CHAPTER-4
SYNTHESIS, CHARACTERIZATION AND ION EXCHANGE
BEHAVIOUR OF THREE COMPONENT ION EXCHANGER:
TITANIUM (IV) BORATO OXALATE

4.1 INTRODUCTION

Now a days, an ion exchange technology has versatile applications in numerous fields. The ion exchange materials have been the essentials constituents for a number of processes attaining to analysis preconcentration and recovery of a number of precious metals, rare earth chemicals from aqueous as well as non-aqueous system. During the last decades an active research has been undertaken in different laboratories in order to find new selective ion exchangers and absorbents. As a result of the intensive work done, a wide variety of synthetic inorganic compounds exhibiting ion exchange properties were found, specifically, metal hydrous-oxides, hetero poly acids, metal ferro cyanides\textsuperscript{[1-5]}. Some of these compounds due to their high thermal stability, resistance to the oxidization and radiation and good selectivity to certain ions, appear as promising material capable of operating in extreme conditions (high radiation, temperature, pressure, presence of oxidants, organic solvents and high concentration of background electrolyte etc.) in which organic ion exchange resins fail to work efficiently.
Ion exchangers have played a prominent role in water processing and in the chemical industry. Meeting the stringent coolant purity requirement of nuclear industry is solely attributable to ion exchangers. In the last decade, Ion exchangers have been used extensively in the chemical decontamination process for metal ion recovery, regeneration of decontaminants and removal of the formulation chemicals from the coolant [6]. Therefore there is a continuing need to find new inorganic ion exchangers, which are capable of removing toxic substances from an aqueous effluent [7], as they have good stability towards temperature ionizing radiation and oxidizing solutions.

Synthetic inorganic ion exchangers based on tetravalent metals have been objects of considerable study in recent years because of their selectivity and intercalation properties [8-16]. Zirconium based ion exchangers have received attention because of there excellent ion exchange properties and some important chemical applications in the field of ion exchange, ion exchange membrane and solid state electrochemistry.

Various number of heteropolyacid salts based on tin (IV), titanium (IV) and zirconium (IV) etc. have been studied and reported in earlier literature as good ion exchange material exhibiting improved properties over the simple salts of metals [17-20]. Inorganic ion exchangers of the class of TMA salts have been extensively studied in the field of separation science
and catalysis. However attempts have been made to study the transport properties of these materials\textsuperscript{[21-23]}. The mechanism of diffusion and ionic transport in crystalline \( \alpha \)-Zirconium phosphate has been studied in detail\textsuperscript{[24]}. The number of water molecules depends upon the method of preparation, drying condition etc. They possess structural hydroxyl protons, which are responsible for their ion exchange behavior. When these -OH groups are hydrated, the protons can easily move on the surfaces, thus accounting for their conductivities which depend strongly on relative humidity, the surface area and the degree of crystallinity\textsuperscript{[25]}.

A wide range of materials is available for the ion exchange treatment of radioactive liquids. These materials are available in a variety of forms, have widely differing chemical and physical properties and can be naturally occurring.

Ion exchange materials can be categorized according to their suitability for different applications, nuclear grade organic ion exchange resins are normally used when liquids from primary circuits or fuel pools are purified. The type of material to be used is selected based on its ability to remove impurities and ions and to control pH. Nuclear grade ion exchangers
are similar to commercial grade resins but have a tighter specification for particle size and composition. Organic resins are often used for a number of treatment cycles by eluting the absorbed radioisotopes with suitable solutions and then restoring the ion exchanger to its original ionic form before its reuse.

Inorganic materials are commonly used for the treatment of liquid waste streams for which very high chemical cleanliness is not required; for example, inorganic ion exchange media can be used in systems in which contaminated liquid concentration in the liquid to allow its reclassification. Highly selective inorganic materials also make it possible to utilize ion exchange in the event that very high concentrations of competing ions are present. Inorganic ion exchangers are almost entirely used once through basis only.

Even if an inorganic ion exchanger is highly selective for a certain radionuclide, it needs to meet several other requirements to become a product that can be used in industrial scale separation process. Some inorganic ion exchangers can be produced in a granular form, but the granules are often of a low mechanical strength and when in contact with aqueous solutions, they break down and may peptize to produce colloidal particles.
To overcome the problem of poor physical strength of the intrinsic exchanger granules, methods for incorporating inorganic ion exchangers into supporting binder materials, both inorganic and organic, have been developed.

4.2 EXPERIMENTAL SECTION

4.2.1 REAGENTS AND CHEMICALS

Titanium chloride, Sodium Oxalate and Boric acid were obtained from CDII (India) and all other reagents and chemicals were of analytical grade. Standard solutions for the analytical work were prepared by either direct weighing of AR grade reagents or by indirect standardization.

4.2.2 INSTRUMENTATION

pH measurements was performed using an Elico (India) LI-10 model pH meter. FTIR model shimadzu 820 PC, Philips X-ray unit, Duprot 900 and 950 thermal analyser and an electric shaking machine were used for IR studies, X-ray diffraction, thermal analysis and shaking respectively. SEM images were obtained by using a JEOL JSM 840, an electron microscope.

4.2.3 SYNTHESIS OF ION EXCHANGE MATERIALS

The ion exchange material was synthesized by mixing 0.10 M Titanium chloride solution gradually to a mixture of potassium borate and sodium Oxalate solution with continuous stirring in various mixing volume
ratios and is given in Table-4.1. The gelatinous precipitate so obtained was allowed to settle down for 24 hours at room temperature. The supernatant liquid was removed and the precipitate was washed with distilled water and finally filtered under pressure. The product was dried at 40± 1°C in an electric oven. The material was broken down into small granules by placing it DMW. The granules were converted into H⁺ form by treating with 1M HNO₃ solution for 24h. The material was then washed several times with DMW water to remove excess of acid and finally dried at 40±1°C. Six samples are prepared by using above same method.
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Molar Concentration</th>
<th>Mixing Ratio</th>
<th>pH</th>
<th>Appearance of beads after drying at 40°C</th>
<th>I.E.C. Meq/g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ti(M)</td>
<td>BA (M)</td>
<td>OA(M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>1:1:1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>1:2:1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>2:1:2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>2:2:1</td>
<td>1</td>
</tr>
<tr>
<td>5*</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>2:2:3</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>2:3:2</td>
<td>1</td>
</tr>
</tbody>
</table>
4.3 CHARACTERIZATION

4.3.1 DETERMINATION OF ION EXCHANGE CAPACITY

Ion exchanger capacity of the synthesized compound sample was determined by column process\textsuperscript{[26]}. The ion exchanger in H\textsuperscript{+} form was placed in a glass column containing a cotton support. Different salt solutions were used as eluents. 200 ml of each electrolyte was passed through the ion-exchanger column made from 0.5 gram of the exchanger in hydrogen ions form were hydrogen ions eluted from the column were determined titrimetrically. Ion exchange capacity of the material was determined for some mono and bivalent cations.

The ion exchange capacity (IEC) was calculated using the following equation:

\[
\text{IEC} = \frac{V \times M}{W_{\text{dry}}}
\]

Where, IEC is the ion exchange capacity (Meq/g), V the added titrant volume at the equivalent point (ml), M is the Molar concentration of the titrant and W_{\text{dry}} is the dry Mass of the sample (g).
Table 4.2: Ion Exchange Capacity (Meg g$^{-1}$ dry exchangers) of Titanium Borato Oxalate (Sample TiBO-5 for various metal ions).

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Cation</th>
<th>Salt Used</th>
<th>I.E.C. (Meg g$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Li$^+$</td>
<td>LiCl</td>
<td>1.10</td>
</tr>
<tr>
<td>2</td>
<td>Na$^+$</td>
<td>NaCl</td>
<td>1.12</td>
</tr>
<tr>
<td>3</td>
<td>K$^+$</td>
<td>KCl</td>
<td>1.16</td>
</tr>
<tr>
<td>4</td>
<td>Mg$^{2+}$</td>
<td>Mg(NO$_3$)$_2$</td>
<td>1.05</td>
</tr>
<tr>
<td>5</td>
<td>Ba$^{2+}$</td>
<td>Ba(NO$_3$)$_2$</td>
<td>1.12</td>
</tr>
<tr>
<td>6</td>
<td>Ca$^{2+}$</td>
<td>Ca(NO$_3$)$_2$</td>
<td>1.14</td>
</tr>
</tbody>
</table>

4.3.2 pH TITRATION

The pH titration of material was performed by the method of Toppe and Pepper. In this method 0.50 gram of exchanger was equilibrated with varying amounts of 0.1M NaCl and NaOH solutions. pH titration curve is shown in figure 4.1.
Figure 4.1:

pH Titration Curve of Titanium Borato Oxalate
4.3.3 **THERMAL STABILITY**

The ion exchanger sample was dried at different temperature from 40°C to 600°C in a muffle furnace. Thermal stability of the material was evaluated by heating it at various temperatures for one hour in a muffle furnace and the Na⁺ ion exchange capacity in meq g⁻¹ dry exchanger was determined.

**Table-4.3: Effect of heating temperature on the ion exchanger capacity of Titanium Borato Oxalate**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Heating Temperature</th>
<th>Color of beads after drying</th>
<th>Ion exchanger Capacity Meq g⁻¹ dry exchanger</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>White</td>
<td>1.10</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>White</td>
<td>0.90</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>Brown</td>
<td>0.80</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>Brown</td>
<td>0.60</td>
</tr>
<tr>
<td>5</td>
<td>400</td>
<td>Brown</td>
<td>0.30</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>Black</td>
<td>0.20</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>Not Stable</td>
<td>0.00</td>
</tr>
</tbody>
</table>
4.3.4 **CHEMICAL COMPOSITION AND STABILITY**

For the determination of chemical composition of the sample TiBO$_5$, 0.1gram of exchanger was dissolved in minimum amount of hot concentrated sulphuric acid. The solution was diluted to 100ml with DMW. The amounts of Titanium and Borate were determined spectrophotometrically using alizarin red-S and pyrogallol as colouring reagents respectively. Oxalate was determined titrametrically using the standard method$^{[29]}$. 

500mg of the sample TiBO-5 was shaken with 50ml of the various solutions at 30$\pm$2$^\circ$C for 8 hours. The amounts of Titanium, Borate and Oxalate released in the solutions were determined spectrophotometrically$^{[29]}$. The material is found to be quite stable in lower concentration of mineral acid, such as HCl, H$_2$SO$_4$ and HNO$_3$. The sample is quite stable in organic acids.

Chemical stability, especially low solubility, is important for the usefulness of inorganic ion exchange materials. Most Zeolites for example, only work over a limited range pH range (4-9), since they are soluble both in acidic and alkaline media. Of the inorganic ion exchange materials developed so far, those based on pure or mixed Zirconium or titanium oxides have been shown to be the most stable. The results are given in Table 4.4.
Table 4.4: Chemical Stability of Titanium Borato Oxalate in different Solvents

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Solution</th>
<th>Ti Released (Mg/50ml)</th>
<th>BA released (Mg/50ml)</th>
<th>OA Released (Mg/50ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H₂O</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>0.1M HClO₄</td>
<td>0.00</td>
<td>0.24</td>
<td>0.38</td>
</tr>
<tr>
<td>3</td>
<td>1.0M HClO₄</td>
<td>0.46</td>
<td>0.79</td>
<td>0.70</td>
</tr>
<tr>
<td>4</td>
<td>0.1M HNO₃</td>
<td>0.00</td>
<td>0.12</td>
<td>0.20</td>
</tr>
<tr>
<td>5</td>
<td>1.0M HNO₃</td>
<td>0.36</td>
<td>0.72</td>
<td>0.26</td>
</tr>
<tr>
<td>6</td>
<td>0.1M HCl</td>
<td>0.00</td>
<td>0.00</td>
<td>0.12</td>
</tr>
<tr>
<td>7</td>
<td>1.0 M HCl</td>
<td>1.26</td>
<td>0.57</td>
<td>0.44</td>
</tr>
<tr>
<td>8</td>
<td>1.0M CH₃COOH</td>
<td>0.00</td>
<td>0.20</td>
<td>0.22</td>
</tr>
<tr>
<td>9</td>
<td>0.1M NaOH</td>
<td>0.91</td>
<td>1.60</td>
<td>1.45</td>
</tr>
<tr>
<td>10</td>
<td>2.0 M NaOH</td>
<td>Completely Dissolved</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3.5 DISTRIBUTION STUDIES

The distribution studies of various metal ions in distilled water and nitric acid were carried out by the batch equilibrium technique. For this purpose, 0.50 gram of the exchanger in H⁺ form was equilibrated with 20.0 ml of 0.1M solutions of different metal ions.

The mixture was shaken for 6 hours to attain equilibrium. The amount of metal ions left in the solutions was then determined by titrating against 0.01M EDTA solution using appropriate indicators.

The Kₐ values, were calculated using the following equation

\[ K_d = \frac{(I - F)\nu}{F \times M} \text{ ml/g} \]

where, I and F denote the volume of EDTA solution required before and after equilibrium respectively, V is the solution volume in ml and M is the mass of the exchanger in gram.

4.3.6 X-RAY STUDY

X-ray studies were carried out using a Philips pw-1730 high angle diffractometer (Poland) Cu-Kα (Ni Filter) radiation and it was found that material shows amorphous nature. The graph of x-ray is given in 4.2.
4.3.7 **FTIR SPECTRUM**

FTIR spectrum of sample TiBO-5 was obtained by KBr disc method. FTIR spectrum of the prepared sample was obtained by using a FTIR model shimadzu 820 PC. FTIR Spectrum is shown in figure 4.3.

4.3.8 **SCANNING ELECTRON MICROGRAPHS-(SEM)**

Surface morphology of the dried exchanger was investigated using SEM. Figure-4.4 shows the scanning electron micrographs of the exchanger.
Figure 4.2:

F.T.I.R Spectrum of Titanium Borato Oxalate
Figure – 4.3

XRD of Ti (IV) Borato Oxalate
Figure 4.4

SEM images of a sample of Titanium Borato Oxalate
4.4 RESULTS AND DISCUSSION

The results from the study of the ion exchange capacity of various samples of Titanium Borato Oxalate are presented in Table 4.2. The improvement in the ion exchange capacity and chemical stability seem to be much higher for sample TiBO-5 and therefore this sample was selected for detailed studies.

The ion exchange capacities for mono- and bivalent metal ions are shown in Table 4.2 these results indicate that ion exchange selectivity of the material is different for different cations. The ion exchange capacities in meq g\(^{-1}\) dry exchanger for various metal ions follow the order:

\[
\text{Co}^+ > \text{Ba}^+ > \text{Mg}^+ > \text{K}^+ > \text{Na}^+ > \text{Li}^+ .
\]

The pH titration curve [figure 4.1] of TiBO-5 performed in NaCl-NaOH system shows one inflexion point indicating that the exchanger is monofunctional.

In order to examine the effect of heating temperature on the ion exchange capacity. The material was heated at 40, 100, 200, 300, 400, 500 and 600\(^{\circ}\)C and ion exchange capacity for Na\(^+\) ion was found to be 1.30, 1.05, 0.90, 0.70, 0.30, 0.20 and ~0 meq g\(^{-1}\) dry exchanger, respectively. The results are summarized in Table 4.3.
These observations reveal that IEC decreases with increasing temperature. Varshney et al.\textsuperscript{[30]} reported similar results while studying the Zirconium (IV) alumino phosphate. The material was found to be fairly stable in lower concentration of mineral acids such as HCl, H\textsubscript{2}SO\textsubscript{4}, HNO\textsubscript{3} and acetic acid. The ion exchanger completely dissolved in 2M H\textsubscript{2}SO\textsubscript{4} and 2M NaOH solution. The results are shown in Table 4.4.

The chemical composition data of material suggests the molar ratio of TiO\textsubscript{2}, H\textsubscript{3}BO\textsubscript{3} and C\textsubscript{2}O\textsubscript{4} as 2:1:3 which may point to the following tentative formula.

$$[(\text{TiO}_2)_2 (\text{H}_3\text{BO}_3) (\text{C}_2\text{O}_4)_3 \cdot n\text{H}_2\text{O}]$$

On the basis of thermal stability measurements if we assume the weight due to presence of water molecules in the gel in 90% of the total weight. The number of such molecules per mole of the exchanger can be determined on the basis of Albert's equation\textsuperscript{[31]}.

$$18n = \frac{x(M + 18n)}{100}$$

where $x$ is the present water content and $(M+18n)$, the molecular weight of the material.

**CALCULATION FOR $n$**

Molecular weight of $(\text{TiO}_2) (\text{BO}_3) (\text{C}_2\text{O}_4)_3$

$\Rightarrow (\text{TiO}_2) = (47.9+15.99)_2 = 127.78$
\((\text{H}_3\text{BO}_3) = (126.90+15.99\times3) = 174.07\)

\((\text{C}_2\text{O}_4)_3 = (12.0 \times 2 + 15.99 \times 4) = 263.88\)

Molecular weight of the material

\[= 127.78 + 61.5 + 263.88\]

\[= 453.16\]

\[\frac{\text{18n} = \frac{x(m+18n)}{100}}{1800n = x (m+18n)}\]

\[1800n = 9.2 \times 453.17 + 18n \times 9.2\]

\[1800n = 4169.072 + 165.6n\]

\[1634.4 \times n = 4169.072\]

\[n = \frac{4169.072}{1634.4} = 2.55\]

The FTIR of Titanium Borato Oxalate shows broad bands in the 3180 cm\(^{-1}\) region characteristic of asymmetric and symmetric hydroxo-OH and aqua-OH stretching frequency. A sharp medium band at 1680 cm\(^{-1}\) is attributed to the aqua (H-OH) bending. The spectrum also shows weak band in the region 1000-500 cm\(^{-1}\) indicating the presence of borate and metal oxide. The FTIR spectrum is shown in figure 4.2.
Absence of sharp peaks in the X-ray diffraction pattern of Titanium (IV) Borato Oxalate indicates that the material is amorphous in nature. Graph of X-ray diffraction is shown in figure 4.3.

Surface morphology of the dried exchanger was investigated using SEM. It is shown in figure 4.4. This figure shows the scanning electron micrographs of 10% TiBO. The distribution of inorganic particles is relatively uniform in the organic matrix. Exchanger is compact with low degree of prosily. In this figure no phase separation was observed, suggesting that the synthesized exchanger was homogeneous in nature.

In order to explore the potential of this cation exchange material in the separation of metal ions, distribution studies for 10 metal ions were performed. The presence of other electrolytes in metal ion solution strongly affects the $K_d$ value of the metal ion. $K_d$ values change depending on the ionic strength and pH of the electrolyte. The degree of ionization of the ionic groups of the exchanger depends on the acid or base strength of the groups i.e. on their $K_d$ value of the groups, the acid groups become predominantly nonionic, and the apartment capacity, and hence the $K_d$ values thus fall off based on such a study a proper electrolyte can be selected for the elution of a particular metal ion from the column of the exchanger when a metal ion pair is to be separated using a column of the exchanger, the $K_d$ value of particular
metal ion in a particular further gives us a guideline to separate out distribution coefficient ($K_d$) calculated for several metal ions in aqueous and various electrolyte media. The distribution studies showed that the material was found to possess exceptional high $K_d$ values for Pb(II). Pb(II) has been considered as a major polluting material in water.

The Table 4.5 reveals that all the metal ions except Ca$^{2+}$, Al$^{3+}$, Ba$^{2+}$ exhibit exceptionally higher $K_d$ values in 0.02M CH$_3$COOH media than in distilled water. Similar observations have been made by others\textsuperscript{[32]}

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Metal ions</th>
<th>DMW 0.01M HNO$_3$</th>
<th>0.1M HNO$_3$</th>
<th>1M HNO$_3$</th>
<th>0.01M HCl</th>
<th>0.1M HCl</th>
<th>1M HCl</th>
<th>0.2M CH$_3$COOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al$^{3+}$</td>
<td>9300</td>
<td>4600</td>
<td>3300</td>
<td>2250</td>
<td>3200</td>
<td>1820</td>
<td>1600</td>
</tr>
<tr>
<td>2</td>
<td>Ba$^{2+}$</td>
<td>3016</td>
<td>1100</td>
<td>932</td>
<td>750</td>
<td>1740</td>
<td>1220</td>
<td>700</td>
</tr>
<tr>
<td>3</td>
<td>Ca$^{2+}$</td>
<td>1755</td>
<td>1200</td>
<td>660</td>
<td>640</td>
<td>1050</td>
<td>510</td>
<td>450</td>
</tr>
<tr>
<td>4</td>
<td>Cu$^{2+}$</td>
<td>695</td>
<td>3800</td>
<td>1540</td>
<td>1050</td>
<td>2100</td>
<td>880</td>
<td>810</td>
</tr>
<tr>
<td>5</td>
<td>Co$^{2+}$</td>
<td>3700</td>
<td>1650</td>
<td>880</td>
<td>800</td>
<td>1210</td>
<td>820</td>
<td>790</td>
</tr>
<tr>
<td>6</td>
<td>Cd$^{2+}$</td>
<td>450</td>
<td>1224</td>
<td>904</td>
<td>750</td>
<td>1350</td>
<td>1000</td>
<td>900</td>
</tr>
<tr>
<td>7</td>
<td>Ni$^+$</td>
<td>420</td>
<td>2800</td>
<td>1604</td>
<td>1066</td>
<td>2033</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Mg$^{2+}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-----------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1600</td>
<td>1332</td>
<td>900</td>
<td>750</td>
<td>1500</td>
<td>840</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Pb$^{2+}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8600</td>
<td>8700</td>
<td>7200</td>
<td>1150</td>
<td>7700</td>
<td>200</td>
<td>1250</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sr$^{2+}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2150</td>
<td>1050</td>
<td>830</td>
<td>520</td>
<td>1220</td>
<td>800</td>
<td>620</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Zn$^{2+}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>132</td>
<td>1010</td>
<td>630</td>
<td>400</td>
<td>1120</td>
<td>630</td>
<td>460</td>
<td>1020</td>
</tr>
</tbody>
</table>
CHAPTER-4

References:


*****