Production cross sections for α-particle-induced reactions on ^{nat}La

S. Ebata,[*1,*2] M. Aikawa,[*3,*2] G. Damdinsuren,[*4,*2] and H. Haba[*2]

The application of radionuclides was started several decades ago. Given its widespread use, it is important for the nuclear medicine field to generate new medical isotopes using more safe and effective methods. To this end, radionuclides suitable for both therapy and diagnosis have been investigated in recent years. The radionuclide ^{142}Pr ($T_{1/2} = 19.12$ h) is one of the applicable candidates because of its β decay ($\langle E_{\beta^-} \rangle = 810$ keV, 96.3%) and low-intensity specific γ emission with $E_\gamma = 1575$ keV (3.7%).[1)] Among the possible ways to generate ^{142}Pr, the proton-, deuteron-, and alpha-particle induced reactions on cerium and lanthanum can be considered for on-site production at small light-ion accelerators used in hospitals. In the literature survey, only two experimental studies were found for the ^{nat}La$(\alpha, x)^{142}$Pr reaction,[2,3)] and they did not provide consistent results (See Fig. 1.). Therefore, we focus on the α-particle-induced reaction on natural lanthanum and measure the production cross sections for the reaction using an activation method.

Two independent experiments were performed using 50-(#1) and 29-MeV (#2) α beams at the RIKEN AVF cyclotron. The stacked-foil technique was adopted in the activation method, and high-resolution germanium-detector based γ-spectrometry was used to measure γ rays from the 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 natural abundances of ^{138}La and ^{139}La are 0.09% and 99.91%, respectively. The measured thicknesses of the foils were 15.4 mg/cm^2 (^{nat}La), 2.25 mg/cm^2 (^{nat}Ti), and 1.22 mg/cm^2 (^{27}Al). The ^{nat}Ti foils were interleaved for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction to assess beam parameters and target thicknesses. The ^{27}Al foils were used as catchers for recoiled products and for energy degradation. Eighteen sets of La-Al-Ti-Ti (#1) and eight La-Al-Ti foils (#2), which were cut into a size of 8 × 8 mm^2, were stacked into target holders served as Faraday cups.

Both stacked targets were irradiated with α beams for 30 min. The average beam intensities were 196 (#1) and 210 nA (#2), which were measured on the Faraday cups. The measured primary beam energies were 50.6 (#1) and 29.0 MeV (#2). The energy degradation of the beams in the stacked targets was calculated using stopping powers by the SRIM code.[4)]

The emitted γ rays from the irradiated foils were measured using a high-purity germanium detector. Each ^{nat}La foil with its following ^{27}Al catcher foil was measured several times with a dead time less than 2.8%. The ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction was used to assess beam parameters and target thicknesses by comparing the measured cross sections for the reaction with the IAEA recommended values.[5)] Only the thickness of the ^{nat}La foils was corrected by +1% within uncertainties to ensure consistency with the recommended values.

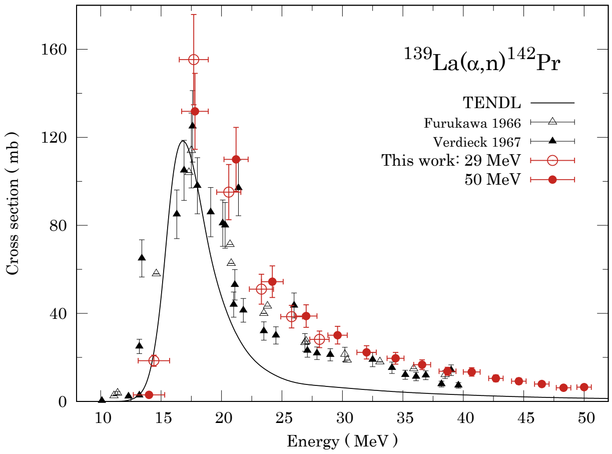

Fig. 1. Cross sections of the ^{139}La$(\alpha, n)^{142}$Pr reaction. The previous studies[2,3)] and the TENDL-2019 values[5)] are shown.

The γ line at 1575 keV with the decay of ^{142}Pr was analyzed to derive the cross sections of the ^{nat}La$(\alpha, x)^{142}$Pr reaction. The cross sections are practically the same as those of the ^{139}La$(\alpha, n)^{142}$Pr reaction because the contribution of the capture reaction on the less-abundant ^{138}La is negligible. The results with 50 and 29 MeV α beams are shown in Fig. 1 and are compared to those reported in previous studies[2,3)] and the TENDL-2019 values.[6)] Our independent data for 50 and 29 MeV agree well with each other. The present cross sections are slightly larger than those reported in the literature above 20 MeV, whereas the TENDL values underestimate all experimental data. Moreover, the peak widths of the experimental data were broader than those of the TENDL values.

References
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*1 Department of Physics, Saitama University
*2 RIKEN Nishina Center
*3 Faculty of Science, Hokkaido University
*4 Graduate School of Biomedical Science and Engineering, Hokkaido University