Behaviour of radioactive iodide and bromide ions from aqueous solution on ion exchange resins Amberlite IRA-400

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ABSTRACT

The ion exchange resin Amberlite IRA-400 in iodide and bromide form where equilibrated separately with the respective labeled iodide and bromide ion solution of different concentrations varying from 0.005M to 0.100M in the temperature range of 32.0 °C to 48.0 °C. The distribution coefficient $K_d$ values calculated for iodide and bromide ion exchange increases with rise in ionic concentration of the external solution, however with rise in temperature the $K_d$ values calculated where found to decrease. Also the $K_d$ values calculated where higher for iodide exchange than bromide exchange. Among the different alternative techniques available for obtaining the $K_d$ values, the radioactive tracer technique used in the present experimental work offers high detection sensitivity. It is expected that the distribution coefficient data obtained from such experimental work will significant in environmental impact assessment on the disposal of radioactive waste.

Keywords: Ion Exchange Resin; Amberlite IRA-400; Distribution Coefficient; Temperature Effect; Concentration Effect; $^{131}$I, $^{82}$Br; Radioactive Tracer Isotope

1. INTRODUCTION

There are number of liquid processes and waste streams at nuclear power plants, fuel reprocessing plants and nuclear research centers that require treatment for removal of radioactive contaminants. One of the most common treatment methods for such aqueous streams is the use of ion exchange, which is a well developed technique that has been employed for many years in nuclear industries [1,2]. The ion exchange process is very effective at transferring the radioactive content of a large volume of liquid into a small volume of solid. Efforts to develop new ion exchangers for specific applications are continuing. In spite of their advanced stage of development, various aspects of ion exchange technologies have been continuously studied to improve the efficiency and economy of their application in radioactive waste management. The selection of an appropriate ion exchange material for the liquid radioactive waste treatment is possible on the basis of information provided by the manufacturer. However since the selection of the appropriate ion exchange material depends on the needs of the system, it is expected that the data obtained from the actual experimental trials will prove to be more helpful. Generally the selected ion exchange materials must be compatible with the chemical nature of the radioactive liquid waste such type and concentration of ionic species present as well as the operating parameters notably temperature. Also while designing an ion exchange processing system it is desirable to have an adequate knowledge of the distribution coefficient values of the ion exchange resin towards different ions present in radioactive liquid waste. These distribution coefficients are very important parameter for environmental impact assessment on the disposal of radioactive waste arising from research institutes [3].

Although there are different alternative methods available to know the distribution coefficient values, but radioactive isotopic technique is expected to be the most appropriate method as it offer several advantages such as high detection sensitivity, capability of in-situ detection, and physico-chemical compatibility with the material under study [4-8]. Attempts where made by the previous researchers to study the concentration and temperature effect on cation exchange systems for computing the distribution coefficient values [9-15]. However very little work was done to study the distribution coefficient values in anion exchange systems [16]. Therefore, in the present investigation, attempts where made to study the effect of external ionic concentration and temperature on...
distribution coefficient, for which radioactive tracer technique was used.

2. EXPERIMENTAL

Ion exchange resin Amberlite IRA-400 (by Rohm and Haas Company, USA), was a strongly basic anion exchange resin in chloride form. The resins where converted in iodide and bromide form by eluting with 10 % KI and KBr solution in a conditioning column. The 1.000 g \((m)\) of conditioned resins in iodide and bromide form was equilibrated separately with labeled 250 mL \((V)\) of 0.005 M iodide and bromide ion solution respectively under continuous and uniform mechanical stirring. The solution was uniformly stirred using the mechanical stirrer for 3h at a constant temperature of 32.0 °C so as to attain equilibrium.

The ion exchange reaction taking place can be represented as follows:

\[
R-I + I^- (aq.) \rightarrow R-I^- + I (aq.) \quad (1)
\]

\[
R-Br + Br^- (aq.) \rightarrow R-Br^- + Br (aq.) \quad (2)
\]

where \(I^- (aq.)\) and \(Br^- (aq.)\) represent aqueous solution of iodide and bromide labeled with radioactive isotope \(^{131}\)I and \(^{82}\)Br respectively.

The initial activity \((A_i)\) and final activity \((A_f)\) in counts per minutes \((c.p.m.)\) of the labeled solutions was measured on \(\gamma\)-ray spectrometer having Na (I) Tl scintillation detector. From the knowledge of \(A_i\) and \(A_f\), the \(K_d\) value was calculated by the equation

\[
K_d = \left[ \frac{(A_i - A_f)}{A_f} \right] \times \frac{V}{m} \quad (3)
\]

The experimental sets where repeated in the same manner by increasing the ionic concentrations up to 0.100 M and the temperature varying up to 48.0 °C. The \(K_d\) values for different sets where calculated by Eq. 3.

The \(^{82}\)Br isotope used was an aqueous solution of ammonium bromide in dilute ammonium hydroxide having activity 5mCi, \(\gamma\)- energy 0.55 MeV, and \(t_{1/2}\) 36h. The \(^{131}\)I isotope used was an aqueous solution of sodium iodide in dilute sodium sulfite, having activity 5mCi, \(\gamma\)-energy 0.36 MeV, and \(t_{1/2}\) 8.04d [17].

3. RESULTS AND DISCUSSIONS

In the present research work the ion exchange resin in iodide and bromide form where equilibrated for 3h with labeled iodide and bromide ion solution respectively of known initial activity. From the results of previous work [4-8,18-24]; it was observed that this time duration was sufficient to attain equilibrium. Due to ion isotopic exchange reactions taking place the activity of the solution decreases with time. The decrease in activity of the solution was measured after 3h which represent the final activity exchanged on the resin. From the knowledge of initial and final activity, the \(K_d\) values were calculated by Eq. 3 to study the effect of temperature and concentration. Heumann et al. [16] in the study of chloride distribution coefficient on strongly basic anion-exchange resin observed that the selectivity coefficient between halide ions increases at higher electrolyte concentrations. Adachi et al. [9] observed that the swelling pressure of

Table 1. Effect of iodine concentration on distribution coefficients. Temperature = 32.0 °C, amount of resin= 1.000 g, volume of solution = 250 mL.

<table>
<thead>
<tr>
<th>Concentration (M)</th>
<th>Log Kd</th>
<th>Iodide ions</th>
<th>Bromide ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>3.58</td>
<td>3.08</td>
<td></td>
</tr>
<tr>
<td>0.010</td>
<td>3.97</td>
<td>3.23</td>
<td></td>
</tr>
<tr>
<td>0.020</td>
<td>4.25</td>
<td>3.55</td>
<td></td>
</tr>
<tr>
<td>0.100</td>
<td>4.50</td>
<td>3.80</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Effect of temperature on distribution coefficients. Concentration of labeled ionic solution = 0.005M, amount of resin= 1.000 g, volume of solution = 250 mL.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Log Kd</th>
<th>Iodide ions</th>
<th>Bromide ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.0</td>
<td>3.58</td>
<td>3.08</td>
<td></td>
</tr>
<tr>
<td>43.0</td>
<td>3.23</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>48.0</td>
<td>2.99</td>
<td>2.76</td>
<td></td>
</tr>
</tbody>
</table>
the resin decreased at higher solute concentrations resulting in larger distribution coefficient values. The temperature dependence of the distribution coefficient on cation exchange resin was studied by Shuji et al. [11], they observed that the distribution coefficients increased with decreasing temperature. The present experimental results also indicates that the distribution coefficient $K_d$ values calculated for iodide and bromide ions increases with increase in ionic concentration of the external solution (Table 1), however with rise in temperature the $K_d$ values calculated where found to decrease (Table 2). Also the $K_d$ values calculated where higher for iodide ions as compared to that for bromide ions (Tables 1 and 2). The variation of $K_d$ values for iodide and bromide ions with temperature and concentration of external ionic solution is graphically represented in Figure 1.

4. CONCLUSIONS

In heavy metal removal processes the rate of removal is considered to be important factor from the practical aspect of reactor design and process optimization [25]. Earlier research was performed demonstrating the feasibility of using the bioresin in a continuous system for decontaminating pool water of $^{60}$Co [26]. It is important here to note that in all the above decontamination processes, distribution coefficient $K_d$ values plays a very prominent role in deciding about proper selection of resins. The work carried out in the present experiment is a demonstration showing application of radioactive active tracer technique to study the parameters affecting the distribution coefficient. The same technique can be extended further to study the $K_d$ values of different ion exchange resins for various ions in liquid radioactive waste. The data base so obtained on $K_d$ value will serve as a very important parameter for environmental impact assessment on the disposal of radioactive waste [3].

REFERENCES


[19] R. S. Lokhande, P. U. Singare, and M. H. Dole, (2007) Application of radiotracer technique to study the ion iso-


