Excitation functions of deuteron-induced reactions on ^{141}Pr for medical radioisotope production

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Investigation of the production of medical radioisotopes is indispensable for the development of imaging and therapy. Radioisotopes ^{140}Nd ($T_{1/2} = 3.37$ d) and ^{142}Pr ($T_{1/2} = 19.12$ h) are expected for ^{140}Nd/^{140}Pr generator in positron emission tomography (PET)[1] and the treatment for arteriovenous malformations,[2] respectively. Some charged-particle-induced reactions can produce these two radioisotopes. Among them, we focused on deuteron-induced reactions on monoisotopic element ^{141}Pr. In a literature survey, only two experimental studies for these reactions were found[3,4] below 30 MeV and their experimental cross-section data are scattered. Therefore, we performed an experiment to measure the production cross sections of ^{140}Nd and ^{142}Pr to contribute to the development of nuclear medicine.

The experiment was performed at the RIKEN AVF cyclotron. The stacked-foil activation technique and high-resolution γ-ray spectrometry were adopted in the experiment.

The stacked target consisted of pure metallic foils of ^{141}Pr and ^{nat}Ti. The ^{nat}Ti foils were interleaved for the ^{nat}Ti$(d,x)^{48}$V monitor reaction to assess the beam parameters and target thicknesses. The ^{141}Pr (purity: 99%, thickness: 100 μm, size: 25×25 mm^2) and ^{nat}Ti (purity: 99.6%, thickness: 5 μm, size: 50×100 mm^2) foils were purchased from Nilaco Corp., Japan. The surface area and weight of each foil were measured and their thicknesses were determined to be 67.6 and 2.3 mg/cm^2. The foils were cut into a small size of 8×8 mm^2 to fit a target folder. Nine sets of Pr-Ti-Ti foils were stacked into the target folder that served as a Faraday cup.

The stacked target was irradiated with a deuteron beam for 30 min. The beam intensity of 107 nA was measured by the Faraday cup. The incident energy of 24.1 MeV was measured using the time-of-flight method. Energy degradation in the stacked target was calculated using the SRIM code.[5]

γ rays emitted from the irradiated foils were measured using an HPGe detector. The efficiency of the detector was calibrated using a standard γ-ray point source. Each ^{141}Pr foil with the next ^{nat}Ti catcher foil for recoiled products was measured five times after cooling times from 2.2 h to 40.2 d. The dead time was kept below 5.2%. The required nuclear data were retrieved from the NuDat 2.8 online database.[6]

The ^{nat}Ti$(d,x)^{48}$V monitor reaction was used to assess the beam parameters and target thicknesses. The cross sections of the monitor reaction were derived from the measurement of the 983.5-keV γ line. The result was compared with the IAEA recommended values.[7] According to the comparison, the beam intensity was corrected by -7%. The corrected intensity and measured thicknesses were used to deduce the production cross sections.

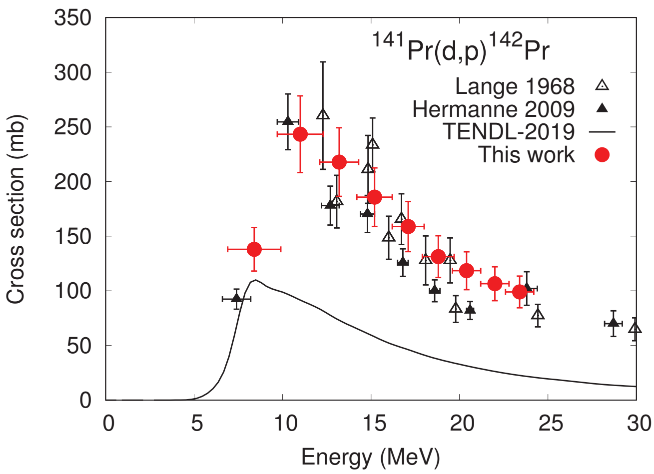

Fig. 1. Cross sections of the ^{141}Pr$(d,p)^{142}$Pr reaction in comparison with the previous data[3,4] and the TENDL-2019 values.[8]

The cross sections of the ^{141}Pr$(d,p)^{142}$Pr reaction were derived from the measurement of the 1575.6-keV γ line ($I_\gamma = 3.7$%) with decay of ^{142}Pr. The result is shown in Fig. 1 with the previous studies[3,4] and the TENDL-2019 values.[8] The previous experimental data and their trends are almost consistent with our result within the uncertainties, which are large due to that of the γ-ray intensity ($\Delta I_\gamma / I_\gamma = 10.8$%). The TENDL-2019 values were found to be smaller than all experimental data.

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