# Activation-cross-section measurement of alpha-induced reactions on natural dysprosium

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Holmium-166 can be used for a liver-cancer treatment called radioembolization.[1)] It is worthwhile to investigate the most efficient method for $^{166}$Ho production by comparing possible production reactions. The alpha-induced reaction on dysprosium is one of them. However, there are no available experimental data for this reaction. Thus, we were motivated to perform an experiment for the $^{\rm nat}$Dy$(\alpha,x)^{166}$Ho reaction.

The experiment was performed using the AVF cyclotron at the RIKEN Beam Factory (Wako, Saitama, Japan). The stacked-foil activation technique and high-resolution $\gamma$-ray spectrometry were used to measure the cross sections of generated radionuclides. The stacked-foil target consisted of natural dysprosium (99% purity, Goodfellow Co., Ltd., UK) and natural titanium (99.6% purity, Nilaco Corp., Japan). The sizes and weights of both foils were measured, and the derived average thicknesses of the natural dysprosium and natural titanium foils were 23.6 $\mu$m and 5.1 $\mu$m, respectively. Both foils were cut into pieces of 8 × 8 mm$^2$ size and inserted into the target holder, which served as a Faraday cup. The target was irradiated with a 50.6-MeV alpha beam. The measured beam intensity was 103.8 pnA. The beam energy was measured using the time-of-flight (TOF) method.[2)] The energy degradation in the target was calculated using the stopping powers obtained from SRIM code.[3)]

After one-hour irradiation, the target was removed from the target holder for off-line $\gamma$-ray spectrometry using a high-purity germanium (HPGe) detector. The 320.08-keV $\gamma$-line ($T_{1/2}$ = 27.704 d, $I_\gamma$ = 9.91%) was used to derive the cross sections of the $^{\rm nat}$Ti$(\alpha,x)^{51}$Cr monitor reaction.

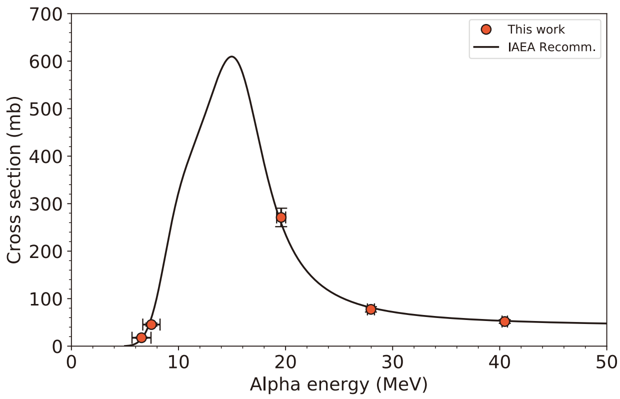


Fig. 1. Comparison of the excitation function of the $^{\rm nat}$Ti$(\alpha,x)^{51}$Cr monitor reaction with IAEA's recommended values.[4)]

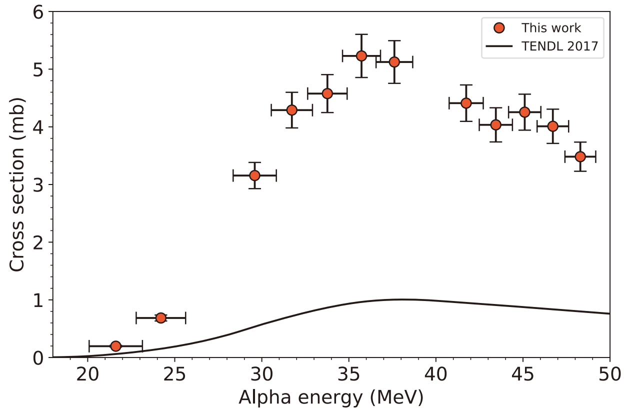


Fig. 2. Comparison of the excitation function of the $^{\rm nat}$Dy$(\alpha,x)^{166}$Ho reaction with the TENDL-2017 data.[5)]

Because the cross sections of the monitor reaction were significantly different from IAEA's recommended values,[4)] an elemental analysis of the dysprosium foil was conducted via scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) using JSM-6610LA with JED-2300, JEOL Ltd. at Hokkaido Research Organization. The foil was found to contain 4.27% oxygen by mass. The stopping power of natural dysprosium was modified by considering the oxygen compounds. Consequently, the excitation function of the $^{\rm nat}$Ti$(\alpha,x)^{51}$Cr reaction showed good agreement with the recommended values[4)] as shown in Fig. 1. The beam intensity was corrected by −4% from the measured one.

The $\gamma$-line of 80.576 keV ($T_{1/2}$ = 26.824 h, $I_\gamma$ = 6.56%) was used to derive the excitation function of the $^{\rm nat}$Dy$(\alpha,x)^{166}$Ho reaction. The result is shown in Fig. 2 with the TENDL-2017 data.[5)] It was found that the TENDL-2017 data[5)] significantly underestimate the cross sections of this reaction.

The production of the radioactive by-products, such as $^{167}$Ho ($T_{1/2}$ = 3.003 h), is being analyzed. The results will be published in a forthcoming paper.

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