Activation cross sections of alpha-particle-induced reactions on natural lanthanum up to 50 MeV†

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In the medical field, radionuclides have been applied to therapy and diagnosis for decades. Ensuring the accuracy of nuclear data is essential for the safe and effective production of radionuclides. Recently, there have been investigations into radionuclides that can be used for both therapy and diagnosis. The radionuclide ^{142}Pr ($T_{1/2} = 19.12$ h) is among the applicable candidates.[1)] The alpha-particle-induced reaction on lanthanum is a practical method to generate ^{142}Pr. We found only two experimental studies of the ^{nat}La$(\alpha, x)^{142g}$Pr reaction,[2,3)] for which the data are scattered and not fully consistent (Fig. 1). Therefore, we measured the production cross-sections of the ^{nat}La$(\alpha, x)^{142}$Pr reaction using the activation method.

Two independent experiments were performed using 50 (#1) and 29 MeV (#2) α beams at the RIKEN AVF cyclotron. To determine the excitation function, we applied the stacked-foil technique, and used a high-resolution germanium detector to measure the γ rays from generated radionuclides. The stacked targets comprised ^{nat}La (99% purity), ^{27}Al (>99% purity) and ^{nat}Ti (99.6% purity) metal foils purchased from Nilaco Corp., Japan. The actual thicknesses were derived as 15.4, 2.25, and 1.22 mg/cm^2 for the ^{nat}La, ^{nat}Ti, and ^{27}Al foils, respectively. The ^{nat}Ti foils were inserted into the stack for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction to assess the beam parameters, energy loss of the particles, and target thicknesses through comparisons of the measured data with the recommended values.[4)] The initial beam parameters were accepted; however, the thicknesses of ^{nat}La foils were corrected by +2% within the uncertainties (2%).

The ^{27}Al foils were used as catchers of recoiled products and for energy degradation. In experiment #1, eighteen sets of La-Al-Ti-Ti, and in experiment #2, eight La-Al-Ti foils were stacked into the target holders and served as Faraday cups. The energy degradation of the beam in the target was calculated using stopping powers obtained from the SRIM code.[5)] Both targets were irradiated for 30 min. The average beam intensities were 196 (#1) and 210 nA (#2), and the measured primary beam energies were 50.6 (#1) and 29.0 MeV (#2).

The ^{nat}La foils with the following ^{27}Al catcher foil were measured together using a high-purity germanium detector after cooling times of 7–28 h. The γ line at 1575.85 keV ($I_\gamma = 3.7\%$) with no interferences from decay of ^{142g}Pr was analyzed to derive the cross-sections of the ^{nat}La$(\alpha, x)^{142}$Pr reaction. The ^{142m}Pr isomer ($T_{1/2} = 14.6$ min) produced simultaneously in the reaction decayed by IT decay mode to the ground state during the cooling time. The cross-sections derived from the γ ray spectra were cumulative owing to the contribution from the decay of its isomer.

The results of the experiments #1 and #2 are shown in Fig. 1 and compared with the previous studies[2,3)] and the TENDL-2021 values.[6)] Data from our experiments were consistent with each other. However, our cross-sections were slightly larger than the previous data above 17 MeV. The TENDL curve underestimated all data above 17 MeV, its peak was located at slightly lower energy and its width was narrower than those of all data.

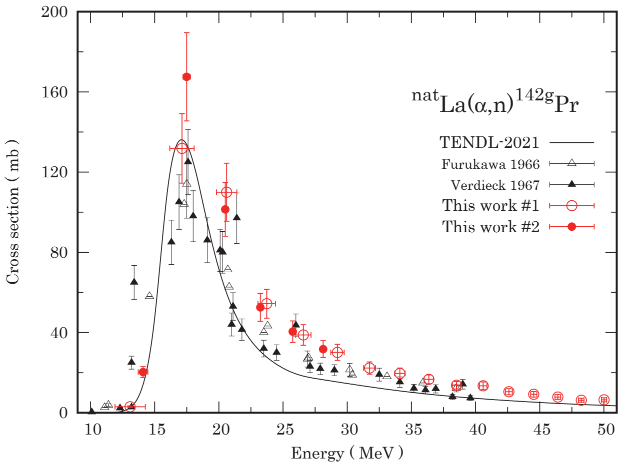

Fig. 1. Cumulative cross-sections of the ^{nat}La$(\alpha, n)^{142g}$Pr reaction in comparison with the previous data[2,3)] and the TENDL-2021 curve (solid line).[6)]

In addition to ^{142}Pr, production cross-sections for ^{139,138m}Pr and ^{141,139g}Ce were also obtained in this study. Furthermore, data of ^{139g}Ce and ^{138m}Pr were determined for the first time.

References

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