Production of $^{67}$Cu using the $^{70}$Zn($d,an$)$^{67}$Cu reaction

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Since 2007, we have distributed purified radioisotopes such as $^{66}$Zn and $^{109}$Cd prepared at the RIKEN AVF cyclotron for the purpose of contribution to society throughout industrial application of accelerator based-science. Copper-67 (half-life $T_{1/2} = 61.83$ h and β−-decay branch $I_{β−} = 100\%$) is one of the promising radioisotopes for radiotherapy and radiodiagnosis. Although several routes have been proposed for the production of $^{67}$Cu, the high-energy proton-induced reaction of $^{68}$Zn($p,2p$)$^{67}$Cu has been used most often. In this route, however, a large-scale cyclotron is required to accelerate protons up to ~100 MeV, and a large contamination of the radionuclidal impurity of $^{64}$Cu is unavoidable in the $^{67}$Cu product. Further, the long-lived byproduct of $^{67}$Zn ($T_{1/2} = 244.06$ d) is also undesired in the recycle process of the enriched target material of $^{68}$Zn. Thus, we plan to produce $^{67}$Cu in the $^{70}$Zn($d,an$)$^{67}$Cu reaction, where small amounts of $^{64}$Cu and $^{68}$Zn are produced. In this work, for the future distribution of $^{67}$Cu, we investigated a procedure to prepare purified $^{67}$Cu in the $^{70}$Zn($d,an$)$^{67}$Cu reaction at the AVF cyclotron.

In the $^{70}$Zn($d,an$)$^{67}$Cu route, $^{66}$Ga can be produced from $^{66}$Zn isotopes such as $^{67}$Zn and $^{66}$Zn, which are contained in small amounts in the enriched $^{70}$Zn target. The γ-ray energies of $^{66}$Ga are identical to those of $^{67}$Cu, because $^{66}$Ga and $^{67}$Cu decay to the same excited levels of $^{67}$Zn by EC- and β−-decay, respectively. In addition, the half-life of $^{66}$Ga ($T_{1/2} = 3.26$ d) is almost the same as that of $^{67}$Cu. Thus, it is difficult to distinguish between $^{67}$Cu and $^{66}$Ga by γ-ray spectrometry. Also the expensive enriched isotope of $^{70}$Zn should be recovered for reuse. To develop a chemical procedure to remove $^{66}$Ga from $^{67}$Cu and to recover the rare $^{70}$Zn material, we first produced radiotracers of $^{67}$Cu, $^{66}$Ga, and $^{65m}$Zn in the $^{nat}$Zn($d,X$) reactions by irradiating 24-MeV deuterons on a metallic $^{nat}$Zn foil (nat: natural isotopic abundance; chemical purity: >99.99%; thickness: 71.4 mg cm$^{-2}$). The average beam intensity was 150 nA, and the irradiation time was 26 min. An enriched $^{70}$ZnO target ($^{70}$Zn isotopic abundance: 96.87%; thickness: 327 mg cm$^{-2}$) was also irradiated with the 24-MeV deuterons in order to evaluate the production yield of $^{67}$Cu from the enriched $^{70}$Zn target. The average beam intensity was 18 nA, and the irradiation time was 56 min. After the irradiation, as shown in Fig. 1, Cu isotopes were separated from the $^{nat}$Zn and $^{70}$ZnO targets through a two-step chromatographic separation using the Eichrom Cu resin and the Dowex 1X8 anion-exchange resin. We carried out the chemical procedure using the radiotracers of $^{67}$Cu, $^{66}$Ga, and $^{65m}$Zn produced in the $^{nat}$Zn($d,X$) reaction. A high chemical yield of 97% was obtained for $^{67}$Cu. Decontamination factors of $^{66}$Ga and $^{65m}$Zn from $^{64}$Cu were evaluated to be ~10$^3$ and >10$^3$, respectively. The recovery of >99% for $^{64}$Cu was high enough for recycling of the $^{70}$Zn target material. Figure 2 shows the γ-ray spectrum of the purified $^{67}$Cu from the enriched $^{70}$Zn target. Under the present experimental condition, the production yield of $^{67}$Cu was 4.0 MBq μA$^{-1}$h$^{-1}$. The radioactivity ratio of $^{67Cu}/^{67Ga}$ was about 2×10$^4$ after the chemical separation. Based on the present results, we estimate that about 1 GBq of $^{67}$Cu could be distributed after 3-days irradiation of a metallic $^{70}$Zn target of 357-mg cm$^{-2}$ thickness with a 24-MeV and 10-μA deuteron beam, followed by 3 days for chemical separation and shipment.

![Fig. 1. Chemical separation procedure for $^{67}$Cu produced in the $^{70}$Zn($d,an$)$^{67}$Cu reaction.](image1)

![Fig. 2. γ-ray spectrum of the purified $^{67}$Cu from the enriched $^{70}$Zn target irradiated with the 24-MeV deuteron.](image2)

References
5) Eichrom technologies’ Product Catalog for 2013.