Design of thermal diffusion column cascade for Ne stable isotopes separation

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Abstract

One of the methods used to separate stable isotopes is the thermal diffusion column. In this research, the R cascade is used for designing and determining the number of columns to separate two Ne stable isotopes. Accordingly, all cascades that have enriched Ne isotopes to more than 99% are investigated. In this regard, a calculation code entitled "R CASCADE" has been developed. The unit separation factor is considered to be 3 and the number of stages varies from 10 to 20. The results show that the column separation power, the relative total flow rate, and the required columns are linearly related to the number of stages. The column separation power and the relative total flow decrease as the number of stages increase. In contrast, the number of columns are increased. Therefore, the cascade by 10 stages and 85 columns is recommended for separation of Ne stable isotopes.

Keywords: Thermal diffusion, Cascade, Isotope separation

Introduction

Since the use of gas centrifuges is suitable for the separation of some isotopes, extensive and comprehensive research should be conducted on other methods as well. Acquiring knowledge of separation using different methods provides the production of a significant amount of stable isotopes. Among them, the thermal diffusion is of great importance due to features such as high separation coefficient, simplicity in the process and cascade operation. The thermal column has the ability to separate isotopes to a very high degree. This method is used to produce expensive isotopes on a small scale (1-2 grams of target isotope per day) and purity of more than 99%. The most important factor of mass transfer being the temperature difference.

In this regard, Saxena and Watson optimized the physical parameters of the thermal diffusion column [1]. Rutherford et al. Reviewed experimental and theoretical results for Ar, Xe, and methane gases. They also investigated the separation of O_2, N_2 and Ne-21 isotope in the thermal column and its cascade [2]. Roger and Rutherford designed a cascade to separate Kr-85 using a thermal diffusion column [3]. Rutherford analyzed cascade behavior by changing the time to separate multicomponent isotopes. Zieger et al. optimized the intermediate isotope enrichment in multicomponent systems [4]. Vasaro and George studied the separation of C-13 in a 7-stage cascade using 19 thermal diffusion columns [5]. Liangjong et al. Compared the design parameters of a thermal diffusion column with experimental and theoretical results for Ne-22 separation in a cascade consist of two thermal columns [6]. In the researches for the separation of Ne isotopes, studies were done for a cascade with a specific structure.

In this paper, the thermal diffusion column cascade for separation of two Ne stable isotopes is designed and required number of columns are determined. Match abundance ratio cascade (R cascade) is used for the initial design and estimation of the required columns number.

Experimental calculation

The different R cascades and their effects on the separation of Ne stable isotopes are studied and the cascade design is performed based on it. Therefore, a computational code called "R CASCADE" has been created. Sequently, by changing the number of cascade stages from 10 to 20, the required parameters determined so that the enrichment of both the first and second Ne isotopes reach to 99%. The concentration of the first isotope (Ne-20) is 91% and the concentration of the second isotope (Ne-22) is 0.09. The parameters that determine the number of stages are: column separation power, number of columns, and relative total flow (product flow rate to intermediate flow). The optimum feed flow rate of thermal column and the unit separation factor is 50 cm^3/s and 3 in this study.

Results and discussion

As can be seen from Figure (1,a), the amount of column separation power decreases with increasing the number of stages. The variation of this parameter is from 27.48 to 26.95, which is a little more for the 10-stage cascade.

As shown in Figure (1,b), the number of columns increases from 85 for a 10-stage cascade to 105 for a 20-stage cascade. Despite increasing the number of stages as well as the number of columns, the amount of column separation power does not change significantly. In addition, the flow rate of light and heavy products

remains almost constant. On the other hand, according to Figures (1,c) and (1,d), the relative total flow rate decreases with increasing the number of stages.

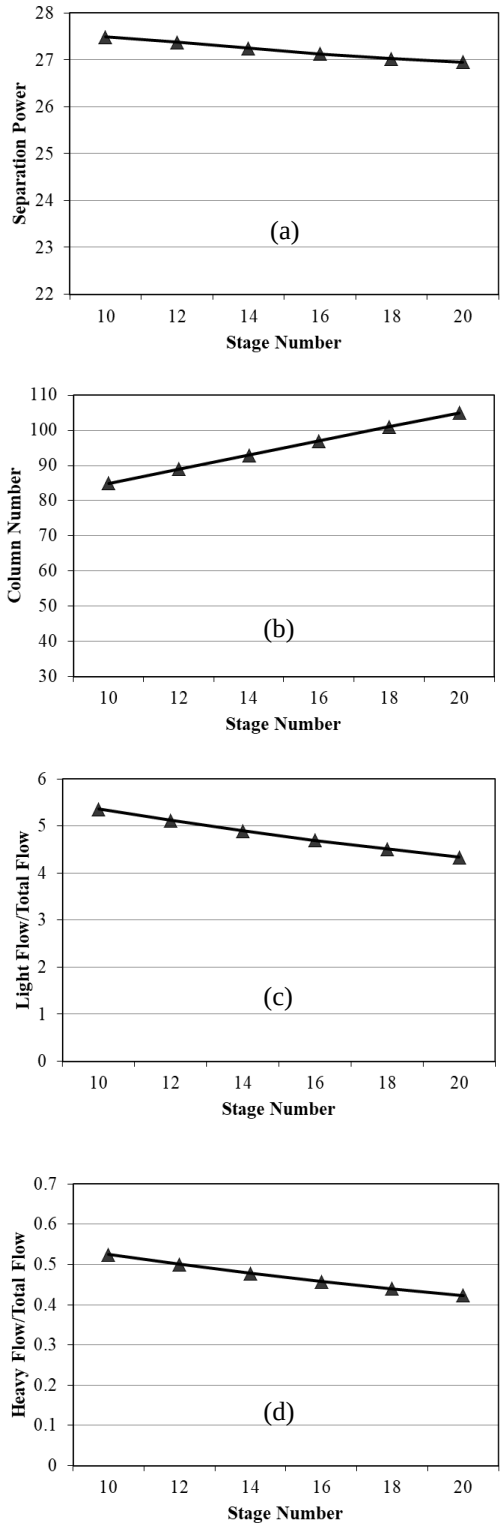

Figure 1. The variation of (a) column separation power; (b) column number; (c) light relative total flow; (d) heavy relative total flow according to the number of stages.

This indicates that by increasing the number of cascade stages, the total flow rate increases. Therefore, it is better to choose a cascade with 10 stages that has fewer columns and at the same time has better separation power. It can also be found that reducing the number of columns results in lower operating costs and at the same time better separation efficiency.

Therefore, the R cascade with 85 columns is selected according to the same light and heavy flow rates, the same enrichment and also the greater column separation power.

Conclusions

In this research, the thermal diffusion column cascade for Ne isotopes separation was investigated. It is better to use the R cascade for separation of the Ne stable isotopes due to its proximity to the ideal conditions. In this regard, a calculation code was prepared in MATLAB. Thereafter, the thermal column separation power, the light and heavy relative total flow rate were studied in the R cascade from 10 to 20 stages to determine the required column numbers. The results suggested the R cascade by 10 stages and 85 columns for the separation of Ne stable isotopes. Due to the fact that in this cascade different stages cut are required, single-column tests should be prepared in accordance with such conditions.

If the goal in the long run is to separate the isotopes of other noble elements, it is better to use a square cascade with flexibility. A study on the square cascade is also underway and the results will be published later.

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