# Production cross sections of dysprosium-159 radioisotope from the deuteron-induced reactions on terbium-159 up to 24 MeV†

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Dysprosium-159 ($T_{1/2}$ = 144.4 d) can be used to determine of bone mineral density.[1] The dysprosium radionuclide can be produced by the charged-particle-induced reactions on the monoisotopic element terbium-159. In this work, the production cross sections of $^{157,159}$Dy and $^{160}$Tb in the deuteron-induced reactions on $^{159}$Tb were studied. The results were compared with experimental data published previously[2,3] and TENDL-2017 data.[4]

The experiment was performed at the RIKEN AVF cyclotron. The stacked foil technique, the activation method, and high-resolution $\gamma$-ray spectrometry were used to determine the activation cross sections.

The stacked target consisted of $10 \times 10$ mm$^2$ foils cut from a large Tb foil (25 $\mu$mt, $25 \times 50$ mm$^2$, 99.9% purity, Nilaco Corp., Japan) and two Ti foils (5 $\mu$mt, $50 \times 100$ mm$^2$, 99.6% purity and 20 $\mu$m, $120 \times 100$ mm$^2$, 99.5% purity, Nilaco Corp., Japan). The sizes and weights of the large foils were measured to derive the thicknesses. The thicknesses of the Tb and two Ti foils were found to be 20.56, 2.25, and 9.31 mg/cm$^2$, respectively. The Ti foils were interleaved to check the beam parameters using the $^{\mathrm{nat}}$Ti$(d,x)^{48}$V monitor reaction. The cut foils were stacked in a target holder, which also served as a Faraday cup.

The deuteron beam was accelerated to 23.9 MeV using the RIKEN AVF cyclotron. The beam energy was measured by the time-of-flight method.[5] The stacked target was irradiated by the beam for 60 min with an average intensity of 94.3 nA. The beam intensity was measured using the Faraday cup. Energy degradation in the stacked target was calculated using SRIM code.[6]

The $\gamma$-rays emitted from the irradiated foils were measured using a high-resolution high-purity germanium (HPGe) detector. The $\gamma$-ray spectra were analyzed using the software Gamma Studio (SEIKO EG&G). The $\gamma$ line at 58.0 keV ($I_\gamma = 2.27\%$) emitted with the $^{159}$Dy decay ($T_{1/2}$ = 144.4 d) was measured to derive the cross sections of the $^{159}$Tb$(d,2n)^{159}$Dy reaction. The measurements were performed after a cooling time of 94 days. The $\gamma$ line had negligible interference with the x-ray of the lead shielding of the detector, which could be confirmed by the absence of peaks at the energy in the two foils at the downstream of the beam. The self-absorption of the low-energy $\gamma$ line in the Tb foils was considered using the mass attenuation coefficient.

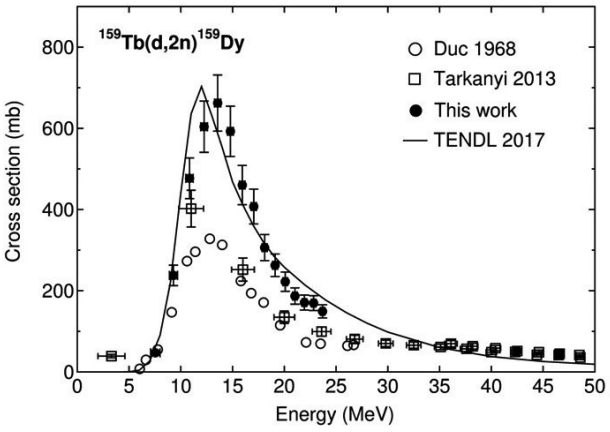


Fig. 1. Excitation function of the $^{159}$Tb$(d,2n)^{159}$Dy reaction.

The cross sections derived from the corrected activities for $^{159}$Dy production are presented with previous experimental data[2,3] and TENDL-2017 data[4] in Fig. 1.

Our experimental data show a peak at approximately 14 MeV, which is consistent with other experimental data, while the amplitudes are substantialy different. The TENDL-2017 data slightly deviate from ours.

In summary, we performed an experiment to measure the excitation functions of deuteron-induced reactions on $^{159}$Tb up to 24 MeV at the RIKEN AVF cyclotron. The production cross sections of $^{157,159}$Dy and $^{160}$Tb were determined. The results were compared with previously obtained experimental data and TENDL data.

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