Status and Plans of Sr-82 Development Using a High Energy Proton Accelerator

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1. Introduction

Sr-82 is the parent radioisotope of Rb-82, which is a radioisotope for the diagnosis of heart disease (myocardial infarction) using PET (positron emission tomography), with a half-life of 25.35 days. Detail information on Sr-82 is shown in Table I. Rb-82, derived from the parent species, is produced in the form of a generator and is used for PET imaging through the positron emission. RI such as Rb-82, O-15, N-13 and K-38 is used for cardiovascular PET imaging. These RIs have a short half-life than Tc-99m and Tl-201, which is advantageous for PET diagnosis. However, in order to use RIs other than Rb-82, a cyclotron must be provided in hospitals. The Rb-82 can be supplied via the Sr-82/Rb-82 generator, so it can be used anywhere. Ischemic cardiovascular studies using Rb-82 have not progressed because there is no supplier in Korea. On the other hand, studies are being conducted mainly in North America where Sr-82 is available.

Table I: Characteristics of Sr-82/Rb-82

Application field	PET imaging of myocardial infarction (Sr-82/Rb-82 generator)
Administration dose	~1.5 GBq / 70 kg (Rb-82)
Half-life	25.4 d
Gamma energy	511 keV, 776.5 keV (from daughter Rb-82)
Target	RbCl or Rb metal
Nuclear reaction	^{85}Rb(p,4n)^{82}Sr

Although various methods (Table II) have been proposed as a producing Sr-82 it is known as the most practical method to use ^{nat}Rb(p,x)^{82}Sr nuclear reaction by using a high energy and high current proton beam irradiation. To produce Sr-82 by this nuclear reaction a proton beam of energy is required of greater than 50 MeV. Therefore, Sr-82 could not be produced in Korea. Recently, Korea Multi-purpose Accelerator Complex (KOMAC) has constructed a RI production facilities dedicated to RI production, and the RI production facilities have a suitable specification for producing Sr-82. In this study, we will discuss the results of our research and future plans for Sr-82 production at KOMAC.

Table II: Methods of producing Sr-82

Nuclear reaction	Target	Energy [MeV]	Remark
^{89}Y(p, spallation)	Y_2O_3	60-240	Low purity & yield
natMo(p, spallation)	Mo	500-700	Low purity & high cost
^{nat}Rb(p,xn)	RbCl or Rb	40-90	Preferred
^{Nat}Kr(α,pxn)	Kr	20-120	Low purity & yield
^{Nat}Kr(^{3}He,xn)	Kr	20-90	Low purity & yield

2. Results and Future plans

We have constructed facility for irradiation of proton beams to RI target to produce Sr-82 and have developed proto-type targets capable of producing Sr-82 up to 100 GBq. Currently, a chemical processing laboratory is being installed for pure separation of Sr-82 from the RbCl target irradiated with proton beams.

2.1 RI target and RI production facilities at KOMAC

A proto-type RbCl target was prepared to produce Sr-82. The RbCl target is in the form of pellets with a 50 mm-Φ and 16 mm-thick structure. The pellet is a shape enclosed in a stainless steel cladding. The RI production facilities are composed of a beam line and target chamber, a target transfer unit between the target chamber and the hot cell, a hot-cell and a target water cooling unit (Fig. 1). The specifications of RI production facilities are shown in Table III. The RI production facility allows remote handling of targets using hot-cell, transfer unit, transfer vessel, etc. to minimize radiation exposure to operator.

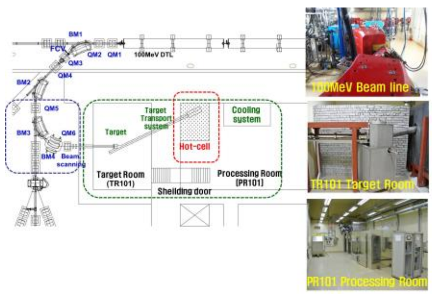

Fig. 1. Layout of RI Production facilities

A chemical processing laboratory was constructed to separation and purifying Sr-82 from the irradiated target. There are 5 hot-cells and 2 RI hood in the chemical processing lab. This will be used to purely separate the target RI.

Table III: Specifications of RI production facilities

Beam energy	103 MeV
Beam current	300 μA
Beam spot	50 x 50 mm^2
Beam time structure	20 mA, 500 μs, 60 Hz
Peak power density	60 W/cm^2
Target diameter	50 mm

2.2 Sr-82 production yield calculation

To investigate Yield of Sr-82 production, we carried out the Monte Carlo simulation. We calculated secondary neutron spectra, which were produced by primary proton beam, using MCNPX v. 2.5 code, then production rates of RIs for RbCl target were calculated with PHITS v. 2.15 code. With the results of MCNPX and PHITS code simulations. We calculated activities of residual radioisotopes and their time-dependent decay characteristics using DCHAIN-SP code. The results of simulation show that the yield of Sr-82 is 3.6 MBq/ μAh when multiple target stack of ZnO-RbCl-Ga are used. In order to verify the calculation results, we calculated and verified the results using the same structure as the target of Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL). The verification results are shown in Table IV.

Table IV: Comparison of KOMAC calculation results with LANL calculation and experimental results.

Unit: (MBq/ μAh)

	LANL results			KOMAC
	Exp. data	ALICE-IPPE	MCNPX /CINDER90	
^{82}Sr (High E.)	2.8	5.0	3.2	3.4
^{82}Sr (Med. E.)	4.7	7.3	5.9	4.5
^{68}Ge (Low E.)	0.3	1.0	0.9	0.5

2.3 Target inspection and quality control

It is most important to identify defects in the target prior to proton beam irradiation and to manage the quality of the purified RI. An x-ray CT scanner and a vacuum water bath were equipped with a target inspection system. Defects in the welds and defects in the target are inspected using an x-ray CT scanner and pin-holes in the cladding surface are inspected using a vacuum water bath. Fig. 2 shows the results of x-ray CT scan of the target. The quality of purified Sr-82 is confirmed by using ICP-MS and HPGe detector. The specific activity, radiopurity and other metal impurity of Sr-82 product will be controlled in accordance with Sr-82 fact sheet of nordion.

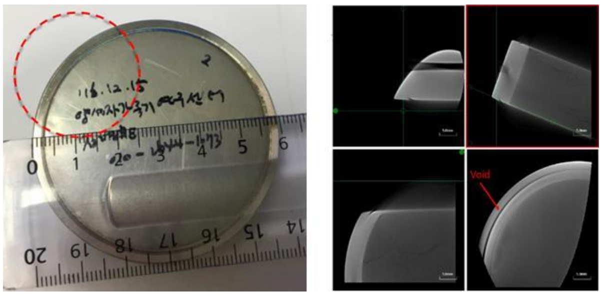

Fig. 2. Picture of RbCl target (left) and x-ray CT image (right).

2.4 Future plans

We plan to produce up to 370 MBq of Sr-82 within the next five years. We will also produce Sr-82/Rb-82 generator and supply them to domestic researchers for use in preclinical research. In addition, In connection with the national isotope program, we will establish the mass production system of the Sr-82. The technology acquired through the research and development of Sr-82 will be applied to RI development such as Cu-67, Na-22, Ra-223 and Ac-225 in the future.

3. Conclusions

We built a facility dedicated to RI production to produce RI such as Sr-82. In order to the production of Sr-82 up to 370 MBq, we have established a chemical processing laboratory for separation and purification of Sr-82, target inspection and RI quality management system. For this purpose, we carried out basic researches such as Monte Carlo simulation and proto-type target fabrication.

ACKNOWLEDGMENT

This work has been supported through KOMAC operation fund of KAERI by MSIP (Ministry of Science, ICT and Future Planning)

REFERENCES

[1] J. M. Fitzsimmons et al., Specific activity and isotope abundances of strontium in purified strontium-82, J. Anal. At. Spectrom. Vol.31, p.458, 2016
[2] NSAC Isotope Subcommittee, 2015. 7
[3] NORDION Sr-82 fact sheet.
[4] S. J. Ra et al., Monte Carlo simulation for radioisotope production yield of Pd-109, Sr-82, Cu-67, and Ge-68 and radiation shielding, proceeding of KNS Autumn meeting, 2012