Estimation of Dispersal Rate in Strontium-82 Extraction Process from Rubidium Chloride Target Irradiated with 100-MeV Proton Beam

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1. Introduction

KAERI is preparing a facility for the production of various radioisotopes based on a 100 MeV proton linear accelerator [1]. Using this facility, ^{82}Sr production is being prepared first [2]. RI production facilities should be prepared for RI contamination through various routes. Among them, dispersion generated while handling RI is very difficult to estimate, so in general, facilities are designed very conservatively. In the case of the KOMAC RI facility, it is assumed that 1/10,000 of the maximum amount of RI used per day is dispersed for the design of exhaust facilities, etc. However, in the case of actual RI works, the dispersal rate may be different depending on the nuclide, physical state, chemical state, and how to handle. Therefore, it is necessary to estimate a more realistic dispersal rate for the ^{82}Sr production process under development.

2. ^{82}Sr Production Process

Rubidium chloride powder is compressed into pellets, and a metal cladding is placed on it to produce a target. When the target is irradiated with a 100 MeV proton beam, a radioactive isotope, ^{82}Sr, is produced. The irradiated target is transferred to the hot cell to start the ^{82}Sr separation process. RI contamination is not a concern as it remains sealed until transferred to the hot cell unless the target is accidentally damaged.

Dispersion begins as soon as the rubidium chloride pellets (containing a small amount of ^{82}SR and other RIs) are exposed to air by removing the cladding in the hot cell. This pellet is dissolved in a buffer solution to convert it to an aqueous solution, and it goes through several processes to remove unnecessary elements and extract ^{82}Sr. Fig. 1 shows the extraction process currently under development [3].

The conditions of this procedure for estimating the dispersion during the process are as follows.

Nuclide	^{82}Sr (alkaline earth element) and other metals
Chemical state	Inorganic compound (chloride) and aqueous solution
Physical state	Lump (pellet) and liquid (aqueous solution)
Handling process	Machining (lump) and drying (Aqueous solution)

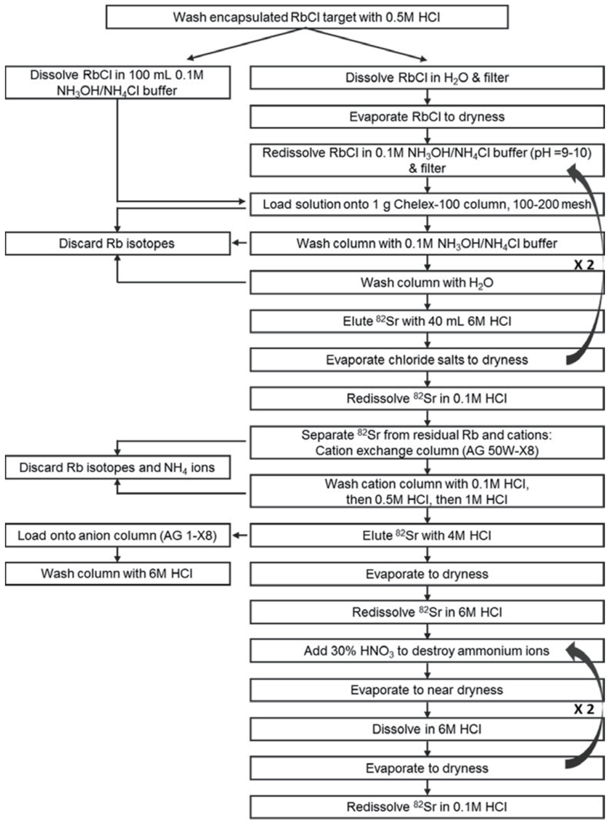

Fig. 1. Draft version of ^{82}Sr separation/purification procedure.

2. Dispersal Rate Estimation Formula [4]

There are few references for dispersal rate estimation. The dispersal rate was estimated by the method presented in REFERENCE 4, which is summarized as follows.

The experiment was set up as shown in Fig. 2, and the following experiment was performed to obtain the results.

a. Add 25-ml RI solution to 50-ml beaker and stir
b. Allow 50-cm/s air to flow for one hour
c. Measure the RI collected by the filter
d. Calculate the dispersal rate by collected/original RI

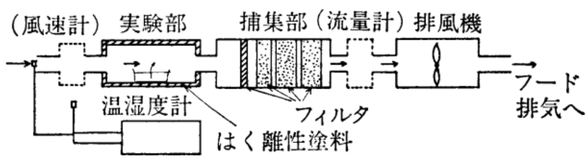

Fig. 2. Experimental setup for dispersal rate measurements.

The results of the experiment are summarized as follows.

a. The dispersal rate of metal RI is very small compared to non-metal RI

b. The dispersal rate of organic compound RI is higher than that of inorganic compound

c. The dispersal rate is in the order of H, C, S, Se > I, Cs > most metal RI

d. The dispersal rate of most metal RI is about 10^{-7} or less

Based on these experimental results, the following total dispersal rate per day calculation formula was proposed.

Total dispersal rate per day =

$$\sum \text{(Daily dispersal rate per day by nuclide} \times \text{Shape coeff.} \times \text{Handling coeff.)} \quad (1)$$

Daily dispersal rate by nuclide, shape coefficient, and handling process coefficient are given in Tables I, II and III.

Table I: Dairy Dispersal Rate by Nuclide

Nuclide	Dispersal Rate per Day
^{3}H, ^{14}C, ^{35}S, ^{75}Se	10^{-3}
^{131}I, ^{137}Cs, ^{197}Hg, etc.	10^{-4}
Most other metals	10^{-7}

Table II: Coefficient by Shape

Shape	Coefficient
Powder	× 10
Liquid	× 1
Lump	× 0.1

Table III: Coefficient by Handling Process

Handling Process	Coefficient
Heating (drying, etc.)	× 100
Chemical reaction, mechanical machining, animal experiment, etc.	× 10
General manipulation	× 1
No manipulation	× 0.1

3. Dispersal Rate Calculation for ^{82}Sr Production Process

The ^{82}Sr extraction process includes a) machining to remove metal cladding, b) chemical reaction to dissolve chloride to make an aqueous solution, c) general manipulation of aqueous solution, and d) evaporation of aqueous solution. Each dairy dispersal rate is obtained according to the calculation formula above.

a. ^{82}Sr chloride, lump, machining:

$$10^{-7} \times 0.1 \times 10 = 10^{-7}$$

b. ^{82}Sr chloride, lump, chemical reaction:

$$10^{-7} \times 0.1 \times 10 = 10^{-7}$$

c. ^{82}Sr aqueous solution, liquid, manipulation:

$$10^{-7} \times 1 \times 10 = 10^{-6}$$

d. ^{82}Sr aqueous solution, liquid, evaporation:

$$10^{-7} \times 1 \times 100 = 10^{-5}$$

The sum of all dairy dispersal rates in the process (a+b+c+d) is 1.12×10^{-5}.

3. Conclusions

The daily dispersal rate of the process for extracting ^{82}Sr from irradiated target is estimated to be about 10^{-5}. Since this is lower than 1/10,000 originally used in the design of the RI production facility, it can be confirmed that this facility has a sufficient safety margin for the ^{82}Sr extraction process.

The process that accounts for a large portion of the dispersal rate is the drying process. Therefore, it will be helpful to prevent contamination by RIs if the experimental equipment is configured to minimize dispersion in this drying process and the experiment is conducted with more caution compared to other processes. In this sense, vacuum drying currently used for the ^{82}Sr extraction process development [5] is a very appropriate method.

The same dispersal rate will be estimated for other metal RIs generated in the ^{82}Sr production process and for most other metal RI production process that undergo a similar procedure.

ACKNOWLEDGEMENT

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