Activation cross section measurement of alpha-particle induced reactions on natural neodymium[†]

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Some samarium radionuclides can be used for nuclear medicine. ^{153}Sm ($T_{1/2}$ = 46.3 h) is a beta and gamma emitter available to treat bone metastases.[1)] ^{145}Sm ($T_{1/2}$ = 340 d) decays with the emission of low-energy X rays, which is applicable in brachytherapy.[2)] These samarium radionuclides can be generated simultaneously in alpha-particle-induced reactions on natural neodymium. Highly accurate cross sections of the reactions are indispensable for practical use. However, there is only one previous experimental study on the ^{nat}Nd$(\alpha, x)^{153}$Sm reaction up to 26.2 MeV.[3)] Further, the literature survey did not reveal any experimental research on the ^{nat}Nd$(\alpha, x)^{145}$Sm reaction. Therefore, we measure the cross sections of the alpha-particle-induced reactions on natural neodymium up to 51 MeV.

The experiment was performed at the RIKEN AVF cyclotron. The stacked-foil activation technique and high-resolution gamma-ray spectrometry were adopted for the experiment. The target consisted of pure metal foils of ^{nat}Nd (99.0% purity, Goodfellow Co., Ltd., UK) and ^{nat}Ti (99.6% purity, Nilaco Corp., Japan). The thicknesses of the ^{nat}Nd and ^{nat}Ti foils were 16.7 and 2.35 mg/cm^2, respectively, which were deduced from the measurement of their weights and surface areas. Twenty-one Nd and fourteen Ti foils were arranged in seven sets of Nd-Nd-Nd and Ti-Ti pairs. The second and third Nd foils and the second Ti foil of each pair were assumed to compensate the recoiled products. The ^{nat}Ti foils were inserted for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction to assess the measured beam parameters and target thicknesses.

The stacked target was irradiated with an alpha-particle beam for 60 min. The measured beam energy and intensity were 51.1 ± 0.2 MeV and 172 nA, respectively. Energy degradation through the stacked target was calculated using the SRIM code.[4)] The gamma-ray spectra were acquired for the recoil-compensated foils by an HPGe detector without chemical separation. Measurements were performed several times after cooling from 0.7 h to 4.0 d to follow the decay of the produced radionuclides with different half-lives. The distances between the foils and the detector were adjusted to keep the dead time less than 5%.

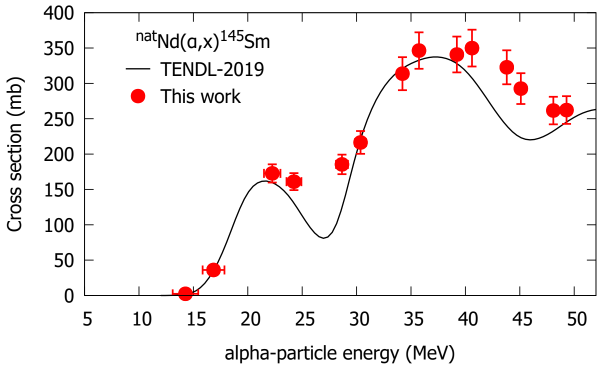

Fig. 1. Excitation function of the ^{nat}Nd$(\alpha, x)^{145}$Sm reaction compared with the TENDL-2019 data.[6)] No experimental data published earlier was found in a survey.

The derived cross sections of the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction were compared with the IAEA recommended values.[5)] The observed shift on the energy scale was corrected by changing the thickness of the Nd foils by −1.5% within its 2% uncertainty to 16.4 mg/cm^2. No additional adjustments were adopted for the data analysis to determine the cross sections of the alpha-particle-induced reactions on natural neodymium.

^{145}Sm ($T_{1/2}$ = 340 d) can be produced in (α, xn) reactions on the stable isotopes of ^{142,143,144,145,146}Nd below 51 MeV. The gamma line at 61.2265 keV (I_γ = 12.15%) emitted with the decay of ^{145}Sm was measured after cooling for 1.4–4.0 days. The net counts of the gamma line were corrected by +8.4% because of the self-absorption effect in the ^{nat}Nd foils. The cross sections of the ^{nat}Nd$(\alpha, x)^{145}$Sm reaction were derived from the corrected net counts. The result is shown in Fig. 1 in comparison with theoretical values from the TENDL-2019 library.[6)] The TENDL-2019 values are almost consistent with our experimental data. Activation cross sections for other radionuclides ^{153}Sm, ^{151,150,149,148m,148g,144,143}Pm, and ^{149,147}Nd were also determined.

References
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