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Current Status of RFT-30 Cyclotron and Radioisotope Production

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1. Introduction

RFT-30 cyclotron has been developed not only for the production of radioisotopes (RIs) and their applications, but also for proton beam utilization to various research fields including material science, bio science, and so on. RFT-30 Cyclotron has been designed in which proton beam energy can be controlled from 15 to 30 MeV by adjusting the position of a carbon stripper foil, which detaches two electrons from negative hydrogen ions and therefore results in the conversion of negative hydrogen ions to protons.

RFT-30 cyclotron has been regularly operated since 2013, and research on the production of radioisotopes has been performed using this cyclotron. Fluorine-18 (^{18}F), which is the most widely-used positron emitter, has been produced regularly since 2015. In 2018, mass-production of zirconium-89 (^{89}Zr) is successfully achieved. In addition, long-term proton irradiation for the production of germanium-68 (^{68}Ge), which is one of the typical generator RIs, was also performed. A generator is a device used to extract the positron-emitting daughter radioisotope from a source of the decaying parent radioisotope which has a relatively long half-life.

In addition, proton beam service and RI supply have been provided to the users of various research fields including material science, medical science, and so on.

2. Methods and Results

2.1 Target Materials

For the production of ^{18}F, enriched Oxygen-18 water ($H_2{}^{18}O$) was used as a target material. For the production of ^{89}Zr and ^{68}Ge, natural yttrium (^{89}Y: 100%) and gallium (^{69}Ga: 60.1%, ^{71}Ga: 39.9%) were used respectively.

2.2 Proton Irradiation Condition

Target materials were installed at the end of the beamline 1-1 (Fig. 1) and then irradiated with a proton beam generated from RFT-30 cyclotron of Korea Atomic Energy Research Institute (KAERI). Proton beam energy was initially 29.4 MeV and controlled by adjusting the thickness of degrader material before the proton beam was incident on the target. Average beam current was around 40 μA and irradiation time was changed to control the total dose. Metal targets were water-cooled during the proton irradiation process.

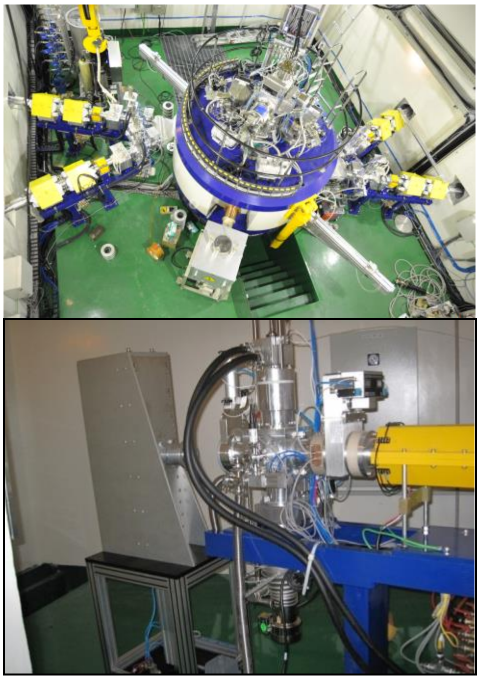

Fig. 1. Photo of RFT-30 cyclotron and the beamline 1-1 for the production of PET RIs.

2.3 Production of RIs

RIs were produced via the nuclear reactions induced by the proton irradiation listed below (Fig. 2).

1) $^{18}O(p, n)^{18}F$
2) $^{89}Y(p, n)^{89}Zr$
3) $^{nat}Ga(p, xn)^{68}Ge$

^{18}F is produced routinely or by request and we provide ^{18}F-labelling experiment service to users. For ^{89}Zr, because it has a half-life of 3.3 days which is well matched to the circulation half-lives of antibodies, intensive research on ^{89}Zr has been performed [1]. After the production of ^{89}Zr using RFT-30 cyclotron (Fig. 3), it was delivered to several hospitals and research institutes as a form of zirconium oxalate or chloride for research purpose. ^{68}Ge has a relatively long half-life of ~270 days and produces daughter RI, ^{68}Ga. Therefore experiments using ^{68}Ga can be performed for several months without daily-production of ^{68}Ge if ^{68}Ge/^{68}Ga generator is provided [2]. We have performed sufficient proton irradiation of more than 2,000 μAh, and the target is being cooled for the elimination of short-lived impurities. The estimated radioactivity of ^{68}Ge is ~70 mCi.

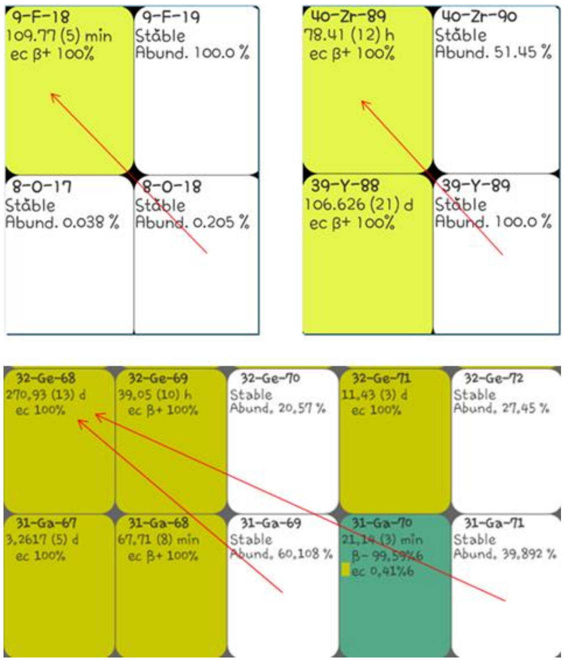

Fig. 2. Nuclear reactions for the production of RIs [3].

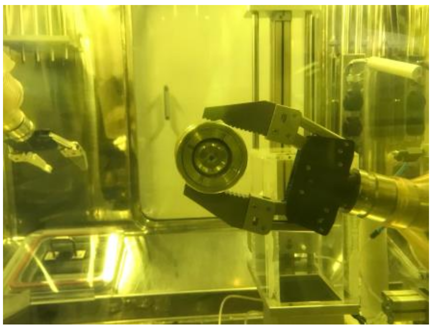

Fig. 3. Proton-irradiated yttrium target in hot-cell for ^{89}Zr separation.

3. Conclusions

In this research, various positron-emitting RIs including ^{18}F, ^{89}Zr, and ^{68}Ge were successfully produced using RFT-30 cyclotron at KAERI. We are trying to optimize irradiation conditions for RI production and following processes after the irradiation. Produced RIs and proton beam itself can be used for the user service as well as for our own research purpose. In the future, research on the production of other useful RIs and the performance improvement for mass-production will be carried out.

REFERENCES

[1] Y. Zhang, H. Hong, and W. Cai, PET Tracers Based on Zirconium-89, Current Radiopharmaceuticals, Vol.4, p.131, 2011.

[2] F. Rösch, Past, present and future of ^{68}Ge/^{68}Ga generators, Applied Radiation and Isotopes, Vol.76, p.24, 2013.

[3] Isotope Browser, IAEA Nuclear Data Section