

Studies in Interaction Between Bivalent Transition and Alkaline Earth Metal Ions with Substituted Ketimine Drugs Under 75% Dichloromethane (DCM) - Water Mixture at 302 ± 1 K pH Metrically

Ganesh Andhale^{1*} & Sanjay Wagh¹

¹ P. G. Department of Chemistry Shri Shivaji Art's, Commerce & Science College, Akot. Dist. Akola (M.S.) - 444101 India

Abstract

The interaction between bivalent transition and alkaline earth metals such as Sr(II), Ba(II), Ni(II) and Cu(II) ions with substituted ketimine drugs have been studied pH metrically at 302 ± 1 K and 0.1 M (KNO_3) ionic strength in 75% dichloromethane (DCM)- water medium. The observed pH metric data were used to estimate the values of proton-ligand and metal-ligand stability constants. The estimated data of proton-ligand and metal-ligand stability constants (pK and logK) were calculated by using half integral and pointwise calculation methods. From the calculated values of pK and logK the formation of 1:1 and 1:2 metal complexes as well as interaction between metal ions and ligands has been studied.

Keywords: Dichloromethane (DCM), ketimines, stability constants, metal ligand stability constants, etc.

1. Introduction

The advances in coordination chemistry invented numerous complex compounds that we utilize in our real life. The coordination compounds has many applications in various fields such as industry, agriculture, medicine, biology, chemical reactions etc. e.g. Coordination compounds have characteristic colors since they are used in dye and pigment industry for coloration to fabrics. These are extensively used for extraction of metals from their ores e.g. Silver and gold extracted from their ores due to formation of soluble cyanide complexes such as $[\text{Ag}(\text{CN})_3]$ and $[\text{Au}(\text{CN})_2]$ respectively. Now a days coordination compounds involves their applications as catalyst in various chemical reactions e.g. Complexes of titanium and

aluminium are used as a catalysts in polymerization reactions.

The reliable information of stability constants are applicable for correct interpretation of metal complexes and also helps to govern the nature as well as interaction between central metal ion and ligand, therefore stability constant is an important tool for chemist. In the last five decades appreciable work has been done on complexes in liquid medium. The substantial work in the coordination chemistry has been made possible with the help of experimental techniques and predicted number of logistic conclusions which has been remarked by Martell and Calvin [1]. Irving and Rossotti [2], Calvin and Bjerrum [3], Hearson and Gilbert [4], Wilkins and Lewis [5], Rossotti and Rossotti [6] have proposed general methods for determination of stability constants of complexes by pH-metry and potentiometry.

Now a day there has been great interest in the study of metal complexes by pH metric method. Many researchers have studied stability constants of metal complexes by pH metric techniques. Patil [7] investigated interaction of Mn(II), Co(II), Ni(II), Cu(II) and Zn(II) metal ions with nicotinic acid (NA) and ascorbic acid (AA) have been studied by pH-metric technique at 0.1 M (KNO_3) ionic strength at 302 ± 0.5 K in aqueous medium. Dhage et al. [8] has investigated PH-metric study of binary and ternary complexes of inner transition metals with carboxylic acids and amino acids. Rajbhoj et al. [9] studied the dissociation constant and stability constants vitamin K3 complexes with transition metal ions in 25% (v/v) methanol-water and 20% (v/v) acetonitrile-water medium at 298K. Mohod and Tayade [10] studied interaction of Cu(II), Cd(II) and Ni(II) metal ions with phenyl thiocarbamidophenol at 0.1 M ionic strength.

Jaiswal and Narwade [11] studied interaction of Pr(III), Nd(III) and Sm(III) metal ions with substituted isoxazolines in 70% ethanol-water medium pH metrically. Jahangir Alam et al. [12] studied the stability of ternary complexes of metal ion with 2,2 bipyridyl and oxalic acid, tyrosin ethylenediamine, glycine, α alaline, phenylalanine and tryptophan.

The compound having azomethine group (C=N) has great importance in the field of coordination chemistry because of potentially capable of forming stable complexes with metal ions [13]. Recently the study of chemistry of ketimines continuously is increasing because of their applications in various biological systems, polymer stabilizer, homogeneous and heterogeneous catalysis, medicine, pharmacy and other technologies [14]. This class of compounds shows wide range of biological activities such as antibacterial, antifungal, anti-inflammatory, antiviral and antipyretics [15-16].

So keeping these views in consideration present study deals the behavior of Sr(II), Ba(II), Ni(II) and Cu(II) ions with substituted ketimine drugs pH metrically at 302 ± 1 K and 0.1 M (KNO₃) ionic strength in 75% dichloromethane (DCM)- water medium.

2. Experimental

2.1 Ligands: In the present investigation following substituted ketimine ligands were used

1. 5-Bromo-2-hydroxy-4-chloro(p-methyl phenyl) ketimine (LA)
2. 5-Bromo-2-hydroxy-4-chloro(p-amino phenol) ketimine (LB)

2.2 Metals:

Transition metals Ni(II) and Cu(II) Alkaline earth metals Sr(II) and Ba(II).

2.3 Solutions:

Free Acid – 0.01M Nitric acid

Ligand solution – 0.002M

Metal salt solution – 0.0004M

Sodium hydroxide (NaOH) – 0.1M

Solvent System – 75% Dichloromethane (DCM)- Water mixture.

Potassium nitrate (KNO₃) – 1M

2.4 Titration method: The pH metric titrations were performed according to Calvin Bjerrum method and ionic strength of solutions was maintained by adding appropriate amount of 1 M KNO₃ solution. The pH metric titration system consisted-

1. Free Acid
2. Free Acid + Ligand solution
3. Free Acid + Ligand Solution + Metal Salt Solution

titrated against 0.1M sodium hydroxide solution carried out in 75% DCM-Water mixture. The graphs plotted between pH of solution and volume of alkali added (fig. 1-2).

2.5 Instruments: All the titration and pH measurements were performed on Equip-Tronic Digital pH meter model EQ-614A (accuracy ± 0.02 units) along with glass and calomel electrode.

3. Observations & calculations:

3.1 Calculation of Proton Ligand (\bar{n}_A) and Metal Ligand Formation Number (\bar{n}):

The proton ligand and metal ligand formation number were calculated from the experimental results obtained from titration curves. The titration curves are made by plotting pH against volume of alkali (NaOH) added (ml) (Fig. 1& 2). From the titration curves values of V_1 , V_2 and V_3 is determined. By using these values, \bar{n}_A and \bar{n} is determined at different pH. The difference (V_2-V_1) was measured accurately, between titration of free acid (V_1) and acid + ligand (V_2). It was used to

calculate formation number \bar{n}_A using Irving Rossotti equation

$$\bar{n}_A = \gamma - \frac{(V_2 - V_1)(E^0 + N)}{(V_0 + V_1) T^0 L} \quad (1)$$

Where,

V_0 = Initial volume of solution

V_1 = Volume of alkali required during free acid titration.

V_2 = Volume of alkali required during free acid +ligand titration.

N = Normality of sodium hydroxide.

E^0 = Concentration of mineral acid (HNO₃)

γ = Number of replaceable hydrogen ion.

The metal ligand formation number (\bar{n}) were calculated by Irving-Rossotti's equation.

$$\bar{n} = \frac{(V_3 - V_2)(N + E^0)}{(V_0 + V_2)(T^0 M \times n_A)} \quad (2)$$

The meanings of notation is same as given in equation 1

3.2 Calculation of Proton Ligand and Metal Ligand Stability constants:

The proton ligand and metal ligand stability constants (pK and log K) values of substituted ketimines in 75% DCM water mixture were calculated by half integral and point wise calculation method shown in table 10 & 11.

Half integral method: Initially the values of proton ligand stability constants (pK) were

calculated from formation curves \bar{n}_A vs. pH (fig. 3 & 4). From these curves the values of pH where $\bar{n}_A = 0.5$ corresponds to value of pK for only one dissociable group.

Point wise calculation method: For the value of \bar{n}_A and \bar{n} less than 1.0 for 1:1 complexes, accurate values of pK determined and log K determined by using the following equations

$$\text{Log} \frac{\bar{n}}{1 - \bar{n}} = \text{Log}K_1 - \text{pH} \quad (3)$$

For 1:2 complex formations metal-ligand stability constants are estimated by using equation 4. The values of metal-ligand formation number due to second complex are used to calculate $\text{Log}K_2$ in the region $1 < n < 2$.

$$\text{Log} \frac{(n - 1)}{(2 - n)} = \text{Log}K_1 - \text{pH} \quad (4)$$

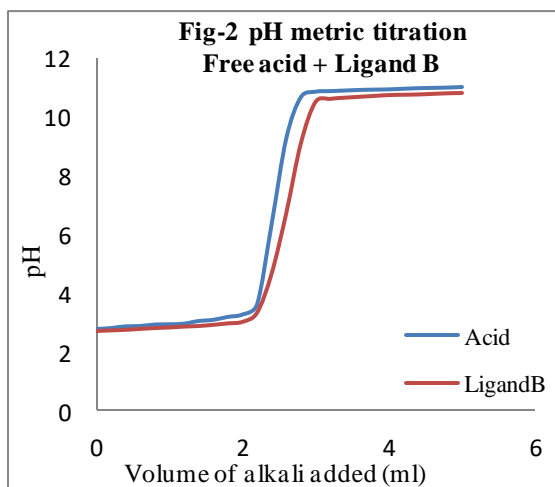
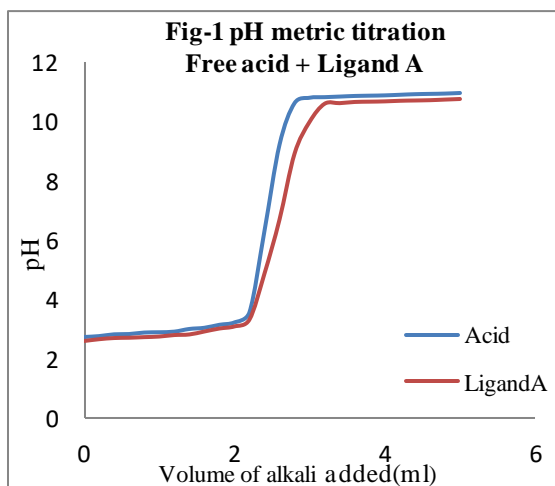


Table: 1 Determination of \bar{n}_A Values of L_A

pH	V ₁	V ₂	V ₂ -V ₁	\bar{n}_A
4.5	2.28	2.34	0.06	0.7801
5.0	2.31	2.40	0.09	0.6705
5.5	2.35	2.46	0.11	0.5978
6.0	2.38	2.51	0.13	0.5252
6.5	2.41	2.58	0.17	0.3798
7.0	2.45	2.63	0.18	0.3443
7.5	2.49	2.68	0.19	0.3088
8.0	2.52	2.71	0.19	0.3096

Table: 2 Determinations of \bar{n}_A Values of L_B

pH	V ₁	V ₂	V ₂ -V ₁	\bar{n}_A
3.50	2.2	2.28	0.08	0.7059
4.00	2.24	2.33	0.09	0.6696
4.50	2.28	2.38	0.10	0.6334
5.00	2.31	2.42	0.11	0.5972
5.50	2.35	2.47	0.12	0.5612
6.00	2.38	2.51	0.13	0.5252
6.50	2.41	2.56	0.15	0.4528
7.00	2.45	2.62	0.17	0.3807
7.50	2.49	2.67	0.18	0.3452

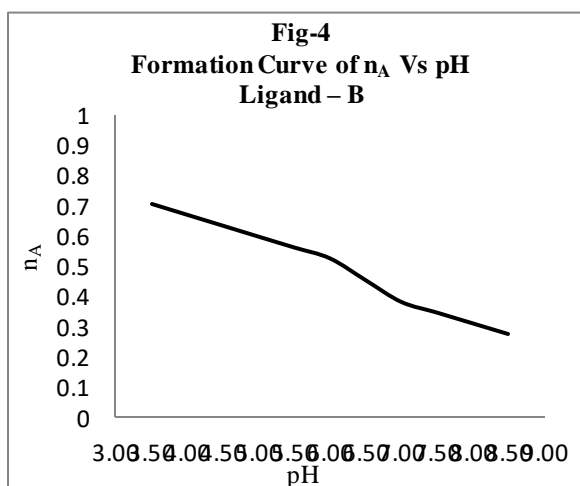
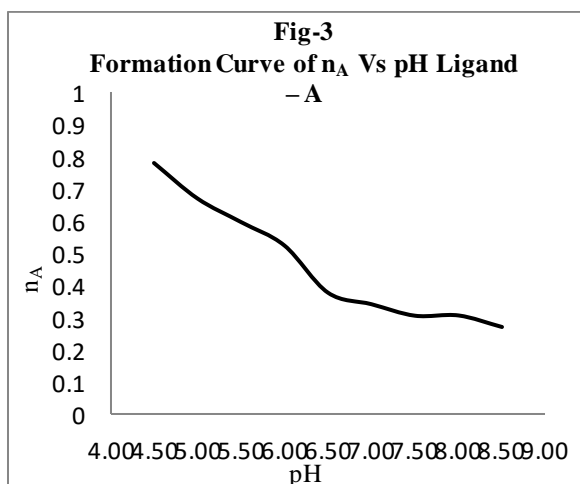


Table: 3 Determinations of \bar{n} [L_A +Sr (II)]

pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.23	2.24	0.01	0.2064
4.0	2.29	2.31	0.02	0.4488
4.5	2.34	2.38	0.04	0.9377
5.0	2.40	2.46	0.06	1.6329
5.5	2.46	2.54	0.08	2.4367
6.0	2.51	2.61	0.10	3.4606

Table: 4 Determination of \bar{n} [L_A +Ba(II)]

pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.23	2.24	0.01	0.2063
4.0	2.29	2.31	0.02	0.4488
4.5	2.34	2.38	0.04	0.9377
5.0	2.4	2.46	0.06	1.6329
5.5	2.46	2.54	0.08	2.4367
6.0	2.51	2.61	0.10	3.4606

Table: 5 Determination of \bar{n} [L_A +Ni(II)]

pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.23	2.24	0.01	0.2064
4.0	2.29	2.31	0.02	0.4488
4.5	2.34	2.37	0.03	0.7033
5.0	2.4	2.44	0.04	1.0886
5.5	2.46	2.51	0.05	1.5229
6.0	2.51	2.58	0.07	2.4224

Table: 6 Determination of \bar{n} [L_A +Cu(II)]

pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.23	2.24	0.01	0.2064
4.0	2.29	2.31	0.02	0.4488
4.5	2.34	2.39	0.05	1.1722
5.0	2.4	2.47	0.07	1.9051
5.5	2.46	2.55	0.09	2.7413
6.0	2.51	2.61	0.10	3.4606

Table: 7 Determination of \bar{n} [L_B +Sr(II)]

pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.28	2.29	0.01	0.260
4.0	2.33	2.34	0.01	0.273
4.5	2.38	2.42	0.04	1.153
5.0	2.42	2.47	0.05	1.527
5.5	2.47	2.53	0.06	1.946
6.0	2.51	2.61	0.10	3.461

Table: 8 Determination of \bar{n} [L_B +Ba(II)]

pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.28	2.29	0.01	0.260
4.0	2.33	2.34	0.01	0.273
4.5	2.38	2.41	0.03	0.865
5.0	2.42	2.50	0.08	2.443
5.5	2.47	2.56	0.09	2.919
6.0	2.51	2.61	0.10	3.461

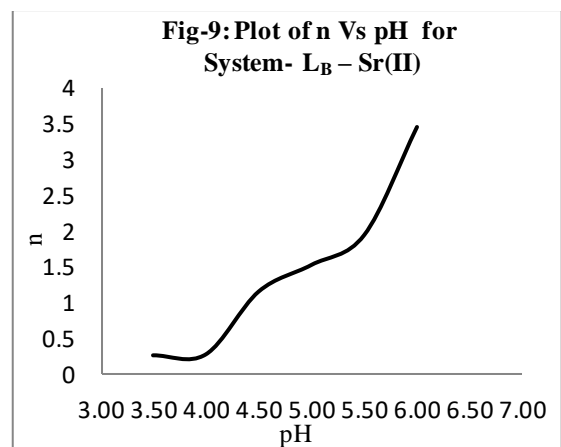
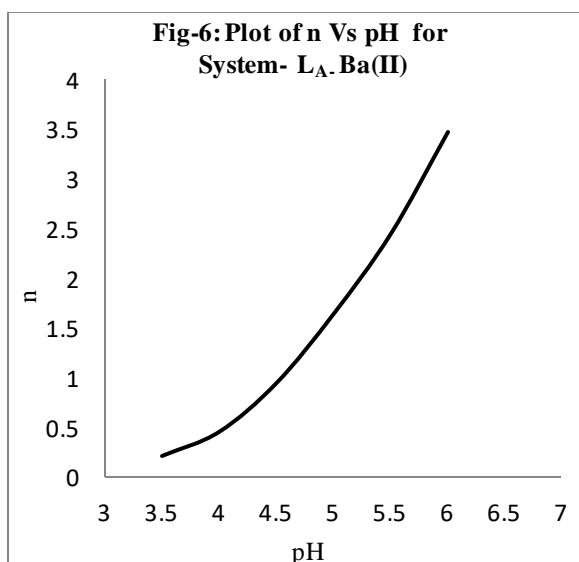
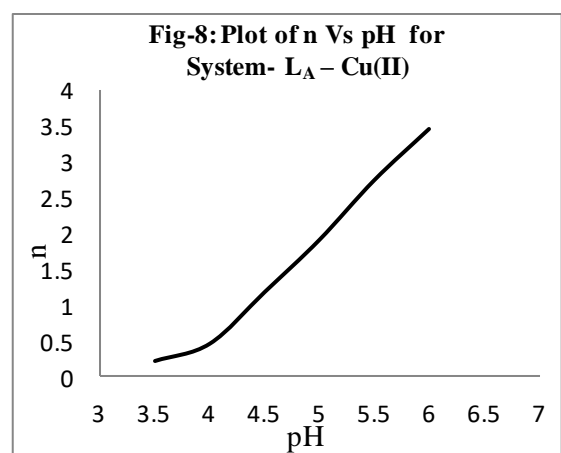
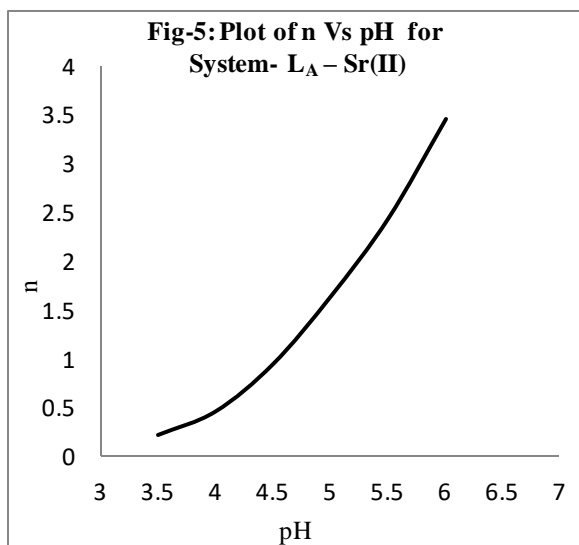
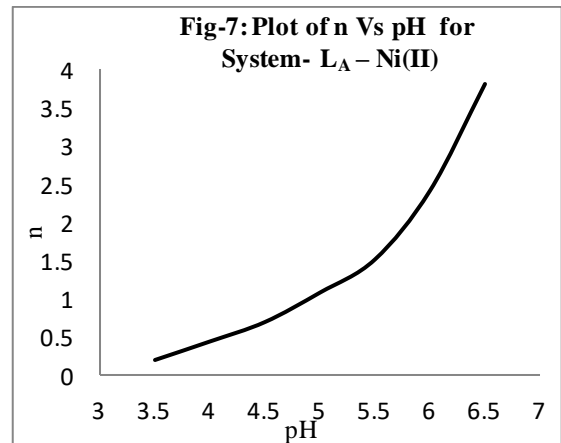
Table: 9 Determination of \bar{n} [L_B +Ni(II)]

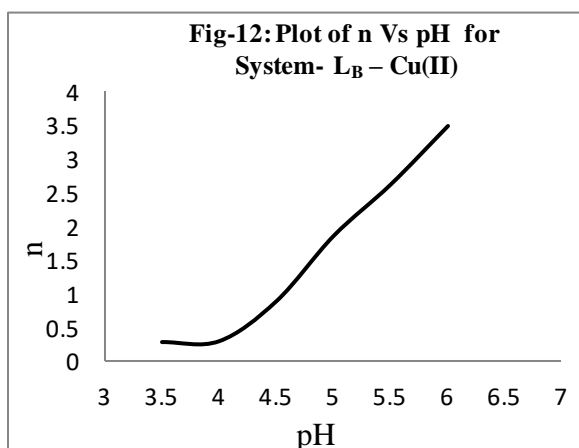
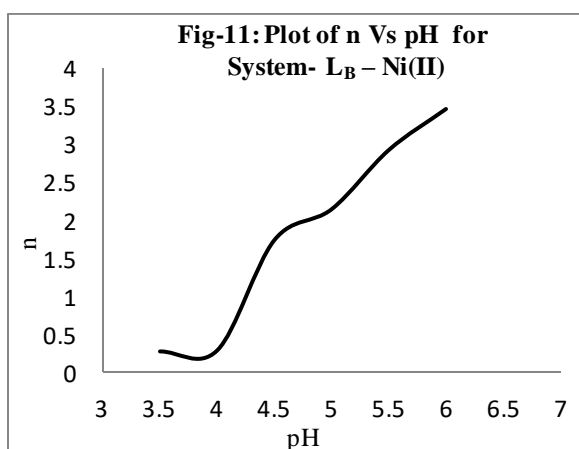
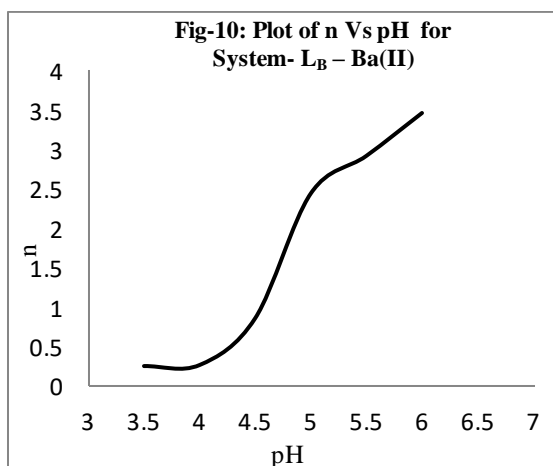
pH	V ₂	V ₃	V ₃ -V ₂	\bar{n}
3.5	2.28	2.29	0.01	0.260
4.0	2.33	2.34	0.01	0.273
4.5	2.38	2.44	0.06	1.730
5.0	2.42	2.49	0.07	2.137

5.5	2.47	2.56	0.09	2.919
6.0	2.51	2.61	0.10	3.461

Table: 10 Determination of \bar{n} [$L_B + Cu(II)$]

pH	V_2	V_3	$V_3 - V_2$	\bar{n}
3.5	2.28	2.29	0.01	0.260
4.0	2.33	2.34	0.01	0.273
4.5	2.38	2.41	0.03	0.865
5.0	2.42	2.48	0.06	1.832
5.5	2.47	2.55	0.08	2.595
6.0	2.51	2.61	0.10	3.461




Table 11: Proton-ligand stability constants (pK)

Ligand	pK (Half Integral Method)	pK (Pointwise Method)
L _A	6.09	6.440
L _B	6.15	6.410

Table 12: Metal ligand stability constants (log K)

Ligand	Metal	logK ₁	logK ₂	logK ₁ / logK ₂	logK ₁ - logK ₂
L _A	Sr(II)	4.7747	4.0338	1.1837	0.7409
	Ba(II)	4.7647	4.0438	1.1783	0.7209
	Ni(II)	4.7447	3.4638	1.3698	1.2809
	Cu(II)	4.7947	4.2338	1.1325	0.5609
L _B	Sr(II)	4.7647	4.5338	1.0509	0.2309
	Ba(II)	4.6947	4.2838	1.0959	0.4109
	Ni(II)	4.7947	4.6038	1.0415	0.1909
	Cu(II)	4.6847	4.1838	1.1197	0.5009

4. Result and discussion:

From table-11 it was observed that there is a close resemblance in the proton ligand stability constants (pK values) between point wise calculation method and half integral method. From these values metal ligand stability constants of substituted ketimines were calculated as shown in table- 12. Fig. 1 & 2 shows significant separation started from pH 3.58 for all metals, which predict conformation of complex formation.

The values of metal ligand stability constants (log. K₁ and log. K₂) presented in table 12 were determined from the formation curves (Fig. 1 & 2) at formation number 0.5 and 1.5 respectively and point wise calculation method. The ratio of log K₁/logK₂ has + ve values and greater than 1 in all the systems (Table 12). This indicates that there is a no steric hindrance to the addition of secondary ligand molecule. Also it has been observed that if the ratio is less than 1.5 then there is simultaneous complex formation take place. While if the ratio greater than 1.5 then there is step wise complex formation take place. Table 12 shows that the entire metal ion has smaller ratio than 1.5 since both the ligands shows simultaneous formation of 1:1 and 1:2 complexes with all the metal ions.

5. Conclusion:

The experimental results in the present investigation for proton ligand and metal ligand stability constants of aromatic substituted ketimine drugs estimated at 302K in (DCM-water) mixture. From the experimental data it is concluded that there is a simultaneous formation of 1:1 and 1:2 complexes with all the metal ions.

References:

- [1] Martell A. E., and Calvin M., "Chemistry of metal chelate compound, Prentice Hall INC., England, Cliffs N. J. (1962).
- [2] Irving H. and Rossotti H., The calculation of formation curves of metal complexes from pH titration curves in mixed solvents, *J. Chem. Soc.*, 76, 2904-2910, (1954).
- [3] Bjerrum J, Calvin M, "Metal amine formation in aqueous solutions". Hass and Son, Copenhagen (1941), Reprinted in (1957).
- [4] Hearson J. Z. and Gilbert J. B., *J. Am. Chem. Soc.*, 77, 2594, (1955).
- [5] Lewis J and Wilkins R G, "Modern Coordination Chemistry", Interscience Pub Co, New York. (1960).
- [6] Rossotti F. J. C. and Rossotti H. S., "The Determination of Stability Constants", McGraw Hill Book Co. INC, New York, (1961).
- [7] Patil A. B., Equilibrium studies of ternary complexes of some transition metal ions with penicilamine, *Rasayan J. chem.*, 5(4), 490-492, (2012).
- [8] Dhage S. D. and Swami M.B., pH metric study of binary and ternary complexes of inner transition metals carboxylic acids and amino acids *IOSR J. App. Chem.*, 2(6), 36-38, (2012).
- [9] Rajbhoj A. S., Gaikwad M. N. and Gaikwad S. T., Potentiometric study of vitamin K₃ complexes with transition metals in methanol-water and acrylonitrile-water medium., *J. Chem. Tech. Res. CODEN (USA)*, , 4(4), 1392-1395, (2012).
- [10] Mohod S.O. and Tayade D.T., pH metric study of phenyl thiocarbamidophenolwith Cu(II), Co(II), Cd(II) and Ni(II)metal ions at 0.1M ionic strength., *Int. J. Pharm. Pharm. Res.*, 8(3), 25-30, (2017).
- [11] Jaiswal G.R. and Narwade M.L., Studies in stability constants of Pr(III), Nd(III) and Sm(III) metal ions complexes with some substituted isoxazolinein 70% ethanol water medium pH metrically., *Ind. J. Res. Pharm. Biotech.*, 5(2), 168-172, (2017).
- [12] Jahangir Alam M., Ullah M.R. and Mousume Akther, Stability of ternary complexes of Cu(II) metal ion with some bio active compounds, *IOSR J. App. Chem.* 11(1), 1-4, (2018).
- [13] Souza P., Garcia-Vazquez J. A. and Masaguer J. R. C: 3 Transitions *Met. Chem.*, 10, 410, (1985).
- [14] Upadhyay K. K., Kumar A. and Upadhyay S., Mishra P., C.: 9. Synthesis, characterization, structural optimization using density functional theory and superoxide ion scavenging activity of some Schiff bases. *J. Mol. Struct.*, 873, 5–16, (2008).
- [15] Dhar D. N. and Taploo C. L. Schiff's bases and their applications. *J. Sci. Ind. Res.*, 41 (8), 501-506, (1982).
- [16] Przybulski A, Huczynski A. Pyta K., Biological properties of imines and azo derivative of phenols., *Curr. Org. Chem.*, 13(2), 124-148, (2009).