CHAPTER V

POLAROGRAPHIC STUDY OF MIXED LIGAND COMPLEXES
OF IN(III) WITH ORGANIC LIGANDS
INTRODUCTION

Prof. J. Heyrovsky (in 1922), of Charles University, Prague Czechoslovakia, invented polarography, his top most contribution in the field of electroanalytical sciences. Polarographic analysis is based on the property of the current potential curve obtained with a dropping mercury electrode, in general or other micro electrodes, viz., HMDE, RFE or MDE, when diffusion is rate determining stage in the discharge of ions.

Polarography is a branch of electroanalytical chemistry which deals with the measurement and interpretation of current voltage relationship during the electrolysis of solution between two electrodes, one of which is very small.

Since its discovery the technique has been widely used for qualitative as well quantitative organic inorganic analysis and for the study of various physico-chemical reactions. The half wave potential, \( E_{1/2} \), is the characteristic property of an electroactive species, whereas, the diffusion current is a measure of its concentration. For its application to the study of binary complexes, Lingane, suggested a method to evaluate the stoichiometry and dissociation constant of the complex formed, which is reversibly reduced at the indicator electrode. Lingane's method is applicable for the study of metal complexes if only a single complex species
is formed over the entire range of ligand concentration. If the complexation is stepwise (i.e. more than one complex species are formed in the solution), DeFord and Hume's method may be successfully applied to evaluate the stoichiometry and the formation constant of each of the complex species formed, provided they are reversibly reduced at the indicator electrode.

**Formation of Mixed Ligand Complexes**

During the last two decades numerous researches on the study of mixed ligand (ternary) complex formation. Mixed ligand complexes are those in which more than one kind of ligand, other than solvent molecules, are present in the coordination sphere of central metal ion. The equilibrium may be represented by general formula –

\[ M + iX + jY + \ldots \ldots \leftrightarrow \text{M}^{i+}X^jY^j \]  

(Charges are not to be written in the equation for simplicity). A logical extension of the DeFord-Hume method by applying the later to cases where the metal ion form a complex with two ligand species simultaneously in solution is developed by Schaap and McMasters. DeFord-Hume type $F_0(X)$ function may be extended to give a new function

\[ F_0(X,Y) = \sum_{i=0}^{\infty} \beta_{\text{M}X^iY^j}(X)^i(Y)^j \]
Eq. (2) may be written in the following most applicable form in terms of measurable data viz. \( \Delta E_x \)

\[
F_{00} (X, Y) = \text{antilog} \left( \frac{0.4343 \cdot n \Delta E_x}{R} + \log \frac{I_M}{I_C} \right) \quad \text{** (3)}
\]

when metal ion forms successive complexes, Laiden's approach for such complexation may be expressed as under:

\[
F_{00} (X, Y) = (\beta_{00} + \beta_{01} (Y) + \beta_{02} (Y)^2 + \beta_{03} (Y)^3) (X)^0
+ (\beta_{10} + \beta_{11} (Y) + \beta_{12} (Y)^2) (X)
+ (\beta_{20} + \beta_{21} (Y)) (X)^2
+ (\beta_{30}) (X)^3 \quad \text{** (4)}
\]

where \((Y)\) is kept constant while \((X)\) is varied. \(
\beta\)'s are single and mixed stability constant respectively. For simplicity eq. (4) may be expressed in the following form

\[
F_{00} (X, Y) = A + B (X) + C (X)^2 + D (X)^3 \quad \text{** (5)}
\]

In actual experiment the concentration of weak ligand is kept constant, while that of stronger is varied. The original graphical method may be extended to \(F_{00}\) data. The intercept of \(F_{00}\) axis gives the value of \(A\), so that

\[
F_{10} = \frac{F_{00} - A}{(X)} = B + C (X) \quad \text{** (6)}
\]
A similar plot of $F_{10}$ vs ($X$) and taking the intercept on $F_{10}$ axis is $B$.

$$F_{20} = \frac{F_{10} - B}{(X)} = C$$  \hspace{1cm} (7)

From the calculated values of $B$, the value of $\beta_{11}$ mixed ligand formation constant can be computed

$$B = F_{10} + \beta_{11} (Y)$$  \hspace{1cm} (8)

In order to determine $\beta_{21}$ and $\beta_{12}$ it is necessary to determine the constant $B$ at least at two different fixed concentrations of weak ligand. Using this criteria $F_{ij}$ functions and hence the scheme for mixed ligand complex formation can be presented$^9$.

Survey of Literature

The study of mixed ligand complexes in solution is the intricate problem, various procedures have been suggested using spectrophotometric, potentiometric and pH metric techniques$^{10-14}$. The first polarographic study on the mixed ligand complexes were made by Schaap and McMastets$^8$. Since then the polarographic method has been widely used to evaluate the stoichiometry and formation constants of mixed ligand species.$^{15-29}$ Polarographic method was used to evaluate
the stoichiometry and formation constants of Cd(II)-DTPA-thiourea and Cd(II)-DTPA-urea systems. Binary complexes of In(III) with citric acid using potentiometric and high frequency titration techniques were reported by Ryabchikov and Marov. Ion exchange method has been utilised to study In(III) complexes with aminopolycarboxylic acid. Munshi and Sarin have reported the stepwise stability constants of In(III) complexes with mercapto, hydroxy, amino substituted analogs of succinic and propionic acids, thio-salicylic, salicylic and anthranilic acid using potentiometric technique. Polarographic studies on binary complexes of indium with salicylic acid and anthranilic acid have been reported by Pitre. There exists many contradictory results, in literature, on polarographic reduction of In(III) in potassium chloride (1.0N), is found to be reversible. Electro chemical reduction of complexes of Pb(II) with itaconic and citraconic acid on a DME was reported by Chitale and Pitre. Same authors also reported ternary complexes of Pb(II) with itaconic and nicotinic acid. Binary and ternary complexes of In(III) with 2,2 bipyridyl and urea were studied polarographically. Polarographic studies of In(III), Y-picoline and citraconic acid were done. Binary and ternary complexes of In(III) with Y-picoline and nicotinic acid were studied electrometrically. Pitre and et al. prepared mixed
complexes of In(III) with 2-2 bipyridyl and thiourea. Electrometric studies of binary and ternary complexes of Zn(II) with γ-picoline and nicotinic acid were done. In the present work ternary complexes of In(III)-glycine-urea, In(III)-glycine-nicotinic acid were studied.

**EXPERIMENTAL**

All the chemicals used were of AnalaR/BDH grade. In(III)nitrate (0.01 mol dm$^{-3}$) was dissolved in distilled water by direct weighing and was standardised. Stock solution of potassium chloride (2.0 mole dm$^{-3}$) has been prepared in distilled water. Solution of urea was prepared in distilled water, whereas, nicotinic acid and glycine solutions were prepared by dissolving requisite amount of their sodium salt in distilled water.

An automatic p$\ddot{a}$n recording polarograph CIC Baroda (India) model 975 was used to record the polarograms. The capillary of the DME had a 'm' value of 2.3733 mg sec$^{-1}$ at a drop time 3.0 sec$^{-1}$ at 41.0 cm, effective height of mercury column, $(m^2/3)^{1/6} = 2.136$ mg$^{2/3}$ s$^{-2}$. An Elico digital pH meter model L 1 – 120 with an assembly of glass
and calomel electrode was used to measure the pH of the test
solutions. Doubly distilled mercury was used throughout the
course of studies. Each of the test solution was deaerated by
bubbling purified nitrogen gas through it before recording
polarograms.

In each case preliminary experimental set was prepared to
study binary systems prior to the study of ternary systems by
keeping over all concentration of metal ion and supporting
electrolyte fixed at 1.0 mol dm$^{-3}$ and 1.0 mol dm$^{-3}$, respectively,
while the concentration of ligand in each case was varied.

For the study of ternary systems two suitable concentrations
of the weak ligand were fixed, where 1:1 and 1:2 predominant binary
species were available, and that of stronger ligand was varied.
The ionic strength $I = 1.0$ was adjusted with necessary addition
of potassium chloride.

**RESULTS AND DISCUSSION**

In(III) as well as its binary complexes with each of glycine,
nicotinic acid and urea and the ternary complexes under study are
reversibly reduced at the dropping mercury electrode in 1.0 m KCl,
$pH = 4.5$ (± 0.02) and $\mu = 1.0$ (KCl), involving three electrons.
As is evidenced by linear plots of log id-i/i vs $E_{de}$. The reduction
is found to be diffusion controlled in nature which is indicated
TABLE 1

In$^{III}$ - Urea - Binary System - Polarographic Characteristics
and F(x) Functions

In$^{III}$ = 1.0 mM i = 1.0 M (KCl)

$\text{pH} = 4.5 \pm 0.02$  Temp. = 30 $\pm$ 1°C

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Ligand concen. (mole)</th>
<th>$E'_{2}$ (V) vs S.C.E.</th>
<th>id (div)</th>
<th>$F_{0}(x)$</th>
<th>$F_{1}(x) \times 10^{-2}$</th>
<th>$F_{2}(x) \times 10^{-3}$</th>
<th>$F_{3}(x) \times 10^{-5}$</th>
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</thead>
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<tr>
<td>1</td>
<td>0.00</td>
<td>0.53</td>
<td>122</td>
<td>3.4954</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
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<td>0.54</td>
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<td>3.4954</td>
<td>1.25</td>
<td>4.9855</td>
<td>1.1943</td>
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<td>3</td>
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<td>0.548</td>
<td>117</td>
<td>9.0344</td>
<td>2.01</td>
<td>4.3965</td>
<td>0.4491</td>
</tr>
<tr>
<td>4</td>
<td>0.06</td>
<td>0.556</td>
<td>116</td>
<td>23.845</td>
<td>3.81</td>
<td>5.9292</td>
<td>0.5547</td>
</tr>
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<td>5</td>
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<td>0.566</td>
<td>113.5</td>
<td>80.8756</td>
<td>9.98</td>
<td>12.168</td>
<td>1.1960</td>
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<tr>
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<td>0.572</td>
<td>112</td>
<td>167.95</td>
<td>16.70</td>
<td>16.445</td>
<td>1.3845</td>
</tr>
</tbody>
</table>

$\beta_{0} = 1$  $\beta_{1} = 25$, $\beta_{2} = 2600$,  $\beta_{3} = 119000$

$\log \beta_{1} = 1.40$, $\log \beta_{2} = 3.42$, $\log \beta_{3} = 5.08$
TABLE 2

In$^{III}$ - Nicotinate Binary System : Polarographic Characteristics and $F_1(X)$ Functions

$[\text{In}^{III}] = 1.0\ \text{mM}, \ [i] = 1.0\ \text{M (KCl)},$

$\text{pH} = 4.5 \pm 0.02, \ \text{Temp.} \ 26 \pm 1^\circ\text{C}.$

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Ligand concentration (mole)</th>
<th>$E_1'(v)$ vs $S.C.E.$</th>
<th>id (div)</th>
<th>$F_0(X) \times 10^{-1}$</th>
<th>$F_1(x) \times 10^{-1}$</th>
<th>$F_2(x) \times 10^{-2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.53</td>
<td>122</td>
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<td>-</td>
<td>-</td>
</tr>
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<td>0.546</td>
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<td>6.5785 29.39</td>
<td>36.96</td>
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</tr>
<tr>
<td>3</td>
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<td>0.550</td>
<td>115</td>
<td>11.6966 26.74</td>
<td>11.85</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.06</td>
<td>0.552</td>
<td>108</td>
<td>15.8307 24.72</td>
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<td>0.08</td>
<td>0.558</td>
<td>101</td>
<td>34.7856 42.23</td>
<td>25.29</td>
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<tr>
<td>6</td>
<td>0.10</td>
<td>0.562</td>
<td>94</td>
<td>60.0000 59.00</td>
<td>37.00</td>
<td></td>
</tr>
</tbody>
</table>

$P_0 = 1, \ P_{01} = 220, \ P_{02} = 2300$

$log P_1 = 2.34, \ log P_2 = 3.36$
TABLE 3

**In**<sup>III</sup> - Glycinate Binary System: Polarographic Characteristics and Fi(x) Functions

In<sup>III</sup> = 1.0 mM, I = 1.0 M (KCl).

pH = 4.5 ± 0.02, Temp. = 28 ± 1°C.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Ligand concentration (mole)</th>
<th>E&lt;sub&gt;1/2&lt;/sub&gt;(V) vs S&lt;sub&gt;2&lt;/sub&gt;C&lt;sub&gt;2&lt;/sub&gt;E&lt;sub&gt;2&lt;/sub&gt; (div)</th>
<th>Fi(x) x 10&lt;sup&gt;-2&lt;/sup&gt;</th>
<th>F&lt;sub&gt;10&lt;/sub&gt;(x) x 10&lt;sup&gt;-3&lt;/sup&gt;</th>
<th>F&lt;sub&gt;20&lt;/sub&gt;(x) x 10&lt;sup&gt;-4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.53</td>
<td>122</td>
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<td>-</td>
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<tr>
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<td>0.580</td>
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<td>6.98</td>
<td>11.62</td>
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<td>111</td>
<td>11.59</td>
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<tr>
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<td>0.590</td>
<td>108</td>
<td>15.14</td>
<td>15.13</td>
</tr>
</tbody>
</table>

F<sub>0</sub> = 1, F<sub>1</sub> = 9000, F<sub>2</sub> = 65000.

log F<sub>1</sub> = 3.95, log F<sub>2</sub> = 4.81.
**TABLE 4**

**InIII - Glycinate - Urea Ternary System: Polarographic Characteristics and Fij (xy) Functions**

In\textsuperscript{III} = 1 mm, \( \mu = 1.0 \) M (KCl)

\( \text{pH} = 4.5 \pm 0.02 \), Urea = 0.1 M (fixed),

Temp. = 30 \( \pm \) 1°C.

<table>
<thead>
<tr>
<th>S. NO.</th>
<th>Ligand concentration (mole)</th>
<th>(-E_2^0(V)) vs S\textsubscript{C}C\textsubscript{2}E\textsubscript{2}</th>
<th>id (div)</th>
<th>( F_{00}^{(xy)} \times 10^{-3} )</th>
<th>( F_{10}^{(xy)} \times 10^{-5} )</th>
<th>( F_{20}^{(xy)} \times 10^{-6} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.53</td>
<td>122</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
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<tr>
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<td>0.625</td>
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<td>105.91</td>
<td>12.74</td>
<td>10.93</td>
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<tr>
<td>6</td>
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<td>0.627</td>
<td>100</td>
<td>138.68</td>
<td>13.47</td>
<td>9.47</td>
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</table>

A = 4000, B = 4000000, C = 10,0000000
**TABLE 5**

**In**$^{III}$ - Glycinate - Urea Ternary System

In$^{III} = 1$ mm, $\mu = 1.0$ M (KCl), pH = 4.5 ± 0.02

Urea = 0.2 M (fixed), Temp. 30 ± 1°C.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Ligand conc. (mole)</th>
<th>$E'_{1/2}$ (V) vs. S.C.E.</th>
<th>id (div)</th>
<th>$F_{co}$ (xy) x $10^{-3}$</th>
<th>$F_{10}$ (xy) x $10^{-5}$</th>
<th>$F_{20}$ (xy) x $10^{-6}$</th>
<th>$F_{30}$ (xy) x $10^{-7}$</th>
</tr>
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<tbody>
<tr>
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<td>122</td>
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<td>-</td>
<td>-</td>
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<tr>
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<td>21.97</td>
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<td>0.634</td>
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<td>98</td>
<td>597.33</td>
<td>58.73</td>
<td>38.73</td>
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</table>

$A = 100000$, $B = 2000000$, $C = 6000000$, $D = 20 \times 10^{7}$
### Table 6

**In III - Glycinate - Nicotinate Ternary System & Polarographic System and $f_{ij} (xy)$ Functions**

In$\text{III} = 1.0$ mM, $\text{pH} = 4.5 \pm 0.02$

$\mu = 1.0$ M (HCl), Nicotinate = $0.1$ M (fixed) $R_o T_o = 31 \pm 0.5^\circ C$

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Glycinate concentration (mole)</th>
<th>$E_2 (V)$ vs S.C.E.</th>
<th>$I_d$ (div)</th>
<th>$F_{\infty} (xy) \times 10^{-3}$</th>
<th>$F_{10} (xy) \times 10^{-5}$</th>
<th>$F_{20} (xy) \times 10^{-6}$</th>
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</thead>
<tbody>
<tr>
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<td>110</td>
<td>16.39</td>
<td>3.60</td>
<td>-</td>
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<td>3.98</td>
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</table>

*A = 2000, B = 300000, C = 3700000*.
### TABLE 7

**In III - Glycinate - Nicotinate Ternary System**

\[ \text{In}^{III} = 1.0 \text{mM} \quad \text{pH} = 4.15 \pm 0.02 \quad \mu = 1.0 \text{M (KCl)} \quad \text{R.T.} = 31 \pm 0.5^\circ \text{C} \]

Nicotinate 0.2 M (Fixed)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Glycinate Conc. (mole)</th>
<th>(-E_2^\circ) (V) vs S.C.E</th>
<th>Id (Div)</th>
<th>(F_{00}(xy)) (x 10^{-3})</th>
<th>(F_{10}(xy)) (x 10^{-5})</th>
<th>(F_{20}(xy)) (x 10^{-5})</th>
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</thead>
<tbody>
<tr>
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<td>0.00</td>
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<td>-</td>
<td>-</td>
</tr>
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<td>14.78</td>
</tr>
</tbody>
</table>

\[ A' = 4000, \quad B' = 8.000000, \quad C' = 137 \times 10^6 \]
by straight lines observed by plotting $d$ vs $\sqrt{h_{corr}}$ (height of mercury column), passing through the origin, in each case.

The following two ternary systems have been studied:

i. In(II) - glycinate - urea system, and

ii. In(III) - glycinate - nicotinate system.

For the polarographic study on the above ternary complexation it is necessary to study the binary systems involving In(III) and each of glycine, nicotinic acid and urea.

1. In(III) - Urea System

For the polarographic study of In(III) urea system Lingane's method was used. The plot of $E_3$ vs log (urea) yielded smooth curve, thereby indicating the formation of successive complexes in solutions. DeFord and Hume's method was therefore applied for the said equilibrium, the results of which have been tabulated (Table - 1). The results indicate formation of 1:1, 1:2 and 1:3. In(III) - urea complexes with formation constants equal to log $\beta_1 = 1.4$, log $\beta_2 = 3.42$ and log $\beta_3 = 5.08$ respectively.
2. **In(III) - Nicotinate System**

The Lingane's treatment\(^6\) of the observed polarographic data yielded smooth curve, revealing the formation of more than one complex in solution. DeFord and Hume's method\(^7\) was therefore applied for the said study. Nicotinate binary system and the polarographic data given in Table - 2 was observed. The results indicate formation of 1:1 and 1:2 In(III) - nicotinate complexes with formation constants log \(\beta_1 = 2.34\) and of log \(\beta_2 = 3.36\) respectively.

3. **In(III) - Glycinate System**

DeFord and Hume's treatment\(^7\) of the observed polarographic data (Table - 3), revealed the formation of 1:1 and 1:2 In(III) - glycinate complexes in solution with formation constants log \(\beta_1 = 3.95\) and log \(\beta_2 = 4.81\) respectively.

**In(III) - Glycinate - Urea Ternary System**

For the study of In(III) glycinate - urea ternary system, separate experimental sets were prepared by keeping the concentration of the weaker ligand i.e., urea fixed at 0.1 mol and 0.2 mol, so that 1:1 and 1:2 In(III) - urea complexes predominantly exists in solutions. A concentration of the stronger ligand i.e., glycinate ion was varied from
0.0 mol to 0.1 mol, keeping all the other experimental conditions alike to those observed in the study of those binary complexes. The polarographic characteristics and $P_{ij}(X,Y)$ functions have been tabulated (Table 4 and 5). The results indicate that on increasing the concentration of glycinate ion the $E_{1/2}$ values are shifted to more electronegative value, as compared to that observed with binary In(III) - urea complex, thereby showing the formation of mixed complexes.

On Schaap and McMaster's treatment of the observed polarographic data it was observed that three mixed complexes $(\text{In(III)}\rightarrow\text{glycine-urea})^{2+}$, $(\text{In(III)}\rightarrow\text{glycine} \rightarrow \text{urea})^{2+}$ and $(\text{In(III)} \rightarrow (\text{glycine})_{2} \rightarrow \text{urea})^{+}$ are formed with formation constants equal to $\log P_{11} = 6.39$, $\log P_{21} = 8.00$ and $\log P_{12} = 7.00$ respectively. The mixing constant $K_m$ and stabilisation constant $K_s$ for the reaction $\frac{1}{2}(\text{In}=\text{(glycinate)}_{2})^{+1} + \frac{1}{2}(\text{In}=\text{(urea)}_{2})^{+3} \rightleftharpoons (\text{In}=\text{(glycinate)}=\text{(urea)})^{+2}$ has been calculated by the relation $K_m = \frac{P_{11}}{\sqrt{P_{20}+P_{02}}}$ and its calculated value is equal to $\log K_m = 2.4782$ and that of $\log K_s (\log K_s = \log K_m - \log^2)$ comes out to be 2.1772.

The positive values of $\log K_m$ and $\log K_s$ is a measure of relative stability of mixed complexes in solution as compared to, indicate that the mixed ligand complex is more stable than the simple binary complex. The tendency of a ligand to add
SCHEME - 1

COMPLEX EQUILIBRIA IN In(III):GLYCINATE-UREA TERNARY SYSTEM.

[In(III)] → [In-(UREA)] → [In-(UREA)₂] → [In-(UREA)]

[In-(GLY)]²⁺ → [In(GLY)(UREA)]⁺² → [In(GLY)(UREA)₂]⁺²

[In(GLY)₂⁻] → [In(GLY)₂⁻(UREA)]⁺²
a complex and to substitute another ligand has been shown in a scheme 1.

**In(III) - Glycinate - Nicotinate Ternary System**

For the study of In(III) - glycinate - nicotinate mixed system, the concentration of stronger ligand (glycinate ion) was varied from 0.0 - 0.1 mol and that of the weaker ligand (nicotinate ion) was kept constant at 0.1 mol. It was observed that the shift in $E_{1/2}$ values was greater to that observed in absence of glycinate ion, indicating the formation of ternary complexes. The experiment was repeated at another concentration of nicotinate ion (0.2 mol) so as to choose predominant 1 and 2 nicotinate ion per In(III) ion respectively. The $F_{ij}$ (XY) functions were calculated following Schaap and McMaster's method. Loden's extrapolation method was used to evaluate the value of constants $A$, $B$ and $C$. The results have been tabulated (Table 6 and 7).

A Schaap and McMaster's treatment of the observed polarographic data revealed the formation of three mixed complex in solution, viz. - (In - (glycinate) - Nicotinate)$^+$, (In - (glycinate) - (nicotinate)$_2$), (In - (glycinate)$_2$(nicotinate) with formation constants $\log \beta_{11} = 6.46$, $\log \beta_{21} = 7.56$ and $\log \beta_{12} = 6.60$ respectively.
SCHEME - 2

COMPLEX EQUILIBRIA IN In(III): GLYCINATE - NICOTINATE TERNARY SYSTEM.

\[
\begin{align*}
\text{In}^{III} & \xrightarrow{3.36} \text{[In-(NICO)]}^{+2} \xrightarrow{1.02} \text{[In-(NICO)\textsubscript{2}]+} \\
\text{[In-(GLY)]}^{+2} & \xrightarrow{6.46} \text{[In(GLY)(NICO)]}^{+} \xrightarrow{4.12} \text{[In(GLY)(NICO)\textsubscript{2}]} \\
\text{[In(GLY)\textsubscript{2}]+} & \xrightarrow{2.75} \text{[In(GLY)\textsubscript{2}(NICO)]} \\
\end{align*}
\]
The mixing constant ($K_m$) and stabilisation constant ($K_s$) for the reaction:

$$\frac{1}{2} \text{(In(glycinate)$_2^+$)} + \text{(In(nicotinate)$_2^+$)} \rightarrow \text{(In(glycinate)(nicotinate))}^+$$

have been calculated as above. Their respective values are $2.3766$ and $2.0756$ indicating the relative stability of mixed complexes in solution as compared to parent binary complexes. The tendency of a ligand to add a complex and to substitute another ligand has been given in a scheme.
REFERENCES


31. D.I. Ryabchikov and I.M. Marov, "Detection and Analysis of Rare Elements", Ed. A.P. Vinogradov and
D.I. Ryabchikov, 1962, p. 744 (Trans. from Russian)


RESEARCH PUBLICATIONS

1. A paper entitled "Spectral studies on Ag(I) - morpholinyl thio-carboxylic acid amide (MTA) complexation and the use of MTA as an amperometric reagent for the trace determination of Ag(I)" has been accepted for publication in the Journal of Indian Chemical Society.

2. A paper entitled "IR and electrochemical studies on Cu(I) - MTA complex" has been communicated for publication in the Indian Journal of Chemistry.