Activation cross-sections of α-particle-induced reactions on ^{nat}Dy

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Dysprosium (Dy) is a rare-earth element that can be used as target material for producing radioisotopes for medical applications. A literature survey revealed only two experimental studies reporting cross-section data of α-particle-induced reactions on a Dy target. The published corresponding datasets are significantly different; therefore, a new experiment was performed to investigate ^{nat}Dy(α, x) reactions and obtain more reliable cross-sections data of possible reactions.

The experiment was performed at the AVF cyclotron of the RIKEN RI Beam Factory by irradiating a stacked-foil target using the standard activation method and high-resolution γ-ray spectrometry. The target was comprised of pure metallic foils of ^{nat}Dy (nominal thickness 21 μm, 99.99% purity, Goodfellow, UK) and ^{nat}Ti (nominal thickness 5 μm, 99.6% Nilaco Co., Japan). The ^{nat}Ti foils were used as monitor foils for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction. For both of the foils the average thickness was determined from the measured lateral size and weight of the purchased original foils. The derived thicknesses of the ^{nat}Dy and ^{nat}Ti foils were 35.4 and 2.24 mg/cm^2, respectively. Target foils, size of 10×10 mm, were prepared and stacked in a target holder, which served as a Faraday cup to collect the charge of the incident beam particles. The stack consisted of three groups of Dy foils of 13, 7, and 2 in number, respectively. Between the groups of Dy foils groups of Ti foils were inserted of 3, 4, and 4 in number, respectively. Therefore, the complete stack composition was 13Dy-3Ti-7Dy-4Ti-2Dy-4Ti. The Ti foils were positioned in the stack to provide maximum information on the beam parameters and energy loss of the α-particles in the target stack. The stacked target was irradiated with a 50.88 ± 0.20 MeV α-particle beam for 1 hour. The primary beam energy was measured using the time-of-flight method.[1)] Energy degradation in the target was calculated using the stopping power data derived from the SRIM code.[2)] The average beam intensity on the Faraday cup was 136.7 nA.

γ-ray spectra of the Dy target and Ti monitor foils were measured using a high-resolution HPGe detector (ORTEC GEM-25185-P) and analyzed by using dedicated software (SEIKO EG&G Gamma Studio and Genie2000). The spectra of each foil were measured several times to follow the decay of the reaction products. Four series of γ-measurements were performed from a cooling time of 1 hour to a cooling time of 76 d. The detector to foil distance was adjusted for the four series of measurements to maintain a low dead time.

Considering the recoil effect, the cross-sections of the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction were determined for every Ti foils except the first one in each group using the γ-line at 320.08 keV ($I_\gamma = 9.910\%$) of ^{51}Cr ($T_{1/2} = 27.7025$ d). The results were compared with the recommended values provided by an IAEA database.[3)] Based on the comparison, the incident beam energy was increased to 50.90 ± 0.2 MeV, and thickness of the ^{nat}Dy foil was adjusted by 0.13% to 35.3 ± 2.5 mg/cm^2. Owing to the escaping of secondary electrons, the beam intensity was reduced by 6% to 120.8 ± 6 nA. With these adopted changes, good agreement was reached with the recommended values.

In principle activation cross-sections can be deduced for several Er, Ho, Dy, and Tb reaction products. Owing to the decay parameters of the reaction products and limitation of certain experimental parameters, the activation cross-sections were determined from the threshold up to 50.3 MeV energy for production of ^{160,161}Er, ^{160m,166m,166g,167}Ho, ^{157}Dy, and ^{160}Tb. The cross-sections for the ^{nat}Dy$(\alpha, x)^{161}$Er reaction are presented as preliminary results in Fig. 1 together with previous experimental data[4)] and the TENDL-2021 values.[5)] The data were assessed using the γ-lines at 314.8 keV ($I_\gamma = 2.49\%$) and 826.6 keV ($I_\gamma = 64\%$) emitted after the decay of ^{161}Er. Measurements were performed after 3 hours–29 hours of cooling times. The figure shows that the earlier experimental data are consistently higher by approximately 25% and that the TENDL-2021 values are even higher ($\sim$40%). The data analysis is ongoing the final results are expected to be obtained in 2024.

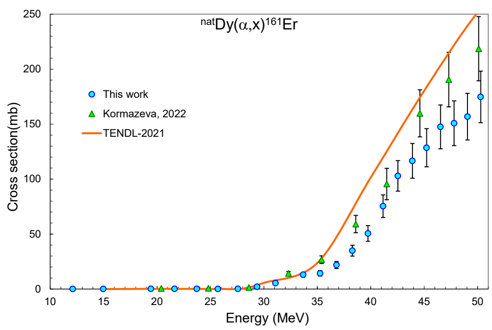

Fig. 1. Experimental cross-sections of the $^{\rm nat}$Dy(α, x)161Er reaction in comparison with the earlier data[4)] and TENDL-2021 values.[5)]

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