CHAPTER 2

STUDIES OF A NEW INORGANIC ION EXCHANGER: ZIRCONIUM (IV) CHLOROTUNGSTATE

2.1 INTRODUCTION

Ion exchange materials have been found widespread application in analytical chemistry and industrial chemistry in view of their unique characteristic. Due to their selectivity, they can be used in various fields such as biological analysis, water treatment, and more. Inorganic ion exchangers are synthetic cation exchangers, made from metal salts and other inorganic compounds.

A good example of Zirconium(IV)-based heteropolyacid salts is Zirconium(IV) ruthenate aluminate, Zirconium(IV) Ethyl diphenylphosphinate, Zirconium(IV) Vanadyl phosphate, Zirconium(IV) Silicophosphate, Zirconium(IV) Wolframophosphate, and others.
CHAPTER-2
STUDIES OF A NEW INORGANIC ION EXCHANGER:
ZIRCONIUM (IV) CHLORO TUNGSTATE

2.1 INTRODUCTION

Ion exchange materials have been found extensive application in analytical chemistry and industrial chemistry in view of their elegant characteristics such as insoluble matrix, stiochiometric coefficient, good ion selectivity and applicability to column operations. They play a vital role in the treatment of environmental pollutants. Amongst the most important inorganic ion exchangers are synthetic clay minerals, hetero poly acid salts, hexacyanoferrates, Zeolite, hydrous oxides and tetravalent metal acid salts.

A good number of Zirconium(IV) based heteropolyacid salts i.e. Zirconium(IV) phospho silicate\textsuperscript{[11]}, Zirconium(IV) Phenyl diphosphananate phosphate\textsuperscript{[12]}, Zirconium(IV) Vanado phosphate\textsuperscript{[13]}, Zirconium(IV) Succino Phosphate\textsuperscript{[14]}, Zirconium(IV) Borato phosphate\textsuperscript{[3-4]}, Zirconium(IV) Molybdo phosphate\textsuperscript{[5-6]}, Zirconium(IV) Molybdo arsenate\textsuperscript{[9]}, Zirconium Phospho antimonite\textsuperscript{[10-11]}, Zirconium(IV) Siliconmolybdate\textsuperscript{[12]}, Zirconium(IV) arseno vandate\textsuperscript{[13]}, Zirconium(IV) tungsto phenolate\textsuperscript{[14]}, Zirconium(IV) tungsto
phosphate\textsuperscript{[15]}, have been studied for their synthesis, ion exchanger behavior and application etc.

Now a days, ion exchange materials have been the essential constituents for a number of processes pertaining to analysis, preconcentration and recovery of a number of ionic species and separation of metal ions\textsuperscript{[16–18]}. These materials have also been employed in the preparation of various types of ion exchange membranes\textsuperscript{[19]}, chemical sensors\textsuperscript{[20]} and ion selective cation exchanger\textsuperscript{[21]}. Inorganic ion exchangers have also been played an important role in chromatographic radionuclide generators\textsuperscript{[22]}. Numerous crystalline and amorphous Zirconium phosphates have been synthesized and studied as selective sorbents for thorium, uranium, transuranium elements, rare earths, radio cesium and heavy metal cations from different solutions\textsuperscript{[23–26]}.

A wide range of materials is available for the ion exchange treatment of liquid radioactive waste. These materials are available in a variety of forms and have widely differing in chemical and physical properties. Ion exchange is used for processing liquid effluents in nearly all phases of the nuclear fuel cycle, including the early stages of uranium for treatments, the chemical control of primary circuit coolants during nuclear power plant
operations and polishing water effluents and spent fueled reprocessing plants. This method is one of the most widely used both in the nuclear industry and the conventional chemical industry for the purification, separation and partitioning of particular non-radioactive and radioactive species with different chemical properties, organic and inorganic naturally occurring and synthetic ion exchangers have found their specific fields of application in different purification and liquid waste treatment processes.

In many cases ion exchange is the most appropriate and the most efficient method for the treatment of a variety of low and intermediate level liquid waste streams. With respect to economy and efficiency, ion exchange stands between the other two major liquid waste treatment processes of evaporation and chemical precipitation. While evaporation may yield higher decontamination factors, it is also more costly than ion exchange. The development of new ion exchangers is narrowing the gap in decontamination factors between evaporation and ion exchange. Chemical precipitation, however, is often less expensive but is not effective in removing radionuclide's from solution. A large number of natural and synthetic inorganic and organic ion exchangers has been developed and is in use today. In spite of their advanced stage of development, various aspects and components of ion exchange technologies have been continuously studied to
improve the efficiency and economy of their application in radioactive waste management\(^{27-30}\). Efforts to develop new ion exchangers for specific applications are novel composites using combinations of existing and new exchangers are also being investigated.

2.2 EXPERIMENTAL SECTION

2.2.1 CHEMICALS AND REAGENTS

Zirconium (IV) oxy chloride (CDH India), Potassium Chlorate (Qualigens India) and Sodium tungstate (CDH India) were used for the synthesis. All other reagents used were of analytical reagent (AR) grade. Standard solutions for the analytical work were prepared either by direct weighing of AR grade reagents or by indirect standardization.

2.2.2 INSTRUMENTATION

A digital pH meter (Century CP 901), I.R. Spectrophotometer (Shimadzu I.R. 435), digital spectrophotometer (GS 5700), X-ray (PWI 130 phillips), Unit Thermo gravimetric analysis (Duport 9900 with 951 module), DTA (Stanton red craft STA with 781 module) and temperature controlled shaker and muffle furnace have been used during these studies.
2.2.3 SYNTHESIS OF ZIRCONIUM(IV) CHLORO TUNGSTATE

Five samples of the exchanger were prepared by adding Zirconium(IV) oxy chloride (0.1 M) solution to a continuously stirred of Sodium tungstate (0.1 M) and Potassium Chlorate (0.1 M) at 60°C, in the volume ratio 2:1:1 under the condition given in Table 2.1. The gelatinous precipitates obtained were digested for 1 hour at 70°C and then filtered and washed with ultra pure water until the all chloride ions had been removed, followed by drying at room temperature. The material was then broken down to the desired particle size [25-26] mesh 30 (ASTM) by grinding and sieving. The material was converted to the acid form by treating the 5 gram material with 40–50 ml of 1.0 Molar Nitric acid for 30 minutes with occasional shaking. The sample was then separated from acid by decantation and treated with DMW to remove adhering acid. This process was repeated at least five times. After the final washing the material was dried at room temperature. The result is summarized in table 2.1.
### Table 2.1: Condition of Synthesis and Properties of Ion Exchanger

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Molar Ratio (M)</th>
<th>Mixing Ratio</th>
<th>pH</th>
<th>Appearance of beads after drying</th>
<th>Ion Exchange Capacity (Meq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zirconyl Oxy Chloride</td>
<td>Potassium Chlorate</td>
<td>Sodium Tungstate</td>
<td>1:1:1</td>
<td>1</td>
</tr>
<tr>
<td>S-1</td>
<td>0.1M</td>
<td>0.1M</td>
<td>0.1M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-2</td>
<td>0.1M</td>
<td>0.1M</td>
<td>0.1M</td>
<td>1:2:1</td>
<td>1</td>
</tr>
<tr>
<td>S-3</td>
<td>0.1M</td>
<td>0.1M</td>
<td>0.1M</td>
<td>2:2:1</td>
<td>1</td>
</tr>
<tr>
<td>*S-4</td>
<td>0.1M</td>
<td>0.1M</td>
<td>0.1M</td>
<td>2:2:3</td>
<td>1</td>
</tr>
<tr>
<td>S-5</td>
<td>0.1M</td>
<td>0.1M</td>
<td>0.1M</td>
<td>3:1:1</td>
<td>1</td>
</tr>
</tbody>
</table>

### 2.3 CHARACTERIZATION

#### 2.3.1 ION EXCHANGE CAPACITY (IEC)

0.5 gram of the synthesized exchanger in H⁺ form was taken into a column with a glass wool support. One (1M) molar solution of mono-valent metal salts, 0.5M of bivalent salts was passed through the column and capacity for Na⁺, K⁺, Mg²⁺, Ca²⁺ was determined and results are summarized in Table 2.2.
Table 2.2: Ion Exchange Capacity of Zirconium(IV) Chloro Tungstate
for Mono and Divalent Cations

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Cation</th>
<th>Salt Used</th>
<th>Ion Exchange Capacity (Meq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Na⁺</td>
<td>Sodium Chloride (NaCl)</td>
<td>1.85</td>
</tr>
<tr>
<td>2.</td>
<td>K⁺</td>
<td>Potassium Chloride (KCl)</td>
<td>1.95</td>
</tr>
<tr>
<td>3.</td>
<td>Mg²⁺</td>
<td>Magnesium Chloride (MgCl₂)</td>
<td>2.00</td>
</tr>
<tr>
<td>4.</td>
<td>Ca²⁺</td>
<td>Calcium Chloride (CaCl₂)</td>
<td>1.65</td>
</tr>
<tr>
<td>5.</td>
<td>Sr²⁺</td>
<td>Strontium Chloride (SrCl₂)</td>
<td>1.65</td>
</tr>
<tr>
<td>6.</td>
<td>Ba²⁺</td>
<td>Barium Chloride (BaCl₂)</td>
<td>1.50</td>
</tr>
<tr>
<td>7.</td>
<td>Cd²⁺</td>
<td>Cadmium Chloride (CdCl₂)</td>
<td>1.35</td>
</tr>
</tbody>
</table>

2.3.2 *pH TITRATION*

pH titration of synthesized inorganic ion exchanger were performed by Toppe and Pepper[27] method for NaCl–NaOH systems only. pH titration curve is shown in figure. 2.1

2.3.3 *CHEMICAL COMPOSITION*

To determine the chemical composition of Zirconium (IV) Chloro tungstate, 0.2 gram of well powdered sample was dissolved in a mixture of 8M sulphuric acid. Out of this solution, Zirconium (IV)[28] tungstate and Chloride after reduction, were determined gravimetrically as Zirconium oxide, Sodium tungstate and potassium chloride.
Figure – 2.1

pH titration curve of Zr (IV) Chloro tungstate

meq of NaOH added/g of exchanger
2.3.4 **CHEMICAL STABILITY**

Chemical dissolution of synthesized ion exchanger in different solvents was determined spectrophotometrically\(^{29}\). The results are summarized in table 2.3.

**Table 2.3: Chemical Dissolution of Zirconium (IV) Chlorotungstate**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Solution</th>
<th>(Zr)</th>
<th>(Cl)</th>
<th>(W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DMW</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>1.0M HNO(_3)</td>
<td>0.28</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>3</td>
<td>2.0M HNO(_3)</td>
<td>0.65</td>
<td>0.30</td>
<td>0.23</td>
</tr>
<tr>
<td>4</td>
<td>4.0M HNO(_3)</td>
<td>0.66</td>
<td>0.36</td>
<td>0.32</td>
</tr>
<tr>
<td>5</td>
<td>1.0M H(_2)SO(_4)</td>
<td>0.65</td>
<td>0.43</td>
<td>0.29</td>
</tr>
<tr>
<td>6</td>
<td>1.0M HCl</td>
<td>0.00</td>
<td>0.09</td>
<td>0.16</td>
</tr>
<tr>
<td>7</td>
<td>2.0M HCl</td>
<td>0.90</td>
<td>0.65</td>
<td>0.75</td>
</tr>
<tr>
<td>8</td>
<td>1.0M HClO(_4)</td>
<td>0.00</td>
<td>0.27</td>
<td>0.35</td>
</tr>
<tr>
<td>9</td>
<td>0.1M NaOH</td>
<td>1.18</td>
<td>0.90</td>
<td>1.23</td>
</tr>
<tr>
<td>10</td>
<td>1.0M NaOH</td>
<td>2.5</td>
<td>4.5</td>
<td>1.65</td>
</tr>
<tr>
<td>11</td>
<td>2.0M NaOH</td>
<td>Partially Hydrolyzed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.1M NH(_4)NO(_3)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.10</td>
</tr>
<tr>
<td>13</td>
<td>4.0M NaOH</td>
<td>Completely Dissolve</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.3.5 **THERMOGRAVIMETRIC ANALYSIS (TGA)**

Thermogravimetric Analysis of Zirconium (IV) Chloro tungstate in H⁺ form was carried out at the rate of 10°C/min. Loss in ion exchange capacity and loss in water percentage for sodium ions as a function of temperature were determined for the compound. The results are summarized in figure 2.2 and table 2.4.

**Table 2.4 Thermal stability of Zr(IV) Chloro tungstate after heating to various temperature.**

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>% Wt. loss</th>
<th>IEC meq/g</th>
<th>Color of Beads after drying</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>5.2</td>
<td>1.24</td>
<td>White</td>
</tr>
<tr>
<td>90</td>
<td>6.8</td>
<td>1.18</td>
<td>White</td>
</tr>
<tr>
<td>110</td>
<td>9.4</td>
<td>1.01</td>
<td>White</td>
</tr>
<tr>
<td>130</td>
<td>12.2</td>
<td>0.94</td>
<td>Dull White</td>
</tr>
<tr>
<td>160</td>
<td>13.9</td>
<td>0.86</td>
<td>Dull White</td>
</tr>
<tr>
<td>200</td>
<td>16.4</td>
<td>0.56</td>
<td>Dull White</td>
</tr>
<tr>
<td>300</td>
<td>18.4</td>
<td>0.43</td>
<td>Brown</td>
</tr>
<tr>
<td>400</td>
<td>20.5</td>
<td>0.28</td>
<td>Black</td>
</tr>
<tr>
<td>500</td>
<td>21.4</td>
<td>0.00</td>
<td>Not Stable</td>
</tr>
</tbody>
</table>

2.3.6 **DIFFERENTIAL THERMAL ANALYSIS**

DTA of the exchanger was carried out at the rate of 10°C/minute. The results are shown in figure 2.3.
Figure - 2.2

TGA Curve of Zirconium (IV) Chloro Tungstate
Figure - 2.3
DTA Curve of Zirconium (IV) Chloro Tungstate

DTA Curve Fig-2.3

Temperature (°C)  RICAKU 8150

(100)  (200)  (300)  (400)  (500)  (600)

(0)  (50)  (100)  (150)

78.8
258.368 mV min/o
101.9
2.3.7 **I.R. STUDIES**

Infra red analysis of the exchanger was recorded by the KBr disc method using a shimadzu I.R. 435 unit. The results are shown in figure 2.4 and Table 2.5:

**Table 2.5: Details of I.R. Spectrum of Zirconium(IV) Chloro tungstate**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Wave Number (cm(^{-1}))</th>
<th>Appearance</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3400</td>
<td>Broad</td>
<td>Hydroxostretching vibrations ([\nu_1(OH)])</td>
</tr>
<tr>
<td>2</td>
<td>2750</td>
<td>Sharp</td>
<td>Deformation vibrations of coordinated water</td>
</tr>
<tr>
<td>3</td>
<td>1650</td>
<td>Sharp</td>
<td>Deformation vibrations of interstitial water</td>
</tr>
<tr>
<td>4</td>
<td>1300–1500</td>
<td>Sharp</td>
<td>Deformation vibrations of Metal hydroxyl group</td>
</tr>
<tr>
<td>5</td>
<td>800–1100</td>
<td>Medium</td>
<td>Superposition of metal oxygen stretching vibrations</td>
</tr>
</tbody>
</table>
Figure 2.4
I.R. Spectrum of Zirconium (IV) Chlorotungstate
2.3.8 DISTRIBUTION COEFFICIENTS (Kd VALUES)

The distribution studies for Mg$^{2+}$, Ca$^{2+}$, Sr$^{2+}$, Ba$^{2+}$, Zn$^{2+}$, Cd$^{2+}$, Hg$^{2+}$, Pb$^{2+}$, Co$^{2+}$, Ni$^{2+}$, Th$^{4+}$, Zr$^{4+}$, U$^{4+}$ metal ions were carried out by Batch method\textsuperscript{[30]}. 150 mg of the exchanger in H$^+$ form was equilibrated with 40 cm$^3$ metal salts solution having metal ions in a conical flask. That mixture was then shaken for 6h at room temperature. The amount of metal ions left in the solution was then titrated against the standard solutions of EDTA. Distribution coefficient was evaluated by using the expression.

$$K_d = \frac{\text{Amount of Metal ions in exchanger phase (g$^{-1}$)}}{\text{Amount of Metal ions in Solution Phase (Cm$^3$)}}$$

2.3.9 SEPARATION OF METAL IONS

A study of the distribution behavior of metal ions in aqueous as well as in various electrolyte media gives an indication of the possible binary metal separations as well as the elements that could be used for the separation. K$_d$ value suggest the possibilities for many important binary separations. Based on separation factor, binary separation have been carried out for four sets of metal ions: Zn(II)–Cd(II), Pb(II)–Zn(II), Cd(II)–Ni(II) and Pb(II)–Ni(II) for binary separations, the ion exchanger (10 gram of H$^+$ form) was placed in a glass column (30x 1.1 cm). The column was washed
thoroughly with DMW. The metal ion mixture (1 ml containing 0.004M of each metal ion) was loaded on to the column at a flow rate of 10–12 drops/min. The separation was achieved by passing suitable eluents through by passing suitable elements through the column. The separation factor of metal ion can be calculated by using expression.

\[
\text{Separation Factor } \left( \alpha^A_n \right) = \frac{K_d \text{ Value of Metal ion A}}{K_d \text{ Value of Metal ion B}}
\]

2.4 RESULTS AND DISCUSSION:

Samples of Zirconium (IV) chloro tungstate of the various compositions have been synthesized but sample–4 was found to have better ion exchange capacity and better stability and hence it is chosen for the detailed study. Synthesized exchanger is obtained as white granules.

The sample exhibits good ion exchange capacity for \( \text{Na}^+, \text{K}^+, \text{Mg}^{2+}, \text{Ca}^{2+}, \text{Ba}^{2+}, \text{Cd}^{2+} \) and \( \text{Sr}^{2+} \) ions. The results are given in the Table 2.2. These results show that ion exchange selectivity of the material is different for different cations.

The pH titration studies using \( \text{NaCl–NaOH} \) systems show nearly bifunctional behavior indicating two type of ionizable group.
The chemical composition of Zirconium (IV) chloro tungstate was found as \( \text{ZrCl}_2\text{O}_3:\text{W}_2\text{O}_3::2:1:1.4 \) which shows that it is a cation exchanger.

The data's of chemical stability of the synthesized ion exchanger show that it is quite stable one. The material was found to be stable in lower concentration of mineral acids such as HCl, H\(_2\)SO\(_4\), HNO\(_3\), HClO\(_4\). Ion Exchanger completely dissolved in 2.0M NaOH. There is 10.4% loss up to temperature 100°C which may be attributed to the loss of gel water and loss onwards. 100°C to 200°C, 6.5% (approx.) loss may be attributed to the loss of water of crystallization, from 200°C to 500°C the loss of 5% may be attributed to the loss of coordinated water and hydroxyl groups. Thus TGA of Zr–Cl\(_2\)O\(_3\)-W\(_2\)O\(_3\) shows a sharp change within the range 70°C to 500°C, corresponding to the loss of moisture. Thermo gram of Zirconium(IV) Chloro tungstate is shown in figure 2.2. On the basis of thermal stability measurements, the value of no. of molecules of crystallization can be calculated by using Alberti & Torracca equation.

**CALCUALTION OF \( n \)**

\[
(\text{ZrO}_2) = (91.22 + 15.99)_2 = 214.42
\]

\[
(\text{Cl}_2\text{O}_3) = (35.5 \times 2 = 71.0 + 47.97) = 118.97
\]

\[
(\text{W}_2\text{O}_3) = (183.84 + 15.9 \times 3) = 231.81
\]
Molecular weight of the material

\[ = 214.42 + 118.97 \]

\[ = 564.93 \]

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

\[ 18n = \frac{17 \times 564.93 + 18 \times n \times 17}{100} \]

\[ 18n = \frac{9603.81 + 306n}{100} \]

\[ 1494n = \frac{9603.81}{1494} = 6.42 \]

DTA analysis also confirms that the above results are true and has been given in figure 2.3.

IR spectrum of the material is shown in figure 2.4 FTIR spectra of exchanger showed a broadband in the region 3450 cm\(^{-1}\) attributed to symmetric and asymmetric–OH stretching, while the band with sharp peak at 2850 cm\(^{-1}\) attributed to coordinated water molecules and band in the region 1635 cm\(^{-1}\) is attributed to H–O–H bending.
A sharp band in the region 1300–1500 cm\(^{-1}\) is attributed to deformation vibrations of metal hydroxyl group. The analysis of I.R. spectrum of the materials absorption peaks shown in Table 2.5.

The X-ray diffraction pattern of the cation exchanger has been shown in figure 2.5. Absence of sharp peaks in the X-ray diffraction pattern indicates that the material is amorphous in nature.
Figure - 2.5

XRD Curve of Zirconium (IV) Chloro tungstate
Distribution behavior of 13 metal ions in De-mineralizing water, in 0.1M HNO₃ and in 1×10⁻²M HNO₃, has been studied and the value obtained from distribution coefficients is given in Table 2.6. The study of this table reveals that the material shows high preference to Mg²⁺, Ca²⁺, Sr²⁺, Ba²⁺, Pb²⁺, Th⁴⁺ even in DMW while it uptakes Cd²⁺, Hg²⁺, Pb²⁺, Ca²⁺, Th⁴⁺, La³⁺, highly in 1×10⁻² M HNO₃. This means that the nitric acid solution is more suitable for their uptake.

A study of the distribution behavior of metal ions in aqueous as well as in various electrolyte media gives an indication of the possible binary metal separations as well as the eluents that could be used for separation. Kd values suggest the possibilities for many important binary separations. Based on separation factor (α) binary separations have been carried out for four sets of metal ions. The results are summarized in table 2.7.
Table 2.6: Distribution Coefficients of Metal ions on Zirconium(IV)

Chloro Tungstate

<table>
<thead>
<tr>
<th>Metal ions</th>
<th>DMW</th>
<th>0.1M HNO₃</th>
<th>0.01M HNO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg²⁺</td>
<td>2700</td>
<td>140</td>
<td>157</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>2000</td>
<td>152</td>
<td>160</td>
</tr>
<tr>
<td>Sr²⁺</td>
<td>2560</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Ba²⁺</td>
<td>1667</td>
<td>240</td>
<td>300</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>32</td>
<td>160</td>
<td>195</td>
</tr>
<tr>
<td>Cd²⁺</td>
<td>98</td>
<td>2232</td>
<td>2312</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>60</td>
<td>1248</td>
<td>1285</td>
</tr>
<tr>
<td>Pb²⁺</td>
<td>2560</td>
<td>2665</td>
<td>2700</td>
</tr>
<tr>
<td>Co²⁺</td>
<td>88</td>
<td>2540</td>
<td>2590</td>
</tr>
<tr>
<td>Ni²⁺</td>
<td>30</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Th⁴⁺</td>
<td>1000</td>
<td>1000</td>
<td>1009</td>
</tr>
<tr>
<td>Zr⁴⁺</td>
<td>30</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>U⁴⁺</td>
<td>No Sorption</td>
<td>No Sorption</td>
<td>10</td>
</tr>
<tr>
<td>Separations Achieved</td>
<td>$\alpha = \frac{k_{d1}}{k_{d2}}$</td>
<td>Eluent</td>
<td>Metal ion (mg)</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
<td>--------</td>
<td>---------------</td>
</tr>
<tr>
<td>Zn(II)–Cd(II)</td>
<td>11.85</td>
<td>1.00×10⁻³ M HNO₃ for Cd(II) 1.00×10⁻¹ MHNO₃ in 0.5M NH₄OH for Zn(II)</td>
<td>1460 1436</td>
</tr>
<tr>
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<td>880 896</td>
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<tr>
<td>Pb(II)–Zn(II)</td>
<td>13.84</td>
<td>1.00×10⁻³ MHClO₄ for Pb(II) 1.00×10⁻³ MHNO₃ in 0.5M NH₄OH for Zn(II)</td>
<td>1460 1436</td>
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<td>1000 80</td>
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<tr>
<td>Cd(II)–Ni(II)</td>
<td>51.37</td>
<td>1.00×10⁻¹ MHNO₃ in 0.5 MNH₄OH for Ni(II)</td>
<td>1636 1650</td>
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<td>875 850</td>
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<tr>
<td>Pb(II)–Ni(II)</td>
<td>60.00</td>
<td>1.00×10⁻² MHClO₄ for Pb(II) 1.00×10⁻³ MHNO₃</td>
<td>1620 1640</td>
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<td>880 860</td>
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Zirconium(IV) Chlorotungstate exhibits a 79–100% separation efficiency for these metal ion. Through the separation factor is very low for Pb(II)–Zn(II), the separation is nevertheless found to be quite efficient.
CHAPTER 2

References


