Cross section measurement to produce ^{99}Mo through alpha-induced reactions on natural Zr

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Radiopharmaceuticals containing ^{99m}Tc ($T_{1/2}$ = 6.0 h) produced from the decay of ^{99}Mo ($T_{1/2} = 66$ h) are used worldwide for imaging in diagnostic nuclear medicine. Although nuclear reactors provide sufficient global supplies of ^{99}Mo, unplanned shutdowns due to technical issues disrupt these supplies. In addition, the nuclear waste created by fission reactions in the nuclear reactors is a problem. Therefore, ^{99}Mo production routes other than neutron-induced fission are needed.

One of the reactions that creates ^{99}Mo is the ^{96}Zr(α,n)^{99}Mo reaction. However, previously obtained experimental cross section data[1,2] and TALYS Evaluated Nuclear Data Library (TENDL)[3] for this reaction exhibit discrepancies in their peak positions. It is very important to provide reliable and consistent cross section data for evaluation of the isotope production yields. Therefore, we performed an experiment to measure the cross sections for this reaction.

The cross sections of the ^{96}Zr(α,n)^{99}Mo reaction were measured using the standard stacked-foil activation method and off-line high-resolution high-purity Germanium (HPGe) γ-ray spectrometry. Natural Zr foils (purity: 99.2%, thickness: 20.3 μm; Nilaco Corp., Japan) having ^{96}Zr isotopic abundance of 2.80% and natural Ti foils (purity: 99.6%, thickness: 5.3 μm; Nilaco Corp., Japan) for the ^{nat}Ti(α,x)^{51}Cr monitor reaction were stacked together as a target. This stacked target was then mounted in a target holder that also served as a Faraday cup, and irradiated by a 51-MeV alpha beam with an average intensity of 203.6 pnA for 2 h at the RIKEN Azimuthally Varying Field (AVF) cyclotron. The alpha particle energy in the i-th foil E_i was derived using the stopping power calculated by Stopping and Range of Ions in Matter (SRIM) software.[4]

After a cooling time of 12 h to reduce the backgrounds, the γ-ray spectra on each foil were measured using high-resolution γ-ray spectrometry with a HPGe detector. The characteristic 739-keV γ-line (I_γ= 12.20%) from the decay of ^{99}Mo in the Zr foils and the 320-keV γ-line (I_γ= 9.91%) from the decay of ^{51}Cr in the Ti foils were measured to derive the cross sections of the ^{96}Zr(α,n)^{99}Mo and ^{nat}Ti(α,x)^{51}Cr reactions, respectively. The distance between the measured foil and detector was optimized to maintain a dead time lower than 10%. To obtain the production cross sections of the assessed radionuclide $\sigma(E_i)$, the well-known activation formula was used.

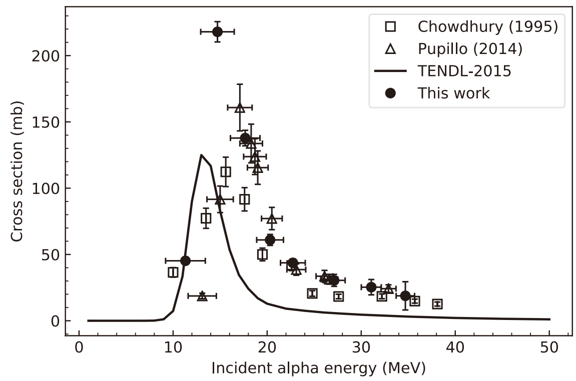

Fig. 1. Experimental cross sections of ^{96}Zr(α,n)^{99}Mo reaction in comparison with previously reported experimental data and TENDL data.

The measured production cross sections of ^{99}Mo are shown in Fig. 1, along with available previous data[1,2] and the TENDL data.[3] Our result shows that the peak is located in the vicinity of 14 MeV with a cross section value of approximately 210 mb, differing from the results of earlier studies.

In this work, the cross sections of the ^{96}Zr(α,n)^{99}Mo reaction were measured using standard methods, *i.e.*, the stacked target method, activation technique, and high-resolution γ-ray spectrometry. The newly measured cross section data were compared with previously reported experimental data and the TENDL data. The peak of the deduced excitation function was higher than that given by the previous data and was located at approximately 14 MeV. To confirm this excitation function behavior, we will repeat this experiment in detail in the energy range of 10 to 20 MeV.

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