9.47	9.32	28.28
	[Fe(Ala)3]	9.48	9.49	9.39	28.36
	[Co(Ala)3]	9.52	9.50	9.35	28.37
	[Ni(Ala)3]	9.46	9.44	9.29	28.19
	[Cu(Ala)3]	9.64	9.63		19.27
	[Zn(Ala)3]	7.95	7.83		15.78

Table 3. Stability constants of arginine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Arginine	[Cr(Arg)3]	11.88	11.71	11.70	35.29
(Arg)	[Mn(Arg)3]	10.72	10.58	10.20	31.50
	[Fe(Arg)3]	10.66	10.64	9.67	30.97
	[Co(Arg)3]	8.09	7.77	9.40	23.26
	[Ni(Arg)3]	9.73	8.48	8.15	25.36
	[Cu(Arg)3]	10.72	10.58		21.30
	[Zn(Arg)3]	8.54	8.74		17.28

Table 4. Stability constants of asparagine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Asparagine	[Fe(Asn)3]	8.58	8.56	8.46	25.60
(Asn)	[Mn(Asn)3]	8.57	8.56	8.32	25.45
	[Co(Asn)3]	8.62	8.60	8.45	25.67
	[Ni(Asn)3]	8.64	8.62	8.38	25.64
	[Co(Asn)3]	8.62	8.60	8.45	25.67
	[Cu(Asn)3]	8.94	8.93		17.87
	[Zn(Asn)3]	8.50	8.48		16.98

Table 5. Stability constants of histidine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Histidine	[Cr(His)3]	7.28	7.30	7.20	21.78
(His)	[Mn(His)3]	7.11	7.12	7.04	21.27
	[Fe(His)3]	6.83	6.81	6.67	20.31
	[Co(His)3]	6.90	6.70	6.68	20.28
	[Ni(His)3]	6.86	6.69	6.68	20.23
	[Cu(His)3]	7.11	7.13		14.24
	[Zn(His)3]	6.77	6.60		13.37

Table 6. Stability constants of lysine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Lysine	[Cr(Lys)3]	10.09	10.00	9.99	30.08
(Lys)	[Mn(Lys)3]	9.66	9.64	9.60	28.90
	[Fe(Lys)3]	9.47	9.45	9.38	28.30
	[Co(Lys)3]	7.00	8.01	8.08	23.09
	[Ni(Lys)3]	9.47	9.25	9.22	27.94
	[Cu(Lys)3]	9.66	9.64		19.30
	[Zn(Lys)3]	9.30	9.27		18.57

Table 7. Stability constants of methionine complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Methionine	[Cr(Met)3]	9.63	9.56	9.56	28.75
(Met)	[Mn(Met)3]	8.90	8.93	8.77	26.65
	[Fe(Met)3]	8.98	8.97	8.87	26.82
	[Co(Met)3]	8.94	8.91	8.73	26.58
	[Ni(Met)3]	8.92	8.90	8.73	26.55
	[Cu(Met)3]	9.34	9.22		18.56
	[Zn(Met)3]	8.88	8.85		17.73

Table 8. Stability constants of phenylalanine complexes

Amino Acid	complexes	LogK1	LogK2	LogK3	Logβ
Phenylalanine	[Cr(Phe)3]	9.44	9.36	9.35	28.15
(Phe)	[Mn(Phe)3]	9.01	8.99	8.88	26.88
	[Fe(Phe)3]	8.91	8.89	8.81	26.61
	[Co(Phe)3]	8.87	8.85	8.67	26.39
	[Ni(Phe)3]	8.75	8.72	8.42	25.89
	[Cu(Phe)3]	9.11	9.10		18.21
	[Zn(Phe)3]	8.65	8.61		17.26

Table 9. Stability constants of proline complexes

Amino acid	complexes	LogK1	LogK2	LogK3	Logβ
Proline	[Cr(Pro)3]	10.63	10.63	10.60	31.86
(Pro)	[Mn(Pro)3]	9.73	9.72	9.62	29.07
	[Fe(Pro)3]	9.62	9.61	9.55	28.78
	[Co(Pro)3]	9.71	9.70	9.62	29.03
	[Ni(Pro)3]	9.62	9.61	9.52	28.75
	[Cu(Pro)3]	9.79	9.77		19.56
	[Zn(Pro)3]	9.27	9.24		18.51

Table 10. Stability constants of threonine complexes

Amino Acid	complexes	LogK1	LogK2	LogK3	Logβ
Threonine	[Cr(Thr)3]	10.31	10.33	10.22	30.86
(Thr)	[Mn(Thr)3]	10.00	9.77	9.68	29.45
	[Fe(Thr)3]	9.70	9.73	9.61	29.04
	[Co(Thr)3]	9.97	9.72	9.62	29.31
	[Ni(Thr)3]	9.37	9.22	8.84	27.43
	[Cu(Thr)3]	10.20	10.12		20.32
	[Zn(Thr)3]	9.37	9.32		18.69

Table 11. Stability constants of tyrosine complexes

Amino Acid	complexes	LogK1	LogK2	LogK3	Logβ
Tyrosine	[Cr(Try)3]	9.75	9.67	10.66	29.08
(Try)	[Mn(Try)3]	9.07	9.05	8.85	26.97
	[Fe(Try)3]	9.00	9.01	8.91	26.92
	[Co(Try)3]	9.04	9.01	8.84	26.89
	[Ni(Try)3]	9.12	9.10	8.95	27.17
	[Cu(Try)3]	9.31	9.30		18.61
	[Zn(Try)3]	8.78	8.74		17.52

Table 12. Stability constants of valine complexes

Amino Acid	complexes	LogK1	LogK2	LogK3	Logβ
Valine	[Cr(Val)3]	9.78	9.70	9.70	29.18
(Val)	[Mn(Val)3]	9.08	9.06	8.90	27.04
	[Fe(Val)3]	9.19	9.17	9.12	27.48
	[Co(Val)3]	9.10	9.08	8.91	27.09
	[Ni(Val)3]	9.14	9.12	9.06	27.32
	[Cu(Val)3]	9.27	9.26		18.53
	[Zn(Val)3]	8.86	8.80		17.66

suggesting stable reaction intermediate species. The overall stability constants, which are the products of the stepwise stability constants of the tetrahedral $(K_1 \, x \, K_2)$ and the octahedral $(K_1 \, x \, K_2 \, x \, K_3)$ metal amino complexes are very high, revealing good stability (Tables 1 - 12). These values are in agreement with the results obtained from similar work carried out by Sovago et al (1993); Berthon (1995); Satya (2006).

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