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Centrifugal extraction of highly enriched ^{120}Te and ^{122}Te using the non-steady state method of separation

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Abstract

This work contains results of the research on centrifugal enrichment of ^{120}Te and ^{122}Te isotopes using non-steady state processes of separation. This method, also known as the method of “remainder reduction”, enabled the effective separation of these isotopes with enrichments of 99.9% in gram quantities. ^{120}Te and ^{122}Te have never been produced before with such high enrichment. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Research on the separation of stable isotopes by centrifugal methods began at the Russian Research Center, Kurchatov Institute in the mid-1960s. Research on centrifugal separation and the creation of specialized centrifuges allowed the development of production technology for stable isotopes of some elements. Currently, the technologies for the centrifugal separation of 21 elements have been developed.

Research on increasing the efficiency of centrifuges applied over a wide range masses has been performed. Research based on feed material forms was also done. As of now, the research on the centrifugal separation of tellurium isotopes using

TeF_6 as the feed material can be considered to be complete [1].

2. Experimental results

The non-steady state separation method and the method of “remainder reduction,” enabled the effective separation of ^{120}Te and ^{122}Te isotope with enrichments of 99.9%. Enrichment of the ^{120}Te and ^{122}Te in the form of gaseous TeF_6 was carried out in the laboratory-type rectangular cascade of gas centrifuges (Fig. 1). Flow of feed from a holding reservoir is supplied to the first step of the cascade. Waste from the first step of the cascade is returned to that same reservoir. Collection of the desired enriched isotope product is made from the last step of the cascade [2].

In this work, TeF_6 remaining from previous work on the enrichment of isotope ^{123}Te [2] was used as the feed material. The isotopic

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concentration of this feed material was: $^{120}\text{C} = 27.5\%$, $^{122}\text{C} = 68.0\%$, $^{123}\text{C} = 4.5\%$. For reference, the concentration of isotopes in the natural tellurium is shown in the Table 1. It can be seen that the feed was primarily ^{122}Te and ^{120}Te and that it did not contain the heavier isotopes of Te.

The principal scheme of the non-steady state process for ^{122}Te and ^{120}Te enrichment on centrifugal cascade is shown in Fig. 2. Waste flow from the first stage (light fraction) is condensed in the condensing–evaporating reservoir (CW-CF). The process of condensation of waste flow from the cascade and supplying the cascade with feed flow from the same reservoir has to be continuous. Because condensation of the waste flow is taking place throughout the enrichment, the isotopic composition of the feed material supplying the cascades is constantly changing.

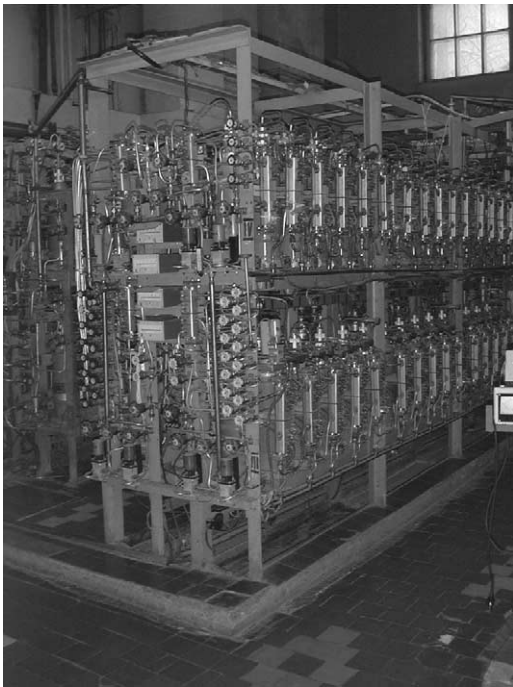


Fig. 1. Photograph of the cascade of gas centrifuges.

The regulator shown on the feed line of the cascade maintains an exact control of the feed flow. The control of the feed flow rate is usually accomplished by controlling the gas pressure in front of the “shim” or orifice (SH-F) in the feed line. The diameter of the “shim” must provide a feed flow speed not less than the speed of sound. The gas pressure in front of the “shim” is linearly proportional to the gas flow passing through the “shim”.

Usually, the pressure in front of the “shim” is controlled by an electronic regulator. However, in this work, it was more convenient to use the mechanical regulator described below and shown in Fig. 3. The regulator consists of the body (1), divided into three cells: entry pressure cell (P_{enter}), exit pressure cell (P_{exit}), and support pressure cell (P_{support}). The cells are separated by a choker (2) and thin membrane (4), which are connected to each other by the stack (3). The support pressure cell is connected to a reservoir consisting of a welded bellows with an adjustable volume (V_{reg}).

The feed gas enters the support pressure cell through the valve (B1) and optical manometer (OM-2) is used to read the support pressure which is adjusted so that $P_{\text{support}} = P_{\text{exit}} + (0.6–0.8)$ mm Hg. The support pressure cell is isolated from the cascade by valves B1 and B2. Feed gas flows into the entry pressure cell through valve B3. The position of the choker (2) is controlled by means of

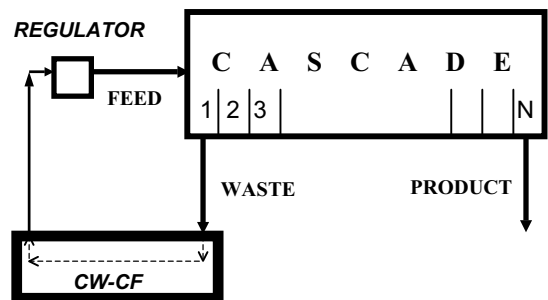


Fig. 2. Diagram of the cascade.

Table 1
Isotopic composition of natural tellurium

Tellurium isotopes	120	122	123	124	125	126	128	130
Natural abundance (%)	0.089	2.46	0.87	4.61	6.99	18.71	31.79	34.48

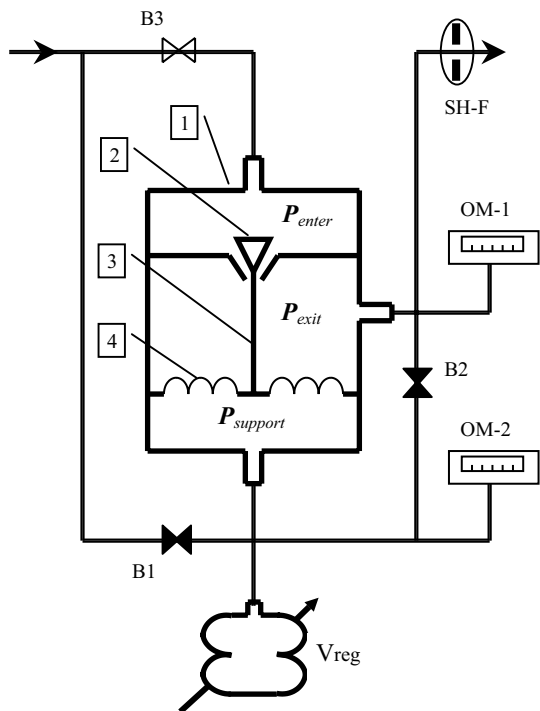


Fig. 3. Scheme of the feed flow regulator for the cascade. (1) regulator body; (2) choker; (3) stack; (4) membrane.

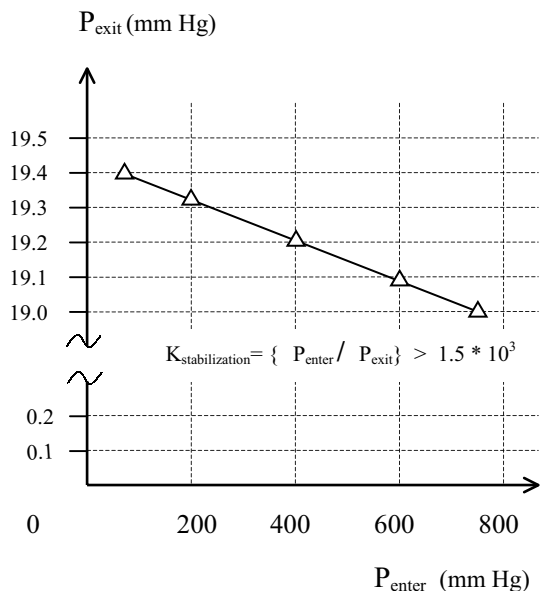


Fig. 4. Regulator characteristics at $P_{support} = 20$ mm Hg.

the stack (3) and membrane (4) to provide a constant pressure $P_{exit} = P_{support} - (0.6 - 0.8)$ mm Hg in the exit pressure cell. Precise pressure adjustment is done by the volume adjustment of the cell (V_{reg}). However, pressure correction can also be done by means of the valves (B1, B2), because $(P_{enter}) > (P_{support}) > (P_{exit})$.

The dependence of the exit pressure (P_{exit}) on entrance pressure (P_{enter}) is plotted in Fig. 4. It can be seen that varying P_{enter} from 50 to 750 mm Hg only changes the exit pressure (P_{exit}) by 0.4 mm Hg. Therefore, the regulator stabilization coefficient is $> 1.5 \times 10^3$ and provides excellent control.

The dependence of the isotopic content of the heavy fraction selection on the time of the process

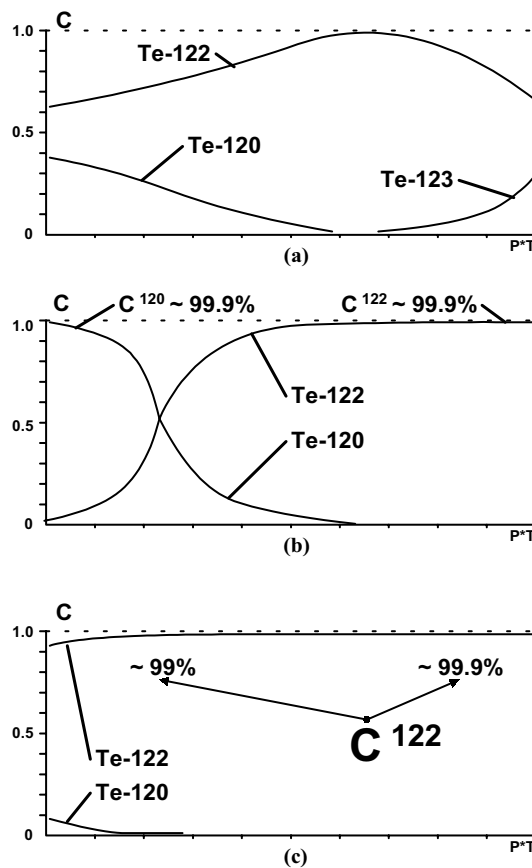


Fig. 5. Dependence of the isotopic content of the heavy fraction selection on the time of the process. Vertical axis = relative isotope concentration C , horizontal axis = mass (= rate \times time). Figs. (a)–(c) show different time intervals.

Table 2
Isotope enrichment of tellurium

120	122	123	124	125–130
99.9	<0.1	<0.05	<0.05	<0.01
99.3	0.6	<0.1	<0.05	<0.01
<0.05	99.9	<0.05	<0.01	<0.01

is shown in Fig. 5. The Y -axis represents the relative concentration of the tellurium isotopic components. The X -axis represents the product of the value of the selection of the heavy fraction of the cascade ($P = \text{mass}/\text{time}$) and the time duration (T) of the selection, giving $(PT) = \text{mass}$.

At an early stage of the process, the heavy fraction is primarily ^{122}Te (Fig. 5a). The ^{123}Te , with low abundance in the starting material, is collected slightly later, and relatively soon depleted. After ^{123}Te has been extracted, ^{122}Te is collected and ^{120}Te is extracted simultaneously from the light end of the cascade. Fig. 5b shows the selection of the product. At the end of the experiment, the flow contains only the molar $^{122}\text{TeF}_6$ (see Fig. 5c).

It should be pointed out that the same methods can be used to enrich isotopes to $>99.9\%$ and this

work will be the subject of a forthcoming paper. Finally, we have obtained high enrichment isotopes of ^{122}Te and ^{120}Te in gram quantities (see Table 2).

3. Conclusion

The ability to enrich ^{120}Te and ^{122}Te isotopes to the previously unobtainable levels of 99.9% has been demonstrated. The resulting material is used as a precursor for producing radionuclides for medical applications. The non-steady state separation method, used here, can also be effectively applied to the enrichment of isotopes of other elements

References

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