

**SOLUTION EQUILIBRIUM STUDIES ON COMPLEX FORMATION BY  
BIOLOGICAL METAL IONS WITH 3- AND 5- ALDEHYDOSALICYLIC  
ACIDS AND THEIR ANILINE SCHIFF BASE MIXED LIGANDS**Basavaraj M.Kalshetty<sup>1\*</sup>, S.S.Suvarnakhandi<sup>1</sup>, B.I.Karlatti<sup>1</sup> and M.B.Kalashetti<sup>2</sup>.<sup>1</sup>Comm. B.H.S Arts & T.G.P. Science College, Jamkhandi-587301.<sup>2</sup>P.G.Department of studies in Chemistry, Karnatak University, Dharwad.

**ABSTRACT:** Equilibrium study on the mixed ligands complex formation of transition metal ions ( $M^{2+} = Cu, Zn, Ni, Co$ ) with 3-aldehydosalicylic acid (3ASA) and 5-aldehydosalicylic acid (5ASA) form variety of binary and mixed – ligand complexes with Cu(II), Zn(II), Ni(II) and Co(II). The mixed ligand complexes dominate the pH range of biological relevance. Formation constants of the proton-ligand and metal-ligand complexes at 30°C in 50% (v/v) water-ethanol medium, at ionic strength  $I = 0.1 \text{ mol/dm}^3$ , were determined employing Calvin Bjerrum titration technique as adopted by Irving and Rossotti. The order of stability constants were found and are in agreement with Irving-Williams order. The changes of colour during titration have been studied with related to stepwise formation constants of different complex species in solution for separate ligand titrations and mixed-ligand titrations. The complex formation equilibria were elucidated by analyzing the speciation curves and correlated with the mode of coordination of the ligands.

**Key words:** 3- and 5- aldehydosalicylic acids, mixed ligands, complex equilibrium, biological metal ions.

**INTRODUCTION**

Co-ordination Chemistry plays an important role in biological processes<sup>1</sup>. The inorganic forms of As (II) are toxic, but the As (II) exists as a non-toxic complex as arsenobetaine in marine organisms like crab and is safe for human consumption. Elemental Hg is not very toxic but the methyl-derivatives are highly toxic and responsible for all fatal cases of Hg poisoning. Biological metal ions, such as, Cu(II), Zn(II), Ni(II) and Co(II) are remain tenaciously bound at the active sites, of the enzymes proteins, at the same time, exchange extremely rapidly with the substrate and the products, involving mixed-ligand complexes. Mixed-ligand complexes formation equilibria of metal ions with amino acids and small peptides as primary ligands provide useful models for mimicking the roles of metal ions at the active sites of metalloenzymes<sup>2</sup>. 5-aldehydosalicylic acid Schiff bases with anilines and 3-aldehydosalicylic acid with 7-amino-4-methyl coumarin are extremely used in medical applications of these materials, it is worth to study the mixed ligand complex formation equilibrium study on the mixed-ligand complex formation of Cu(II), Zn(II), Ni(II) and Co(II) with 3-aldehydosalicylic acid-aniline Schiff base and its related compounds and 5-aldehydosalicylic acid-aniline Schiff base and its related derivatives (scheme 1) by pH-metric method (fig.1) in 50% (v/v) water-ethanol medium at 30°C. Results of such investigation (table 1) are used to calculate stability and formation constants of metal complexes in solution.

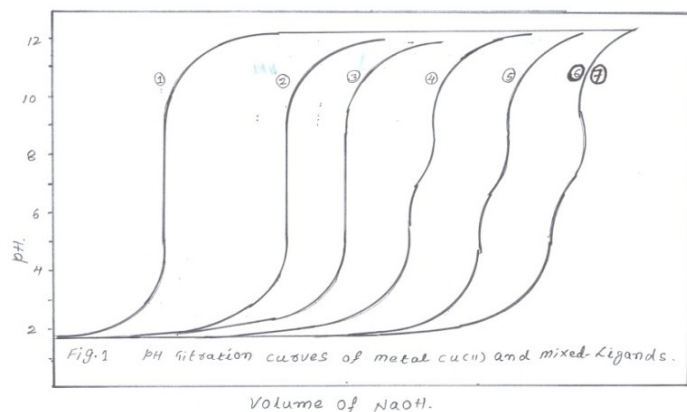
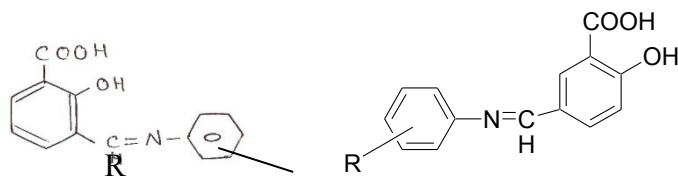


Fig. 1 pH Titration curves of Metal  $\text{Cu(II)}$  and Mixed Ligand systems.

1. 0.01M  $\text{HClO}_4$
2. 0.01 M  $\text{HClO}_4$  + 0.004M 3ASA.
3. 0.01M  $\text{HClO}_4$  + 0.004M 5ASA
4. 0.01M  $\text{HClO}_4$  + 0.004M 3ASA + 0.001M  $\text{Cu}^{2+}$
5. 0.01M  $\text{HClO}_4$  + 0.004M 5ASA + 0.001M  $\text{Cu}^{2+}$
6. 0.01M  $\text{HClO}_4$  + 0.004M 5ASA + 0.004M 3ASA + 0.001M  $\text{Cu}^{2+}$ .
7. 0.01M  $\text{HClO}_4$  + 0.004M 5ASAA + 0.004M 3ASAA + 0.001M  $\text{Cu}^{2+}$

Total volume 50ml, titrant used 0.1N NaOH, ionic strength = 0.1M  $\text{NaClO}_4$ .

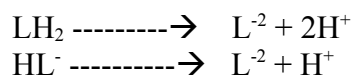


(Scheme 1)

### (3- and 5- aldehydosalicylic acids aniline Schiff Bases)

## RESULTS AND DISCUSSION

At pH= 2-3 both the ligands 3- and 5- aldehydosalicylic acids exist in their protonated forms,



With the rise of pH, both the ligand cations undergo stepwise deprotonation. For the both ligands the formation curves obtained by plotting average proton number  $\bar{n}_A$  vs pH extend over the range  $1 < \bar{n}_A < 2$  shows that the H<sup>+</sup> ion of the carboxylic group (-COOH) and one of the phenolic H<sup>+</sup> ion are dissociated separate steps.

In case of copper titrations a volume of alkali equal to four equivalents of metal ions present in the solution, in excess of that required to neutralize the free perchloric acid, is required to reach pH= 3.0 at which the ligands curve departs from the acid curve as shown by (2), (3) in fig.1. The metal ligand curves for Zn(II), Ni(II), Co(II) follow the same path and they depart at very low pH of the solution. For both ligands (chelating agents) the relative positions of the metal curves indicate the relative stabilities of the metal complexes, which follow the Irving-Williams<sup>3</sup> order; Zn < Cu > Ni > Co.

Complex formation with Cu (II) in the 1 : 1 : 1 ternary Cu : 3ASA:

5ASA system and Cu: 3ASAS: 5ASAA system start around pH+ 3.0 curves (6) and (7) in fig.1. The complex species occurring at different pH ranges for ternary system can be observed by the colour changes during the separate and the mixed- reagent titrations are reported in Table 1 for the temperature of 30°C. 3ASA, 5ASA, 3ASAA, 5ASAA solutions are pale yellow in acidic solutions and as the pH increases during the titration. The yellow colour disappears and becomes colourless around pH= 5.0 – 5.5, on increasing pH further the solutions of these reagents develops yellow colour around pH = 9.0 – 10.2. Yellow colour gradually deepens on increasing the pH values. These changes, therefore, are apparently due to the formation of the ionized species HL<sup>-</sup> and L<sup>-2</sup>.

The titrations from pale yellow to colourless occur when the proton- ligand formation number ( $\bar{n}_A$ ), changes from 2.0 to 1.2 indicating the formation of species HL<sup>-</sup>. The change from colourless to yellow when  $\bar{n}_A$  changes from value 1.2 to 0.8 indicating the formation of species L<sup>-2</sup>. It is observed that at the end of each titration the colour of the reagents are light brownish yellow in above said four different reagents. The same trends in the colour changes observed for the mixed ligands titrations such as 3ASA + 5ASA and 3ASAA + 5ASAA. It is observed that at the end of each titration the colour of mixed- reagents (Table 1) were found to be brownish yellow with green tint. The formation curves obtained by plotting average proton number  $\bar{n}_A$  vs pH extended over the range  $1 < \bar{n}_A < 2$  show the H<sup>+</sup> of carboxylic group and one of the phenolic H<sup>+</sup> ion are dissociated separate steps, their shape indicates the presence of the species HL<sup>-</sup> and L<sup>-2</sup>. The metal-ligand stability constants were obtained from analysis of average ligand number  $\bar{n}$  and pL data. The values of pL at  $\bar{n} = 0.5$  and  $\bar{n} = 1.5$  correspond to the first and second step stability constants observed respectively<sup>4,5</sup>.

The proton- ligand stability constants  $\log K_1^H$  and  $\log K_2^H$  for all four types of reagents and two mixed- reagents, the metal- ligand stability constants  $\log K_1$  and  $\log K_2$  values were calculated for the complexes of all the four metal ions (Table 2). The relative stabilities of the metal complexes follow the order Zn < Cu > Ni > Co are in agreement with that of Irving and Williams. The enormously higher log K value for the Copper chelate in all simple and mixed- ligands were due to the enhanced stabilization arising from John-Teller effect. Closeness of the log K<sub>1</sub> and log K<sub>2</sub> values of the metal (M+2) complexes of the present simple and mixed ligands with corresponding complexes with salicylic acid<sup>7</sup>, 5-sulfosalicylic acid<sup>8</sup>, and 2-hydroxy-3-methylsalicylic acid<sup>9</sup> indicate similar mode of coordination, it is by carboxylate -O and phenolate -O atoms leaving the Schiff base N-atom uncoordinated shown in the following:

TABLE 1. Titration of colour mixed reagents

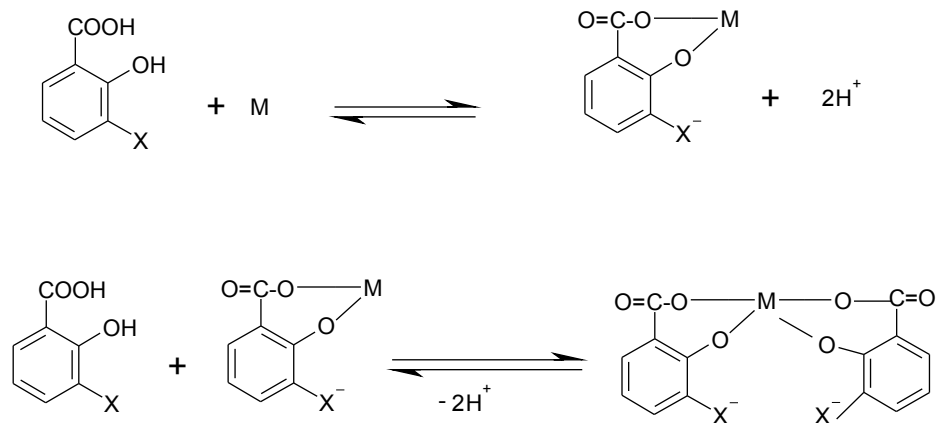
T = 30°C N= 1.0325N Eo= 0.0106M					Vo= 50ml Tlo= 0.004M I = 0.1M
Reagent	Volume of NaOH	pH Free acid	pH Reagent	pH Copper	Colour Changes
3ASA	0.00	2.15	2.13	-	Pale yellow
	0.50	3.17	2.76	2.71	Disappears
	0.70	12.24	4.01	3.67	Appears
	1.00	12.73	12.40	12.31	
	1.50	12.94	12.86	12.72	Brownish yellow.
	2.00	13.12	13.09	12.91	
3ASAA	0.00	2.34	2.22	-	Pale yellow
	0.50	12.11	5.07	3.94	Disappears
	0.70	12.45	12.12	11.88	Appears
	1.00	12.70	12.50	12.49	
	1.50	12.75	12.55	12.50	Brownish yellow.
	2.00	13.67	12.44	-	
5ASA	0.00	2.10	2.11	-	Pale yellow
	0.50	3.10	2.91	2.91	Disappears
	0.70	12.27	4.38	4.01	Appears
	1.00	12.70	12.49	12.39	
	1.50	13.03	12.94	12.91	Brownish yellow.
	2.00	13.16	13.13	13.17	
5ASAA	0.00	2.34	2.32	-	Pale yellow
	0.50	3.66	3.24	3.19	Disappears
	0.70	12.51	10.30	4.61	Appears
	1.00	13.04	12.72	12.07	
	1.50	13.15	12.97	12.32	Brownish yellow.
	2.00	13.26	13.09	-	
3ASA+5ASA	0.00	2.29	2.30	-	Pale yellow
	0.50	12.09	4.56	4.08	Disappears
	0.70	12.43	12.17	11.94	Appears
	1.00	12.69	12.62	12.63	Deepens
	1.50	12.90	12.85	12.74	Brownish yellow with green tint.
	2.00	13.02	12.95	-	
3ASAA+5ASAA	0.00	2.19	2.18	-	Pale yellow
	0.50	12.20	4.51	4.05	Disappears
	0.70	12.54	12.22	11.96	Appears
	1.00	12.89	12.78	12.68	Deepens
	1.50	13.12	12.98	12.81	Brownish yellow with green tint.
	2.00	13.21	13.13	-	

### Experimental

All the chemicals including the metal salts, sodium hydroxide, perchloric acid, potassium biphthalate, borax, EDTA etc., used were of analytical grade. Ethyl alcohol was purified by the method as described by Vogel<sup>10</sup>. Schiff bases of 3- and 5- aldehydosalicylic acids with aniline were prepared by refluxing equimolar quantities of aldehydes with aniline in alcoholic medium for about 2 hours<sup>11,12</sup>. The Schiff bases were more or less strongly coloured and insoluble in water, but soluble in 50% (v/v) water-ethanol solvent medium and in other organic solvents. Purity of the synthesized Schiff bases was confirmed by M.P., Elemental analysis and IR spectra

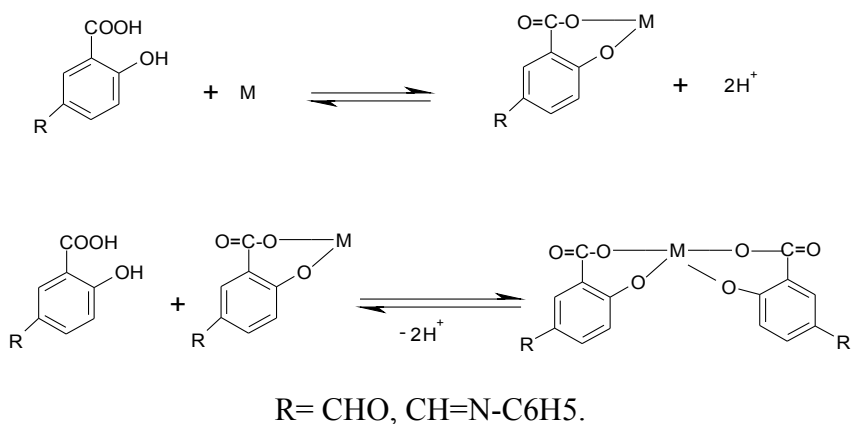
Table 2. Proton- ligand and Metal-ligand  $M^{2+}$  ( $M^{2+} = Cu, Zn, Ni, Co$ ) Stability Constants with Simple 3- and 5- ASAR ligands ( $R = H, =N-C_6H_5$ ) and Mixed-ligands.

Ligands	Stability constants	$H^+$	$Cu^{2+}$ complex	$Zn^{2+}$ complex	$Ni^{2+}$ complex	$Co^{2+}$ complex
3ASA	Log Kn	$H^+$	$Cu^{2+}$	$Zn^{2+}$	$Ni^{2+}$	$Co^{2+}$
	Log $K_1$	-12.82	10.62	8.32	9.27	8.21
	Log $K_2$	-3.18	7.62	4.13	5.65	4.59
3ASAA	Log Kn	$H^+$	$Cu^{2+}$	$Zn^{2+}$	$Ni^{2+}$	$Co^{2+}$
	Log $K_1$	-12.34	10.52	8.31	8.20	7.72
	Log $K_2$	-3.38	6.34	3.87	3.77	3.85
5ASA	Log Kn	$H^+$	$Cu^{2+}$	$Zn^{2+}$	$Ni^{2+}$	$Co^{2+}$
	Log $K_1$	-12.93	11.13	8.97	8.84	7.69
	Log $K_2$	-3.52	6.23	4.58	4.54	7.07
5ASAA	Log Kn	$H^+$	$Cu^{2+}$	$Zn^{2+}$	$Ni^{2+}$	$Co^{2+}$
	Log $K_1$	-12.85	11.50	8.99	8.80	8.50
	Log $K_2$	-4.05	7.15	4.58	4.55	4.73
3ASA+5ASA	Log Kn	$H^+$	$Cu^{2+}$	$Zn^{2+}$	$Ni^{2+}$	$Co^{2+}$
	Log $K_1$	-13.12	11.01	8.66	7.81	7.71
	Log $K_2$	-2.86	8.07	7.30	5.73	6.05
3ASAA+5ASAA	Log Kn	$H^+$	$Cu^{2+}$	$Zn^{2+}$	$Ni^{2+}$	$Co^{2+}$
	Log $K_1$	-12.67	11.99	8.09	8.35	8.31
	Log $K_2$	-3.70	8.73	7.81	6.41	6.57

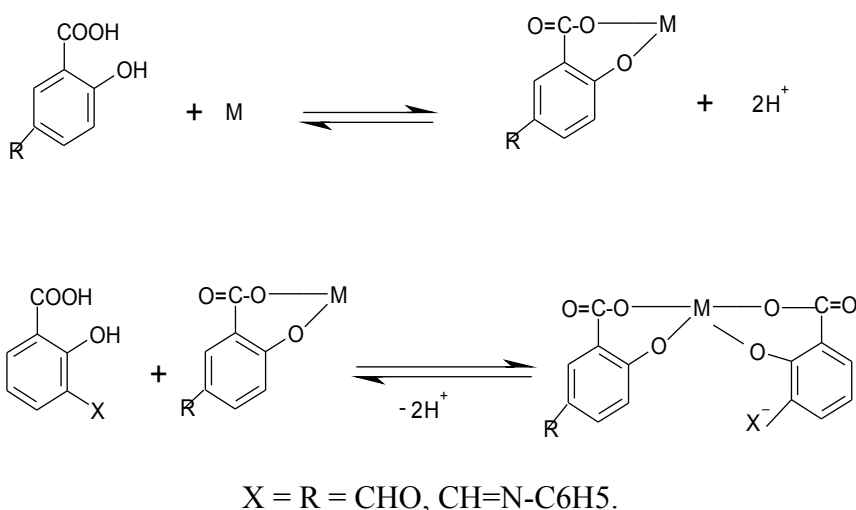


$X = CHO, CH=N-C_6H_5.$

(3-aldehydosalicylic acid and Aniline Schiff base- metal complex)



(5-aldehydosalicylic acid and Aniline Schiff base- metal complex)



(Mixed – ligands Metal complexes)

The concentrations of metal ions in each of the metal perchlorates were estimated by complexometric titrations as described by Schwarzenbach<sup>13</sup>, by using solutions of Na<sub>2</sub>-EDTA and standard sodium hydroxide. pH-metric titrations were carried out<sup>14</sup>, following Calvin-Wilson technique as adopted by Irving and Rossotti. The pH meters (Digital) Model No. 335, systronic with combined electrodes were used over the entire pH range 0 to 14.

The pH reproducibility was within 0.01 pH units. The medium of titration was 50% (v/v) water - ethanol medium. NaClO<sub>4</sub> was added to maintain constant ionic strength<sup>15</sup>; the titrations were carried out in an inert atmosphere by bubbling oxygen free nitrogen gas through the solution at 30°C.

## CONCLUSION

Closeness of the formation constants  $\log K_1$  and  $\log K_2$  values in mixed ligands of the  $M^{2+}$  complexes with the reference to the corresponding complexes with salicylic acid, 5-sulfosalicylic acid and 2-Hydroxy-3-methyl salicylic acid, indicate similar mode of coordination, it is by carboxylate-Oxygen and phenolate-Oxygen atoms leaving the Schiff base N-atom uncoordinated. The complex compounds of same ligand with metal ions have been obtained by varying pH. The basicity and denticity of the 3- and 5- aldehydosalicylic acids and Schiff bases derived from aniline, and the mixed-ligands noticed considerably with the role of pH. The ligands at pH = 3 to 6 acts as monobasic bidentate OO-donor ligand forms monometallic complex compound  $[M(LH)_2]$  where  $M = Cu(II), Zn(II), Ni(II)$  and  $Co(II)$ . In spite of the fact that hydroxyl proton is involved in the intramolecular hydrogen bonding, the salicylic acid group certainly lowers its electron density as the electron withdrawing group operates in the substituted ring system. This indicates less basicity of the chelate site (salicylic acid group). The relationship between ligand stability and chelate stability found in this study is certainly due to ligand nature. It seems that these ligand molecules including mixed type, introduced a more covalent character to the resonance contribution of the substituent group made electron delocalization through the coordinate bonds more effect.

## Acknowledgement

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