Activation cross section measurement of the deuteron-induced reaction on yttrium-89 for zirconium-89 production†

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Zirconium-89 ($T_{1/2} = 78.41$ h) is a positron emitter that is used for positron emission tomography (PET). Its long half-life enables its delivery over long distances and it is suitable for immuno-PET.[1)] High-specific activity of the radionuclide can be produced using charged-particle-induced reactions. There are two promising reactions, namely, the ^{89}Y$(p,n)^{89}$Zr and the ^{89}Y$(d,2n)^{89}$Zr reactions. The former has been well investigated and a large amount of experimental data is present. However, there is a lack of research on the latter reactions and the peak amplitudes of the excitation functions are dispersed.[2)] Therefore, we performed an experiment of the deuteron-induced reactions on ^{89}Y to measure the production cross sections of ^{89}Zr. Additionally, the cross sections for co-produced radionuclides, ^{88}Zr, ^{90m}Y, ^{88}Y, and ^{87m}Sr, were determined.

The experiment was performed at the RIKEN AVF cyclotron. We adopted well-known and established methods, such as stacked-foil activation technique and high-resolution γ-ray spectrometry. Thin metallic foils of ^{89}Y (purity 99.0%, thickness 25 μm, Goodfellow Co., Ltd., UK) and ^{nat}Ti (purity 99.6%, thickness 20 μm, Nilaco Corp., Japan) were used as the target foils. Their weight and area were measured and the derived thicknessess of ^{89}Y and ^{nat}Ti were 12.7 and 9.1 mg/cm^2, respectively. The foils were then cut into a size of 8 × 8 mm^2. Nine sets of four ^{89}Y and two ^{nat}Ti pieces were stacked as the target. The ^{nat}Ti foils were used for the ^{nat}Ti$(d,x)^{48}$V monitor reaction to assess the thicknesses of the foils and beam parameters. The stacked target in a target holder served as a Faraday cup and it was irradiated by a deuteron beam for 1 h. The average beam intensity of 102.3 nA was measured by the Faraday cup. The incident beam energy of 23.6 ± 0.2 MeV was measured by the TOF method. The energy degradation in the stacked target was calculated using the SRIM code.[3)] γ-ray spectra from each irradiated foil without chemical separation were measured using a high-resolution HPGe detector. The foils other than the first one in the same groups were measured to compensate the recoil losses of the products. The efficiency of the detector was calibrated using ^{152}Eu and mixed γ-ray standard sources. Nuclear-decay data were taken from NuDat 2.7.[4)]

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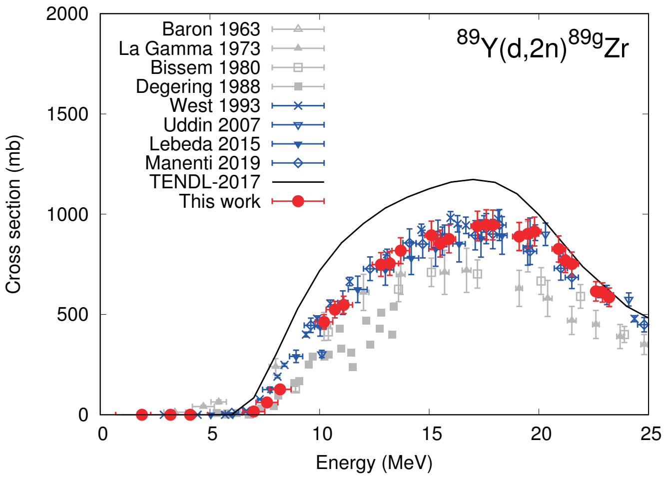

Fig. 1. Cumulative cross sections of the ^{89}Y$(d,2n)^{89g}$Zr reaction in comparison to the previous data[2)] and the TENDL-2017 data.[6)]

The cross sections of the ^{nat}Ti$(d,x)^{48}$V monitor reaction were derived from the measurements of the γ line at 983.5 keV ($I_\gamma = 99.98\%$). Based on a comparison with the IAEA recommended values,[5)] the thicknesses of the ^{89}Y foils were corrected by +2% within their uncertainty and the measured beam parameters were adopted without any corrections.

The cross sections of the ^{89}Y$(d,2n)^{89g}$Zr reaction were derived using measurements of the 909.2-keV γ line ($I_\gamma = 99.04\%$) emitted with the decay of ^{89g}Zr. The metastable state ^{89m}Zr ($T_{1/2} = 4.161$ min) decayed completely during cooling times. The cumulative cross sections were determined, as shown in Fig. 1, with the previous studies and the TENDL-2017 values.[6)] Our experimental data were found to be consistent with the latest four works. The TENDL-2017 values were larger than all experimental data in the energy region between 6 and 20 MeV.

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