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Study of formation constant of schiff base containing Thiazole ring in mixed solvent media and their thermodynamic parameters

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Abstract

The Schiff bases derived from substituted aminothiazole i.e. 2-4-Diamino-5-phenylthiazole and R-Substituted salicylaldehyde (R-5-CH₃, and 5-Cl) or 2-hydroxy-1-naphthaldehyde i.e. (5MS)₂ DPT, (5CS)₂ DPT and (HN)₂ DPT and Rare earth metal ion La^{III}, Ce^{III}, Pr^{III}, Nd^{III}, Sm^{III}, Gd^{III}, Tb^{III}, Ho^{III}, Dy^{III} and Yb^{III} Nitrate Salts.

The stability constants of lanthanide metal ion complexes in mixed solvent media in ethanol-water 50:50 (v/v) at different ionic strength $\mu = 0.05, 0.1, 0.15$ and 0.2 M (NaClO₄) and at different temperature (35°C and 45°C) using Bjerrum pH metric technic as adopted by Irving-Rossoti.

The formation constants are determined by Half Integral method. The stability constants of Rare earth metal (III) ion complexes have been proportional to their ionic strength. The thermodynamic parameter (ΔH , ΔG and ΔS) were determined. The negative free energy change (ΔG) in each cases indicates that the complexation is spontaneous. The enthalpy changes are exothermic. The positive values of ΔS Indicates the reactions are entropically favoured.

Keywords: Stability constant, thermodynamic parameter, rare earth metal

Introduction

In continuation of our earlier work ^[1-3] deals with the stability constants of Schiff bases and their transition metal (CO^{II}, Ni^{II}, Cu^{II} and Zn^{II}) complexes. The Schiff base derived from substituted amino thiazole i.e. 2-aminothiazole, 2-4-diaminothiazole and 2-4-diamino-5-chloro thiazole and O-hydroxy aldehyde i.e. (5-CH₃, 5-Cl and 2-hydroxy-1-naphthaldehydes). The review reveals that no work on 2-4 Diamino-5-phenyl thiazole, the stability constants of Schiff base and their rare earth metal complexes, hence on interest is taken to study the Schiff base and rare earth. Metal complexes in the present investigation. An attempt has been made to study the stability constant, effect of ionic strength and thermodynamic parameter of the Rare earth metal complexes. The Schiff bases derived from 2-4 diamino-5-phenylthiazole and O-hydroxy aldehyde i.e. (5-CH₃, 5-Cl and 2-hydroxy-1-naphthaldehyde) and rare earths. La^{III}, Ce^{III}, Pr^{III}, Nd^{III}, Sm^{III}, Gd^{III}, Tb^{III}, Ho^{III}, Dy^{III}, Yb^{III}.

Result and Discussion

Proton-ligand stability constant (PK) values of the ligands (5MS), DPT, (5CS)₂ DPT and (HN)₂ DPT, were calculated using half-integral method. The values are summarized in table 1.

The ligand possesses two pK values due to dissociable proton of the two phenolic -OH group. The protonation of imino nitrogen (HC=N) does not take place in the pH range under study. The pK values of ligands follow the trend: ligand (5MS)₂ DPT > (5CS)₂ DPT > (HN)₂ DPT and it is explained on the grounds of basic nature of azomethine nitrogen and phenolic oxygen ^[4-6].

The ligand (5CS)₂ DPT exhibits higher proton-ligand stability constant values than the ligand (HN)₂ DPT and this may be due to the presence of -Cl group in the aromatic ring. Cl behaves as an electron-releasing group due to mesomeric effect (+M) rather than (-I) effect (inductive effect). Hence electron density on the phenyl ring increases and azomethine nitrogen and phenolic oxygen become more basic.

The ligand (5MS)₂ DPT possesses a methyl group at the meta position with respect to the azomethine group. Due to the (+I) effect of the methyl group, electron density over the phenyl ring increases and

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azomethine nitrogen and phenolic oxygen become more basic. Hence the ligand posses higher stability constant values. Thus (+I) effect of methyl and stronger (+M) of halogen group present in the phenyl ring in the series of the Schiff base support the trend proposed for proton-ligand stability values.

Metal - Ligand stability constants

The titration curves of acid, ligands and the metal ions are studied. The metal ion curve shows departure from ligand curves at pH much lower than the pH of hydrolysis of metal ion and therefore the liberation of proton is due to chelation 6-8. The metal ligand stability constants were determined by using Half Integral Method and values are summarized in table 2.

The order of stability constant for the trivalent Rare earth complexes have no regular trends that is in many cases no order is apparent^[9-13].

Few observations were made for Rare earth complexes, were the increasing stability constants with increasing atomic number up to Tb^{III} and Yb^{III} respectively^[14-15].

In present observation complexes of Rare earth trivalent metal (III) ions and Schiff bases I, II and III shows increasing in stability from La^{III} to Yb(III) in agreement with increasing Lewis acidity of the metal ions. The order of stability constant of Rare earth complexes with Schiff bases I, II and III has been found to be as follows.

La^{III} < Pr^{III} < Nd^{III} < Gd^{III} < Ce^{III} > Sm^{III} < Tb^{III} < Dy^{III} < Ho^{III}

< Yb^{III} The Gd^{III} has low value of stability constant then Sm^{III} indicates the Gadolinium break. The Ce^{III} cerium show higher value due to the partial conversion of Ce^{III} to Ce^{IV}.

The value of stability constants are decreased with increasing ionic strength which is an agreement with debye-Hukel equation.

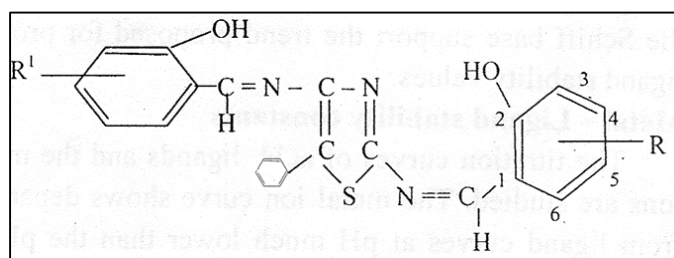
To study the effect of temperature on complexation observed that the value of proton-ligand and metal-ligand decreases with increasing temperature suggesting that low temperature is favorable for complexation. These results are good agreement with pitzer and Garge^[15-16].

Thermodynamic parameters

(ΔH , ΔG and ΔS) have been calculated and are summarized in Table 2. The ΔG and ΔH values are negative, the ΔG free energy change in each case indicates that the complexation is spontaneous. The enthalpy changes are exothermic. The ΔS values are positive. The positive values of ΔS indicates that entropy effect is found to be predominant over enthalpy effect.

Materials and Methods

All chemicals are A.R. grade. The Schiff bases were prepared by condensation of 2-4 diamino-5- phenylthiazole and 5-methylsalicylaldehyde, 5-Chloro salicylaldehyde and 2-hydroxy-1-naphthaldehyde i.e. (5MS)₂ DPT, (5CS)₂ DPT and (HN)₂ DPT respectively. The structure I, II and III.



Sr.	Schiff base	R-R ¹
I	(5MS) ₂ DPT	5-CH ₃
II	(5CS) ₂ DPT	5-Cl
III	(HN) ₂ DPT	

- I. (5MS), DPT: [N-bis (5-methylsalicylindine) 2-4 diamino-5-phenyl thiazole]
- II. (5CS), DPT: [N-bis (5-Chlorosalicylindine) 2-4, diamino-5- phenyl thiazole]
- III. (HN), DPT: [N-bis (2-hydroxy-1-naphthalidine) 2-4 diamino-5- phenyl thiazole]

The fresh solutions of (5MS)₂ DPT, (5CS)₂ DPT & (HN)₂ DPT were prepared in double distilled ethanol and always used. Stock solution of rare earth (Nitrate) salts were prepared in double distilled air-free water and their strength were formed in ethanol - water (50:50%) (v/v) at different ionic strength (n^-)=0.05, 0.1, 0.015 and 0.2 M (NaClO₄) and also at different temperature (35 and 45°C) using Bjerrum pH-metric technic as adopted by Irving and Rossotti. The pH-metric titrations were performed against standard alkali (NaOH) solution as under.

1. Acid titration: A Mixture [2ml 0.2 M HClO₄ + 1ml 0.1 M NaClO₄+17ml distilled water + 20 ml ethanol]
2. Schiff base titration: A mixture [2ml 0.2 M HClO₄+ 1ml 0.1 M NaClO₄ +10 ml ligand solution + 17 ml distilled water + 10ml ethanol]
3. Metal-Ligand titration: A mixture [2ml 0.2 M HClO₄ + 1ml 0.1 M NaClO₄ +10 ml ligand solution + 2 ml metal ion solution + 15ml distilled water + 10 ml ethanol]

The titrations were carried out in inert nitrogen atmosphere using Elico-4T-120pH meter with combined glass electrode. The pH meter was calibrated with standard buffer and the readings were corrected as per literature^[17].

From titration curves at different pH values different sets of n^- values were determined of the corresponding free ligands (L) were calculated. The formation curves were drawn and found to be normal. The values of stepwise stability constant $\log k_1$, and $\log k_2$, of these complexes were determined at $n^- = 0.5$ and $n^- = 1.5$ from the formation curves. At each temperature average values of over all stability constant ($\log k$) were plotted against ionic strength for metal ligand system and the values of thermodynamic stability constant ($\log k_{1-2}$) at zero ionic strength were calculated by extrapolation.

The thermodynamic stability constants, the values of (ΔG°) were calculated at 35 and 45°C using relation free energy change

$$\Delta G^\circ = 2.303 RT \log k^\circ$$

Enthalpy (H^0) $[1/T_2 - 1/T_1] = -2.303 (\log k^0 T - (\log k^0) T_1]$ and
Entropy (ΔS) = $\Delta H^0 - G^0/T$

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Table 1: Stability constant of Rare earth trivalent metal ion in mixed solvent media ethanol – water (50:50) (NaClO) at different ionic strength 25 °C±1.

Sr. No.	Proton-Ligand and metal-ligand stability constant, Ionic strength (μ) - (NaClO ₄) PK and log K			
	0.05M	0.1M	0.15M	0.2M
1) LH, PK ₁ , PK ₂				
I	9.80, 12.70	8.65, 11.40	8.50, 11.30	8.40, 11.10
II	8.50, 11.40	8.26, 11.03	8.05, 10.91	8.85, 10.79
III	8.10, 11.32	8.05, 11.00	7.90, 10.80	7.80, 10.70
2) La ^{III} I	6.95	6.45	6.15	5.95
II	7.50	7.00	6.70	6.50
III	7.94	7.44	7.14	6.94
3) Ce ^{III} I	7.35	6.85	6.55	6.35
II	7.75	7.25	6.95	6.65
III	8.30	7.70	7.40	7.20
4) Pr ^{III} I	7.20	6.70	6.40	6.20
II	7.80	7.30	7.00	6.80
III	8.02	7.52	7.22	7.02
5) Nd ^{III} I	7.40	6.90	6.60	6.40
II	8.10	7.40	7.10	6.90
III	8.25	7.75	7.45	7.35
6) Sm ^{III} I	7.45	6.95	6.65	6.46
II	7.82	7.32	7.02	6.82
III	8.30	7.80	7.50	7.30
7) Gd ^{III} I	7.30	6.80	6.50	6.30
II	7.75	7.25	6.96	6.76
III	8.05	7.63	7.34	7.14
8) Tb ^{III} I	7.45	6.95	6.65	6.65
II	7.80	7.30	7.00	6.80
III	7.36	7.85	7.66	7.47
9) Ho ^{III} I	7.53	7.03	6.73	6.53
II	7.92	7.42	7.22	6.98
III	8.32	7.80	7.50	6.36
10) Dy ^{III} I	7.45	6.95	6.66	6.47
II	7.96	7.46	7.75	6.85
III	8.35	7.85	7.56	7.36
11) Yb ^{III} I	7.67	7.17	6.85	6.66
II	8.05	7.52	7.22	7.03
III	8.40	7.90	7.61	7.42

Table 2: Metal Ligand stability constant of Rare earth trivalent metal ion in mixed solvent media ethanol water (50-50) (V/V) at ionic strength 0.1 M NaClO₄ and their thermodynamic parameters.

Cation	Log ^k			-ΔG KJ Mol ⁻¹			ΔS JK Mol ⁻¹			-ΔH KJ Mol ⁻¹	
	25 ^o C	35 ^o C	45 ^o C	I	II	III	I	II	III	I	II
La ^{III} I	6.45	6.35	6.26	32.50	32.80	27.49	28.12	28.10	44.25	24.11	168.52
II	7.00	6.90	6.81	33.10	34.95	33.80	41.00	43.63	09.56	21.50	36.80
III	7.44	7.34	7.25	38.00	38.31	29.25	31.76	31.76	814.01	28.51	288.15
Ce ^{III} I	6.85	6.76	6.65	33.85	34.51	33.08	63.52	63.53	41.53	14.90	46.35
II	7.25	7.15	7.06	36.80	35.99	34.61	109.00	108.70	27.21	69.52	43.26
III	7.70	7.60	7.50	39.11	39.73	37.35	62.10	62.36	120.16	20.50	75.52
Pr ^{III} I	6.70	6.60	6.51	33.50	33.85	32.13	37.17	37.17	71.10	22.38	54.78
II	7.30	7.20	7.11	35.71	29.26	34.11	64.00	25.09	376.63	227.40	154.10
III	7.52	7.42	7.33	38.72	38.90	33.73	37.92	38.01	401.17	27.18	161.44
Nd ^{III} I	6.90	6.80	6.70	33.94	34.59	33.14	55.85	55.88	30.00	17.26	42.71
II	7.40	7.30	7.20	37.80	37.65	34.92	141.02	14.01	164.23	42.00	87.18
III	7.75	7.85	7.56	39.29	39.88	38.00	60.74	60.76	68.82	21.15	59.94
Sm ^{III} I	6.95	6.85	6.70	32.28	34.73	33.41	24.58	20.54	27.70	41.09	42.25
II	7.32	7.22	7.20	37.52	37.13	34.75	38.30	38.50	139.13	49.02	78.92
III	7.80	7.70	7.56	39.25	39.94	38.00	67.45	67.47	72.70	19.12	61.16
Gd ^{III} I	6.80	6.70	6.60	33.77	46.00	32.51	52.95	91.03	70.45	17.92	54.96
II	7.25	7.15	7.05	36.92	36.00	34.58	94.25	94.26	75.61	65.03	10.56
III	7.63	7.53	7.44	38.84	39.40	36.75	52.46	52.47	145.46	23.18	83.04
Tb ^{III} I	6.95	6.86	6.76	32.75	34.65	33.45	27.35	32.70	18.67	24.55	39.36

II	7.30	7.20	7.10	37.53	37.24	34.65	27.10	27.17	150.50	45.64	82.53
III	7.85	7.75	7.66	39.43	40.45	39.01	102.85	102.80	21.10	8.75	45.75
Ho ^{III} I	7.03	6.97	6.87	34.43	34.90	33.60	45.23	45.26	22.28	20.90	40.71
II	7.42	7.32	7.22	38.03	34.16	29.26	11.95	11.94	799.00	34.45	283.38
III	7.80	7.70	7.60	39.40	40.12	38.30	72.01	72.00	66.85	17.90	59.58
Dy ^{III} I	6.95	6.85	6.76	32.27	34.68	33.46	23.52	11.88	16.60	39.32	39.77
II	7.46	7.36	7.27	38.22	38.30	29.25	08.70	08.70	124.41	35.60	68.86
III	7.85	7.70	7.61	39.50	41.57	39.18	132.71	103.91	10.71	9.37	42.62
Yb ^{III} I	7.17	7.07	6.98	36.43	32.80	34.15	36.29	36.33	34.70	145.00	45.28
II	7.52	7.42	7.33	38.98	39.85	32.05	36.10	36.11	557.60	27.70	215.75
III	7.90	7.71	7.71	34.00	40.52	39.33	42.40	38.90	4.72	160.67	37.80

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