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Ionic and Colloidal Flotation of ^{144}Ce(lll) and ^{147}Pm(lll)

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NOTE

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Abstract

Ionic and colloidal flotation of ^{144}Ce(III) and ^{147}Pm(III) were studied on a laboratory scale from aqueous solutions with anion-active, cation-active, or non-ionic surface-active substances and the dependence on pH, on the concentration of the separated component, and on the surface-inactive electrolyte shown. In addition to separation in one stage, multistage separation was also used in order to achieve higher efficiency.

INTRODUCTION

The principle of the foam separation of substances in ionic and colloidal forms has been described in many papers (*1–7*). Foam separation by surface-active substances has also been used for the isolation of radioactive isotopes from aqueous solutions (*2, 8–15*). In our preceding paper (*8*), we used gelatin and dodecylamine as the surface-active substances for the isolation of ionic and colloidal forms of ^{106}Ru(IV) and ^{106}RuNO(III) from the aqueous phase. In a certain pH range, ^{144}Ce(III) and ^{147}Pm(III) in microconcentrations form a colloid (*16*) and in this work we have studied the flotation of ionic and colloidal forms of both radionuclides from an aqueous solution using an anion-active, a cation-active, and a non-ionic surface-active substance with the aim of determining the conditions for their optimum separation.

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EXPERIMENTAL

Solutions

Solutions of 50 ml and 10^{-8} *M* were used in the most cases. $CeCl_3$ was added as the carrier for $^{144}Ce(III)$, and for $^{147}Pm(III)$, which exists only in the radioactive form, $Nd(NO_3)_3$ was added because Nd as a neighboring element has very similar properties. The ionic strength of the solution was held at a constant value of 0.01 during flotation through the use of sodium nitrate. Colloidal hydroxides of ^{144}Ce and ^{147}Pm were formed by adjusting the pH of the solution to the alkaline region. Among the preliminary tested surface-active substances, the three most efficient ones were selected: cation-active cetyltrimethylammonium bromide (CTAB), anion-active sodium lauryl sulfate (SLS), and non-ionic Slovasol 0100 (ethylene oxide condensate, SS). pH values were adjusted with nitric acid or sodium hydroxide. All chemicals used were of A.R. purity with the exception of the surface-active substances. Carrier-free ^{144}Ce and ^{147}Pm radioisotopes were of Soviet origin (*8*).

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Equipment

Flotation was accomplished in 50 ml of the solution in a 100-ml cylindrical glass vessel narrowed conically to an opening for foam overflow at the top. The bottom part of the vessel was equipped with a fritted glass (mean pore size, 15–40 μ) and a nitrogen inlet. Nitrogen bubbled through during the flotation passed through a potassium hydroxide solution for impurity removal before entering the flotation vessel.

Working Procedure

A surface-active substance was added to 50 ml of the solution containing 10^{-8} *M* $^{144}Ce(III)$ or 10^{-8} *M* Pm(III), the pH was adjusted, and nitrogen was bubbled through the solution. The time of flotation was 1 hr for both radioisotopes and all surface-active substances. After completion of flotation the radioactivity of the solution was determined and the percentage of the separated radioactive component was calculated from this value and from that measured before flotation started.

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RESULTS AND DISCUSSION

A number of factors influencing the flotation has been determined in order to find the optimum efficiency conditions. These conditions were selected in such a way that the losses of the solution caused by foaming did not exceed 5%. For this reason the optimum nitrogen flow-rate was 0.2 liter/min and the concentration of the surface-active substance was 1.5 mg/50 ml for both radioisotopes. The time of flotation was 1 hr in all cases because an additional 3 hr resulted in only a 2% increase of separation with respect to the value obtained after 1 hr, so that increasing the time did not substantially improve separation. The values of separation expressed in percentage for both radioisotopes and for all three surface-active substances (nitrogen flow-rate of 0.2 liter/min, concentration of surface-active substance of 1.5 mg/50 ml, and time of 1 hr) are listed in Table 1. These conditions were also maintained in the next determinations. Table 1 shows that the concentration of the radioactive component was reduced by a maximum of one order. This was valid, however, only with ^{147}Pm(III) in CTAB, when 90.2% flotation was reached.

Figure 1 presents the dependence of the flotation on pH for both radioisotopes and for all surface-active substances. The optimum pH of separation lay between 7.8 and 8.5 for ^{144}Ce and between 6.3 and 8.2 for ^{147}Pm. Cerium(III) hydroxide precipitation started at pH = 7.6 (*17*), and neodymium(III) hydroxide precipitation [^{147}Pm(III)] at 7.0 (*17*).

TABLE 1

Results of ^{144}Ce(III) and ^{147}Pm(III) Flotation

^{144}Ce(III)			^{147}Pm(III)		
Surface-active substance[a]	pH	% of separation	Surface-active substance[a]	pH	% of separation
CTAB[b]	8.5	79.8	CTAB[b]	7.5	90.2
SLS[c]	8.3	75.0	SLS[c]	6.3	70.2
SSr[d]	7.8	83.5	SS[d]	8.2	79.0

[a] Concentration: 1.5 mg/50 ml.

[b] Cetyltrimethylammonium bromide.

[c] Sodium lauryl sulfate.

[d] Slovasol 0100 (ethylene oxide condensate).

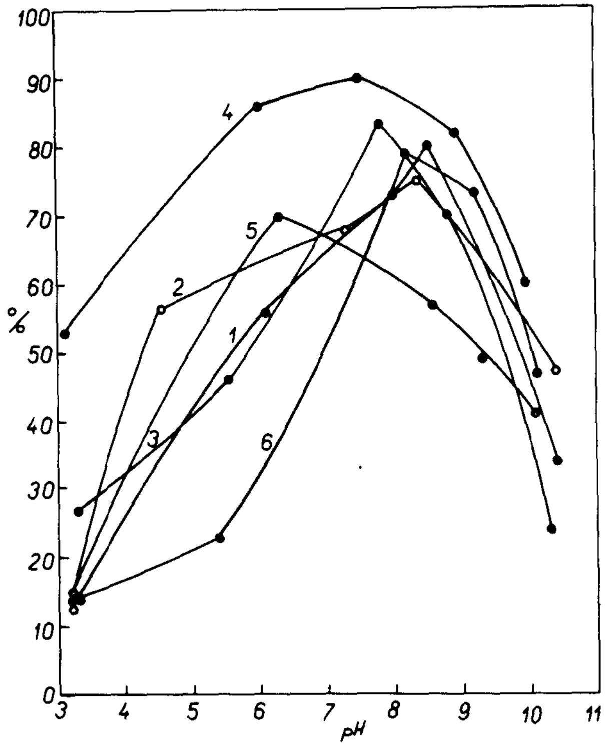

FIG. 1. Dependence of ^{144}Ce(III) and ^{147}Pm(III) flotation on pH. Curves 1 (●), 2 (○), and 3 (⦶) with ^{144}Ce(III), Curves 4 (◒), 5 (◓), and 6 (⊖) with ^{147}Pm(III), Curves 1 and 4 with CTAB, Curves 2 and 5 with SLS, and Curves 3 and 6 with SS.

In the neutral and alkaline region of pH, colloidal hydroxides of both radioelements are formed (*16*) so that the maximum separation of ^{144}Ce(III) and ^{147}Pm(III) lies in the pH range where colloidal Ce(III) and Pm(III) hydroxides are formed. In spite of the fact that different surface-active substances were used, no considerably different dependences on pH were obtained because, with the exception of ^{147}Pm(III) with SS, when the flotation maximum was at pH = 6.3, the maximum of flotation in all cases lay in a moderately alkaline pH range.

The concentration of both separated elements—^{144}Ce(III) and ^{147}Pm(III) [Nd(III)]—considerably affected the efficiency of their separation. This is similar to the case of radioruthenium (*8*) where,

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however, the separation maximum lay at a different concentration of the separated component. As evident from Fig. 2, the percent amount of both radioelements separated decreased with their increased concentrations, and in the region of trace concentrations of both radioelements the separation was also lower than that at the 10^{-8} *M* concentration. This phenomenon may be explained by the fact that the formation of a complex of Ce(III) or Pm(III) at trace concentrations or the electrostatic attraction between the surface-active substance and the radionuclide takes place to a more reduced extent than at the 10^{-8} *M* concentration and the addition of small amounts of a carrier of 10^{-8} *M* concen-

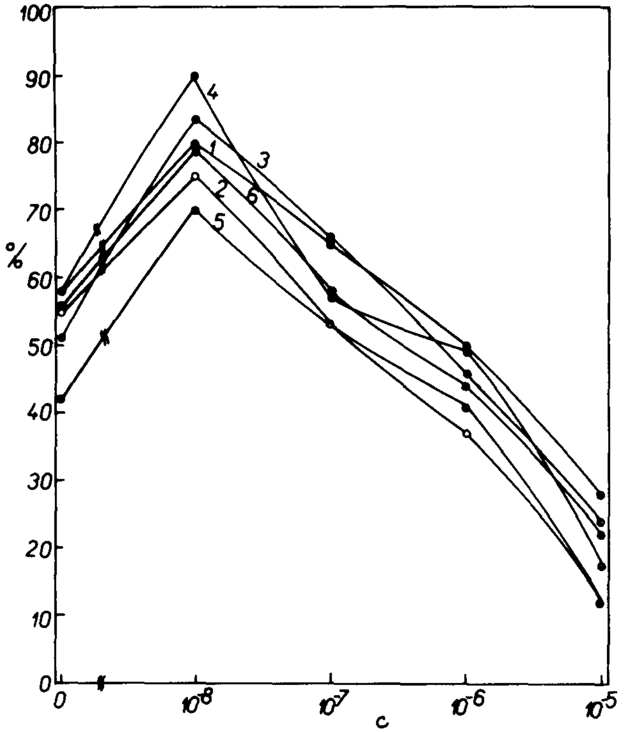

Fig. 2. Dependence of ^{144}Ce(III) and ^{147}Pm(III) flotation on their concentration. *C* is the concentration of the added carrier in moles/liter. Curves 1 (●), 2 (○), and 3 (◐) with ^{144}Ce(III), Curves 4 (◒), 5 (◓), and 6 (⊖) with ^{147}Pm(III), Curves 1 and 4 with CTAB, Curves 2 and 5 with SLS, and Curves 3 and 6 with SS.

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tration is advantageous for the separation of ^{144}Ce(III) or ^{147}Pm(III) by flotation. The interaction between the separated component and the surface-active substances is evidently also reduced at carrier concentrations higher than 10^{-8} *M*.

The increasing concentration of the surface-inactive electrolyte also considerably affected the separation because the percentage of the separated ^{147}Pm(III) or ^{144}Ce(III) decreased by approximately one-half or one-third of its value, respectively, in 1 *M* $NaNO_3$ solution (Fig. 3).

In order to achieve higher efficiency of flotation, five-stage separation was introduced by using 0.5 mg of surface-active substance in each stage for 50 ml of the solution. The time of flotation was 1 hr in each stage, after which the solution was led into the subsequent stage. No sharply increased flotation yield was observed with the multistage separation method, as is evident from Fig. 4, the percent value being, for example, 92.3% for Pm(III) and CTAB in comparison with 90.2% for the

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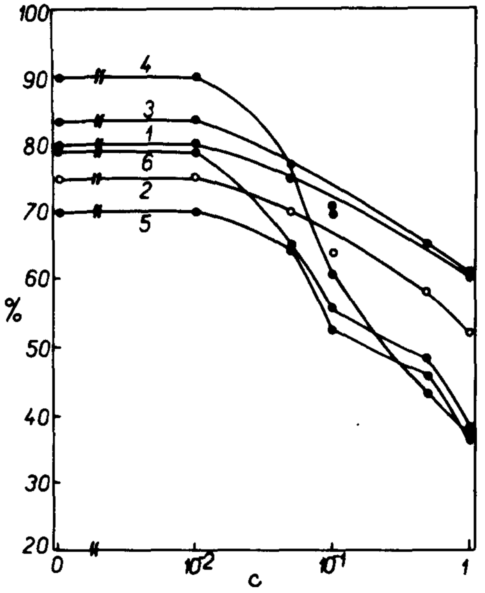

FIG. 3. Dependence of ^{144}Ce(III) and ^{147}Pm(III) flotation on the concentration of the surface-inactive electrolyte $NaNO_3$. *C* is the concentration of $NaNO_3$ in moles/liter. Curves 1 (●), 2 (○), and 3 (◐) with ^{144}Ce(III), Curves 4 (◒), 5 (◓), and 6 (⊖) with ^{147}Pm(III), Curves 1 and 4 with CTAB, Curves 2 and 5 with SLS, and Curves 3 and 6 with SS.

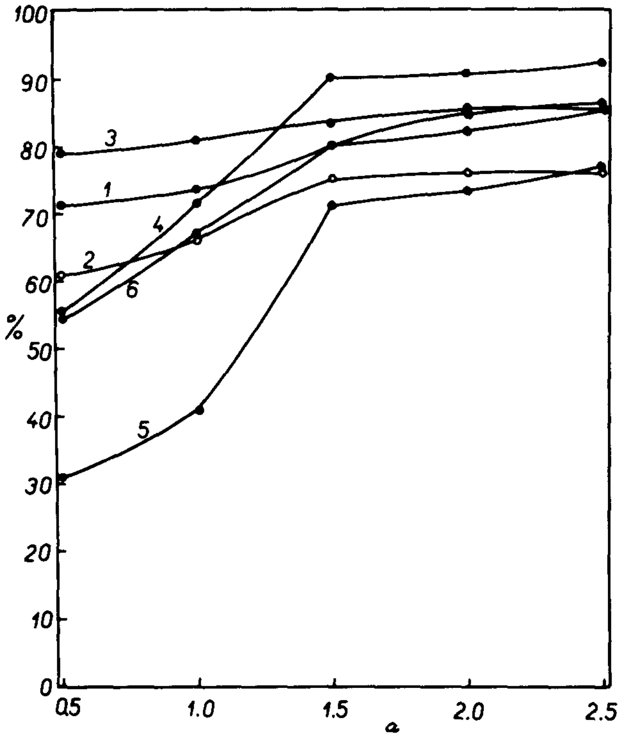

FIG. 4. Multistage ^{144}Ce(III) and ^{147}Pm(III) flotation. *a* is milligrams of surface-active substance in 50 ml of the solution of each stage. Curves 1 (●), 2 (○), and 3 (◑) with ^{144}Ce(III), Curves 4 (◒), 5 (◓), and 6 (⊖) with ^{147}Pm(III), Curves 1 and 4 with CTAB, Curves 2 and 5 with SLS, and Curves 3 and 6 with SS.

separation in one stage. The low flotation efficiency may be explained by the fact that neither the electrostatic attraction between the surface-active substances and ^{144}Ce(III) or ^{147}Pm(III) radionuclide existed to a larger extent, nor was a complex formed, but that very likely only weak physical interaction existed between the surface-active substances and the radioactive ions of ^{144}Ce(III) and ^{147}Pm(III) or their colloidal hydroxides.

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