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COUNTERCURRENT ELUTION OF URANIUM(VI) AND IRON(III) FROM AN ANION-EXCHANGE RESIN

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SUMMARY

A countercurrent elution method for the separation of uranium and iron has been developed. The separation is based on changing the solution composition along the anion-exchange column and on the difference in the stability constants[1] and the ion-exchange distribution coefficients of the sulphate complexes of uranium and iron.

The sulphate complexes of iron(III) are adsorbed on a strongly basic anion-exchange resin together with uranium(VI) complexes from the leach solution obtained in uranium ore processing[2]. By countercurrent elution of the saturated resin, all of the iron passes into the effluent. This impurity results in many difficulties during further treatment of the effluent. An elution process has been developed for the separation of uranium from the iron, using an acidic sodium chloride solution as the eluent.

The countercurrent elution process is performed in a vertical tower in which the saturated resin feed enters at the top and the eluent feed enters at the bottom of the column[3]. The maximum concentration of the sulphate ions is at the inlet of the resin feed and the maximum concentration of the chloride ions is at the inlet of the eluent. Between these two feed points, the sulphate:chloride concentration ratio varies continuously along the column (Fig. 1).

The countercurrent elution of the sulphate complexes of uranium and iron is based on the exchange process between SO_4^{2-}, HSO_4^- and Cl^- ions. The formation of the complexes and their distribution coefficients between the resin and solution phases are determined at every position in the column by the actual concentration of the SO_4^{2-}, HSO_4^- and H^+ ions. The selectivity of these ions is as follows: $Cl^- > [UO_2(SO_4)_2]^{2-} > [UO_2(SO_4)_3]^{4-} > HSO_4^- > [Fe(SO_4)_2]^- > SO_4^{2-}$.

Considering that the exchange of the SO_4^{2-}, HSO_4^- and Cl^- ions is the basic process, the distribution coefficients of the uranium and iron were measured at different concentrations of sulphate and chloride ions. The total salt concentrations of the solutions were 1 mole/l and the sulphate:chloride ratio was varied. The determinations were performed at different concentrations of uranium, iron and hydrogen ions.
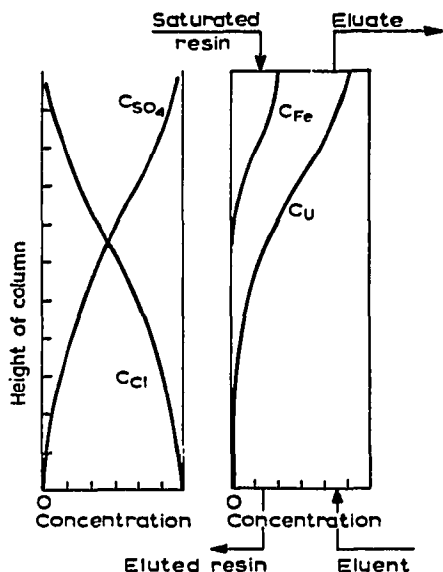
Fig. 1. Countercurrent column and concentration profile along the column.

A typical example is illustrated in Fig. 2. The value of the distribution coefficients (D_U, D_{Fe}) is plotted as a function of solution composition. It can be seen that the sorption of iron decreases rapidly with increasing chloride concentration. At a chloride concentration of 0.15 mole/l, the distribution coefficient of iron becomes less than unity. Alterations in the chloride concentration have only a slight effect on the distribution of uranium if the chloride concentration is less than 0.8 mole/l. The decrease in the distribution coefficient of uranium becomes significant only at the higher Cl^- concentrations. According to the analysis of the resin phase, the $[UO_2(SO_4)_2]^{2-}$ complex is mainly adsorbed. The sulphate:uranium ratio varies between 2 and 2.5.
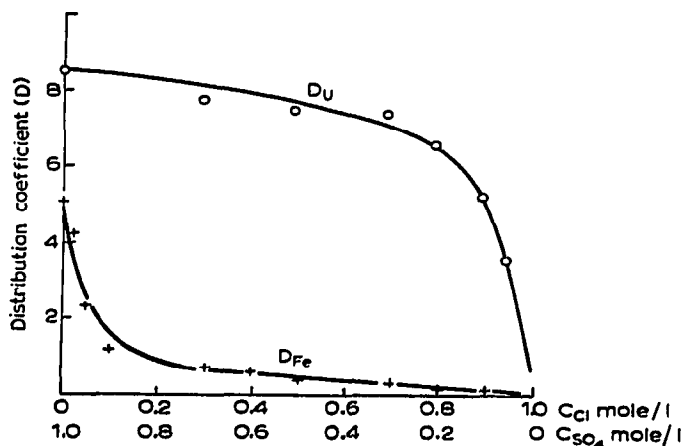

Fig. 2. Effect of the composition of the solution on the distribution coefficients of uranium and iron. $\bigcirc$, D_U (C_U = 0.03 mole/l); +, D_{Fe} (C_{Fe} = 0.03 mole/l).

At low chloride and high sulphate concentrations, the value of D_U does not depend on the iron concentration in the solution. On the other hand, the distribution coefficient of uranium depends strongly on the uranium concentration in these solutions ($D_U = 10\text{--}100$). At high chloride and low sulphate concentrations, the distribution coefficient of uranium is nearly independent of the uranium concentration in the solution.
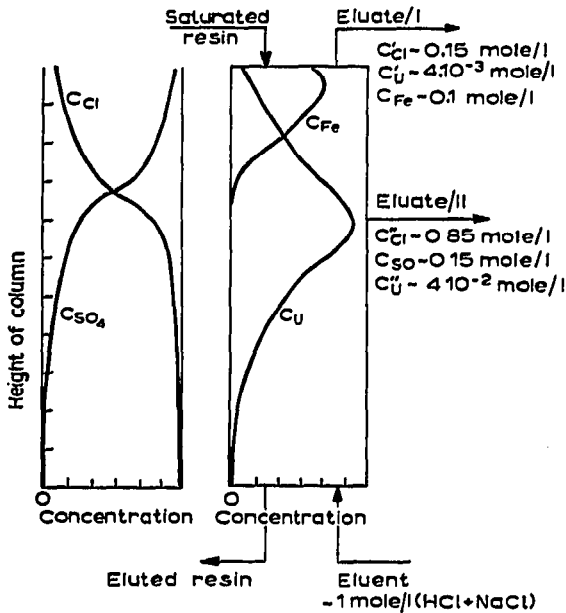

Fig. 3. Fractional column and the concentration profile along the column.

Consequently, if there are two outlets for the effluent on the countercurrent ion-exchange column, the concentration of sulphate and chloride ions can be regulated along the column by changing the flow ratio of the two effluent fractions, so that the chromatographic separation of iron from uranium should be possible. The scheme of this column and the concentration profile in the resin bed are shown in Fig. 3. The chloride and uranium concentrations are low in the "eluate I" solution. On the other hand, the sulphate concentration is low and the chloride and uranium concentrations are high in the "eluate II" fraction. The eluate:resin flow volume ratio is equal to the distribution coefficient of uranium in the range of chloride concentrations in "eluate II":

$$\frac{\text{eluent flow volume}}{\text{resin flow volume}} = \frac{L}{G} = D_U''$$

The flow volume ratio of "eluate I" to resin flow volume is equal to the distribution coefficient of iron at $C_{Cl} = 0.1$ mole/l.

$$\frac{\text{"eluate I" flow volume}}{\text{resin flow volume}} = \frac{L'}{G} = D_{Fe}'$$

The chloride concentration in the eluent (C_{Cl}^0) should be calculated by the following equation:

$$C_{Cl}^0 = \frac{GQ_{eq} + L'C_{Cl}' + L''C_{Cl}''}{L} \text{ mole/l}$$

where Q_{eq} = equivalent capacity of the resin. The elution process should be regulated by changing the flow ratio of the eluent and "eluate II" at constant eluent:resin ratio.

The process has been used succesfully in a pilot plant.

REFERENCES

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