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Numerical modeling of Remainder-reduction cascades for separation of a middle component of Se

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Abstract

The Se stable isotopes have a wide range of applications especially in producing Br radioisotope. In order to produce this radioisotope, the middle component, ^{80}Se, with high concentrations are necessary. Remainder-reduction cascade which is a transient cascade and appropriate case for separation is used in this paper. The conservation equation and solution method are provided. Moreover, the results for the separation of ^{80}Se isotope to 99% are presented.

Keywords: Remainder-reduction cascades, Simulation, q-iteratoin method, Selenuim

Introduction

Se has 6 stable isotope, all of which has medical application. Among them, ^{80}Se has been used for ^{80}Br radioisotope production widely. For this purpose, it is necessary to separate this isotope from the natural mixture. There are several separation methods for the separation of stable isotopes and Gas centrifuge is one of the common methods. This method has been applied for the separation of different isotopes. In the gas centrifuge process, separation units should be used in a cascade to be able to separate to a high concentration of target isotope. A cascade can work in the steady or transient mode for separation. The common method is steady-state, and most of the past research has been devoted to this area. On the other hand, cascades that work in transient conditions ha been introduced by Techletsov et al in 1999[1]. They used a transient cascade for the separation of Te isotope to 99.9% and named the cascade, Remainder-reduction. This type of cascade was also applied for the separation of Ni isotope by the same group of researchers[2]. In all of the researches, they experimentally worked with the cascade and they did not provide any simulation modeling for these cascades. In this paper, numerical modeling of this cascade has been presented. Moreover, results for separation of a cascade with 12 stages and 60 GCs are introduced.

Method

In fig 1, a Remainder-reduction cascade is shown. As can be seen, in this cascade, unlike conventional cascades, the cascade has only one outlet flow and the other outlet flow recirculated to the feed tank. The concentration of outlet flow varies versus time and it provides an opportunity to capture each isotope in a specific time period. As can be seen from Fig 1, based on the mass conservation equation the difference between the inlet and outlet flow of the feed tank is equal to the outlet flow of cascade. Moreover, this type of cascade can have tapered arrangments.

In the simulation of this cascade, the flow distribution considers constant and it is due to the fact that the flows rich to their equilibrium time sooner compare to the concentration of isotopes[3].

The main equations of concentration distribution are the conservation equation of isotopes in the stages and the feed point of each stage. It can be written as below:

$$\frac{\partial H_n \hat{C}_{i,n}}{\partial t} = L''^{a}_{n+1} C''^{a}_{i,n+1} + L'^{a}_{n-1} C'^{a}_{i,n-1} - L''_n C''_{i,n} - L'_n C'_{i,n} \qquad (1)$$

In this equation, C is the concentration of isotopes, prime and double superscripts show the parameter in light and heavy flow of stages. H denotes the holdup of each stage. This equation should be solved in each time step, and it is a nonlinear equation. The q-iteration method which is well known in the simulation of separation cascades and many researchers have used it is an appropriate method for solving this equation without being worried to be sensitive to initial conditions[4–7].

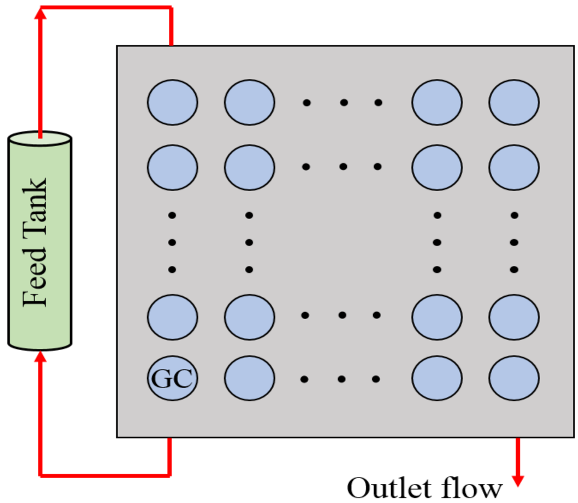

Figure 1. Schematic digram of the Remainder-reduction cascade

Results and discussion

In order to separate Se isotopes, a Remainder-reduction cascade with 20 stages and 60 GCs has been chosen. The unit separation factor of GCs for Se is considered to be 1.4. the natural abundance ratio of the Se isotopes is shown in table 1.

Table 1. Natural abandance ratio of Se isotopes

^{74}Se	^{76}Se	^{77}Se	^{78}Se	^{80}Se	^{82}Se
0.0089	0.094	0.076	0.2381	0.4960	0.0870

The holdup of the tank is equal to 100 g and the outlet flow is equal to 1 g/hr. Moreover, the time step is considered 0.05. The light flow of each stage is 10 g/hr and by considering 5 GC in each stage, the feed flow of GCs equals to 4.

By performing simulation, the concentration of isotopes in outlet flow and tank are shown in figaure 2 and 3. As can be seen, The concentration of light isotopes reached a maximum and exited from the cascade and then heavier isotopes come out from cascades. ^{80}Se reaches a maximum between 80 to 85 hr and can be selected as a product. On the other hand, by applying a threshold on the outlet flow and accumulating 50% enriched ^{80}Se from it, the accumulated mass equals 55 gr with 79% average concentration. As a result, 5 gr of this isotope by 99% enrichment is achievable.

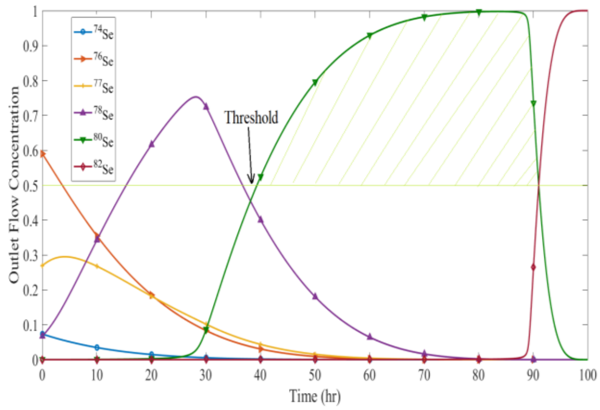

Figure 2. Outlet flow concentration vs time

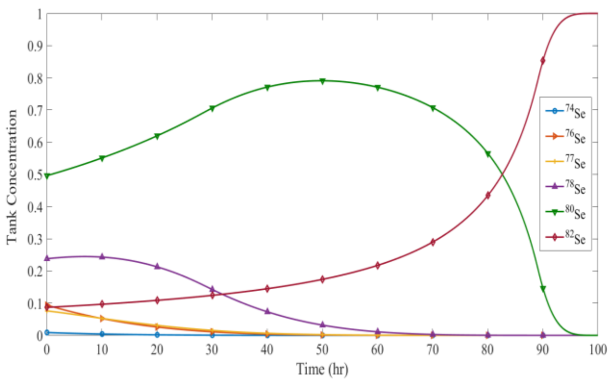

Figure 3. Tank concentration vs time

Conclusions

In conclusion, this paper presents numerical modeling of the Remainder-reduction cascades and these cascades can be used for the separation of middle components. The results showed that for a cascade with 12 stages, the concentration of ^{80}Se reaches 99% in a single run and it would not need any further separation steps, unlike conventional cascades. So, when the amount of feed is restricted, it can be a good option for separation.

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