PRODUCTION AND ACCELERATION OF RNB ^{64}Cu

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Abstract

The method of production and acceleration of radioactive nuclear beam ^{64}Cu (0ff-line) at HI-13 Tandem Accelerator is presented. RNB ^{64}Cu of 1.2 $\times 10^5$/s(80MeV) was got on the target for the experiment of ^{64}Cu Coulomb excitation.

1. INTRODUCTION

In recent years, radioactive nuclear physics is one of the frontier fields in nuclear physics. In order to do some studies as early as possible on radioactive nuclear physics, production and acceleration of RNB off-line has been developed at CIAE. At first, the Model 200 Cesium Sputter Ion Source and the HI-13 Tandem Accelerator were used to produce and accelerate RNB ^{64}Cu (0ff-line). RNB ^{64}Cu of 1.2$\times 10^5$ ions/s (80MeV) was got on the target for the experiment of ^{64}Cu Coulomb excitation.

The technical difficult points for production and acceleration of RNB ^{64}Cu are as follows : preparation for ^{64}Cu cathode of the sputter ion source; installation and shielding of the ^{64}Cu cathode; separating and distinguishing RNB ^{64}Cu ions, etc.

2. SIMULATING TEST OF RNB ^{64}Cu

The stable ^{63}Cu and ^{65}Cu ions were used to simulate production and acceleration of RNB ^{64}Cu.The negative ions of ^{63}Cu and ^{65}Cu were extracted from the Model 200 sputtering ion source with Cu cathode (Cu purity of 99.99%) and injected into the HI-13 Tandem to accelerate. The purposes of the simulating test are to know following information: dimension of a pit on the Cu cathode sputtered by Cs$^+$ ions to determine dimension of ^{64}Cu cathode; consumption of the Cu cathode to determine quantity of ^{64}Cu cathode material; current intensity of ^{63}Cu and ^{65}Cu to estimate ^{64}Cu ion current according to specific activity of ^{64}Cu/(^{63}Cu+^{65}Cu); composition of ion beam on the experimental target and operation parameters of the HI-13. The results of simulating test of ^{64}Cu acceleration are as follows: when the ion source was continuously running for 12h, overage current intensity of ^{63}Cu$^-$ and ^{65}Cu$^-$ is 1.5μa and 0.5μa respectively; the bell pit on the Cu cathode sputtered by $^+$Cs ion is 2.2mm in diameter, 2mm in depth; overall consumption of Cu cathode material is 53.9mg (2.25mg/μa .h).

According to Cu negative ion beam of 2μa, specific activity 6$\times 10^{-6}$ of ^{64}Cu/(^{63}Cu+^{65}Cu) and ion beam transmission of 10% to calculate ^{64}Cu ion intensity, expectant RNB ^{64}Cu of 2$\times 10^6$ ions/s can be obtained on the experimental target.

At the simulating test of ^{64}Cu acceleration, ion beam composition on the experimental target was measured using method of AMS. It is listed in table 1.

Table 1. Ion beam composition on the experimental target

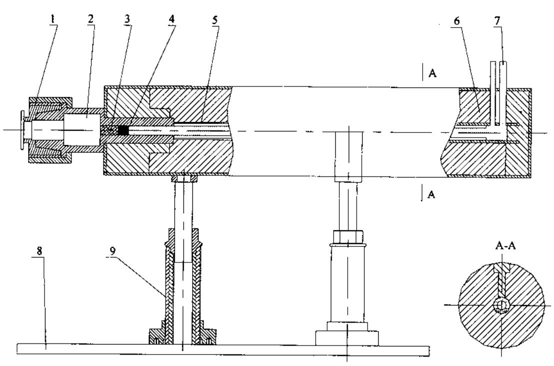
Ion species	Ion intensity/s	Ion content/%
^{64}Ni	8.5$\times 10^4$	92.5
^{65}Cu	< 20	～0
^{63}Cu	< 20	～0
^{64}Zn	4.0$\times 10^3$	4.3

3. Production of radioactive nuclide ^{64}Cu

The cathode（Φ3.5x3 mm) of the cesium sputtering ion source was made from Cu with purity of 99.99%. The cathode was put into the heavy water reactor with neutron flux of 1.2$\times 10^{13}$/cm^2·s to irradiate for 4$\times$12.7hs. ^{64}Cu of 2.7$\times 10^{11}$ Bq was obtained.

4. Shielding and aligning of the ^{64}Cu cathode

One of difficulties for production of RNB (off-line) is how to install and shield the radioactive cathode of the sputter ion source. It took us a lot of time to think about it. The final device for installing, aligning and shielding of the ^{64}Cu cathode was made well. It is shown in Fig.1. The cathode rod is in the cylindrical lead shield. There are the opening guide slot up the shield and the lead cover shaped long trap. So the cathode rod with ^{64}Cu cathode can be moved into the ion source after removing the lead cover. In the shield there is a lead blockage ^{64}Cu cathode at forward direction. While the cathode rod is moving into the ion source, the lead blockage falls down into the trap. There are two adjustable supports under the shield for alignment of the ^{64}Cu cathode.



1.Fast vacuum connector 2.Trap of leak blockage 3.Lead blocage 4.Target 5.Cathode rod 6.Lead shielding 7.Cooling tube 8.Supporting plate 9.Supporting and adjusting unit

Fig.1 Device ofr shielding and aligning ^{64}Cu target of ion source cathode

A permissible radiation does is 5 rem per year and assumed working time is 20hs for one year. In order to reduce radiation does on man body as low as possible, final permissible radiation does of 0.15 rem is determined for one hour. According to the permissible radiation does, the calculated wall thickness of the lead shield is 24mm. The designed wall thickness of the lead shield is 40mm. It is safe to install the ^{64}Cu cathode into the ion source.

5. Separating and distinguishing of ^{64}Cu

The ^{64}Cu cathode was installed in the Model 200 sputtering ion source. Negative ion beam ^{63}Cu, ^{65}Cu and ^{64}Cu from the ion source was injected into the HI-13 Tandem to accelerate respectively. Intensity of ion beam at different points of the HI-13 Tandem Accelerator is listed in table 2.

Table 2. Intensity of Cu ion Beam at different points

Ion species	L. E	Image	Target
^{63}Cu	2400na	560na	120na
^{65}Cu	1200na	280na	60na
^{64}Cu + ^{64}Ni	*560na	/	3.4×10^5/s
^{64}Cu	*560na	/	1.2×10^5/s

* including ^{63}Cu and ^{65}Cu, etc.

The system for separating and distinguishing of RNB ^{64}Cu is showed in Fig.2. At accelerating ^{64}Cu ions, absolute majority of ^{63}Cu and ^{65}Cu from the ion source are deflected by the injector magnet, the 90^0 magnetic analyzer and the switch magnet. But due to that ions pass through the foil stripper and collide with gas, ions have distribution of different charge states and energy. So a few ^{63}Cu and ^{65}Cu ions have momentum as same as ^{64}Cu, and can not be deflected by magnets. They can reach up the experimental target together with ^{64}Cu and ^{64}Ni ions. Their intensity is several classes higher than ^{64}Cu and ^{64}Ni.

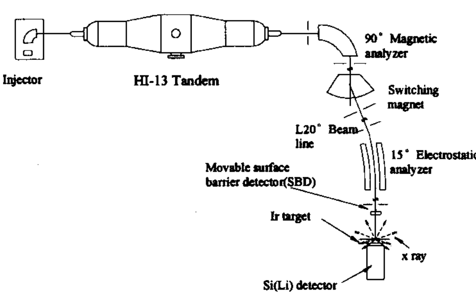


Fig.2 Separating and distinguishing of RNB ^{64}Cu

If different ions have same momentum, their energy is different. The electrostatic analyzer is energy analyzer. So the electrostatic analyzer is installed before the experimental target for deflecting ^{63}Cu and ^{65}Cu. After the electrostatic analyzer, ^{63}Cu and ^{65}Cu ions are deflected, but ^{64}Ni ions are still mixed with ^{64}Cu ions. In order to distinguish ^{64}Cu, ^{64}Cu and ^{64}Ni ions bombard the

Ir target. Characteristic X rays induced by ^{64}Cu and ^{64}Ni ions are measured by the Si (Li) detector. X ray characteristic spectrum of incident ions is showed in Fig.3. According to efficiency of the detector, the ^{64}Cu ion intensity can be determined. RNB ^{64}Cu of 1.2×10^5 ions/s was got on the experimental target.

6. Discussion

Ion intensity of RNB ^{64}Cu (1.25×10^5/s) obtained on the experimental target is lower than expected value. It was caused by two reasons. One, neutron flux (1.2×10^{13}/cm^2·s) of the reactor for irradiating the Cu cathode to produce ^{64}Cu was lower. So radioactivity of ^{64}Cu cathode target was low for producing high current of RNB ^{64}Cu. Another, ionization efficiency of the ion source and ion beam transmission of the HI-13 tandem Accelerator was lower. Some measures will be taken to increase ^{64}Cu beam up to 10^6 ions /s.

During accelerating RNB ^{64}Cu, the radiation does is not over the permissible does far 1m away from the HI-13 Tandem. After shutting down the HI-13 Tandem for two days, no radioactive contamination with long-life and intensive radioactivity could be measured. So it is safe to accelerate RNB ^{64}Cu.

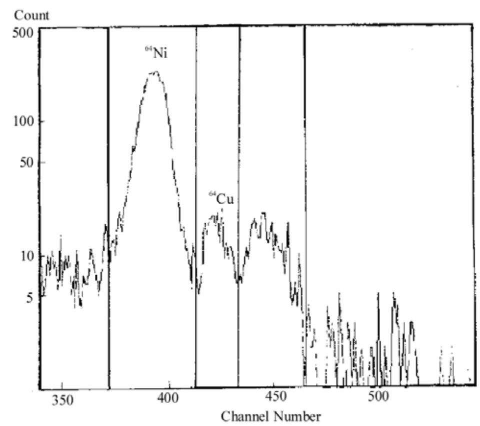


Fig.3 X ray characteristic spectrum of incident ions

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