Excitation function measurement for zirconium-89 and niobium-90 production using alpha-induced reactions on yttrium-89†

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Zirconium-89 ($T_{1/2}$ = 78.41 h) and niobium-90 ($T_{1/2}$ = 14.6 h) are expected to be used for immuno-PET.[1,2] From the viewpoint of radionuclide production, the investigation of effective production reactions is valuable. We focused on the α-induced reactions on the monoisotopic element ^{89}Y to produce the two radionuclides. Five experimental studies on these reactions[3–5] were found in a literature survey. However, significant discrepancies exist among the experimental data. Therefore, we were motivated to investigate α-induced reactions on ^{89}Y. The cross sections of co-produced radionuclides other than ^{89}Zr and ^{90}Nb were also determined.

The experiment was performed at the RIKEN AVF cyclotron. The stacked foil activation technique and high-resolution γ-ray spectrometry, which are well-established methods, were adopted for the experiment. The target was composed of pure metallic foils of ^{89}Y (99% purity, Goodfellow Co., Ltd., UK), ^{nat}Ti (99.6% purity, Nilaco Corp., Japan), and ^{27}Al (> 99% purity, Nilaco Corp., Japan). The sizes and weights of the foils were measured to determine their average thicknesses, which were found to be 24.2, 5.1, and 5.5 μm for Y, Ti, and Al, respectively. The three foils were cut into a small size of 1 cm × 1 cm to fit a target holder, which also served as a Faraday cup. The stacked target was irradiated with a 50.9 ± 0.1-MeV M-beam for 1 h. The incident energy of the beam was measured using the time-of-flight method.[6] The energy degradation in the target was calculated using stopping powers obtained from the Stopping and Range of Ions in Matter (SRIM) code.[7] The average beam intensity was measured as 411 nA using the Faraday cup. The irradiated stacks were dismantled for the off-line γ-ray spectrometry using HPGe detectors. The dead time was kept under 10% by adjusting the distances between the measured foil and HPGe detector. Reaction and decay data for the γ-ray spectrometry were taken from NuDat 2.7.[8]

The beam parameters were verified using the ^{27}Al(α,x)^{22}Na and ^{nat}Ti(α,x)^{51}Cr monitor reactions in comparison with the IAEA recommended values.[9] Based on the comparison, the beam intensity was decreased by 4% from the measured value. The corrected intensity of 398 nA was adopted to derive cross sections.

The excitation function of the ^{89}Y(α,x)^{89g}Zr reaction

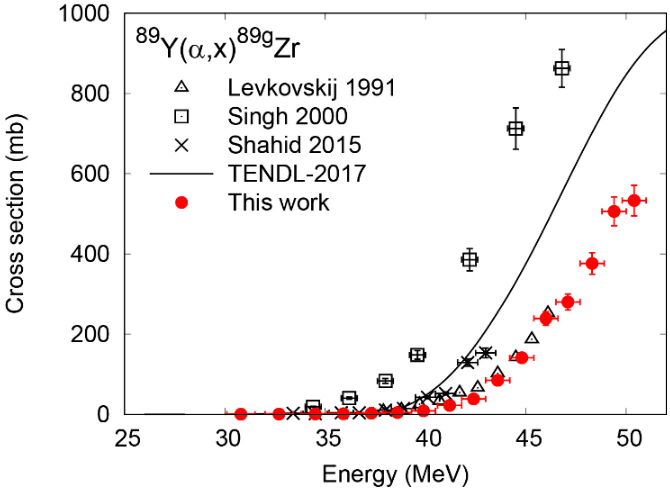

Fig. 1. Comparison of cumulative cross sections of the ^{89}Y(α,x)^{89g}Zr reaction with previously reported data[3–5] and TENDL-2017 data.[10]

was determined. The measurement of the 909.15-keV γ-rays ($T_{1/2}$ = 78.41 h, I_γ = 99.04%) was performed after a cooling time of 10 days, which was long enough for complete decay of the parent nuclei ^{89g,m}Nb and ^{89m}Zr. The cumulative cross sections of ^{89g}Zr were obtained and compared with three previous studies[3–5] and TENDL-2017 data[10] in Fig. 1. One of the three experimental data sets[3] agree with our result. However, the others[4,5] deviate from ours.

In addition to ^{89g}Zr, the production cross sections of ^{90}Nb and other co-produced radionuclides were determined and compared with previous studies and the TENDL-2017 data. Our results are reasonably consistent with some of the previous studies.

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