Production cross-sections of dysprosium-159 radioisotope obtained by α-particle-induced reactions of natural gadolinium up to 50 MeV†

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Dysprosium and terbium radioisotopes are of interest for diagnosis and therapy in nuclear medicine. Dysprosium-157 ($T_{1/2}$ = 8.14 h), dysprosium-159 ($T_{1/2}$ = 144.4 d), and terbium-155 ($T_{1/2}$ = 5.32 d) can be used for bone scanning (skeletal imaging),[1)] determination of bone mineral,[2)] and single-photon emission computerized tomography imaging,[3)] respectively.

Radionuclides can be produced in natural gadolinium by charged-particle-induced reactions. In this study, the activation cross-sections of α-particle-induced reactions in natural gadolinium were investigated. Production cross-sections of ^{155,157,159}Dy, ^{153,155,156g,160,161}Tb, and ^{153}Gd were determined. The results were compared with TENDL-2019 data based on TALYS code calculation.[4)]

Experiments were conducted at the RIKEN AVF cyclotron, which in the stacked foil technique, the activation method and the high-resolution γ-ray spectrometry to determine the activation cross-sections.

A stacked target was formed of 8 × 8 mm^2 foils cut from large Gd (25 μm, 50×50 mm^2, 99.9% purity, Nilaco Corp., Japan) and Ti foils (5 μm, 50 × 100 mm^2, 99.6% purity, Nilaco Corp., Japan). The isotopic composition of the natural Gd target was ^{152}Gd (0.2%), ^{154}Gd (2.2%), ^{155}Gd (14.8%), ^{156}Gd (20.5%), ^{157}Gd (15.6%), ^{158}Gd (24.8%), and ^{160}Gd (21.9%).

The sizes and weights of the large foils were measured to derive the thicknesses of the Gd and Ti foils, which were found to be 25.4 and 2.29 mg/cm^2, respectively. The Ti foils were used in the $^{\rm nat}$Ti$(\alpha, x)^{51}$Cr monitor reaction to assess beam parameters and target thicknesses. The cut foils were stacked into the target holder, which was used as a Faraday cup.

An α-particle beam was accelerated to 51.1 MeV by the RIKEN AVF cyclotron. The beam energy was obtained using the time-of-flight method.[5)] The stacked target was irradiated by the beam for 60 min with an average intensity of 257.6 nA. The beam intensity was measured using the Faraday cup. Energy degradation in the stacked target was calculated using the SRIM code.[6)]

The γ rays emitted from the irradiated foils were measured by a high-resolution high-purity germanium detector.

The γ-ray spectra were analyzed with the Gamma Studio (SEIKO EG&G) software.

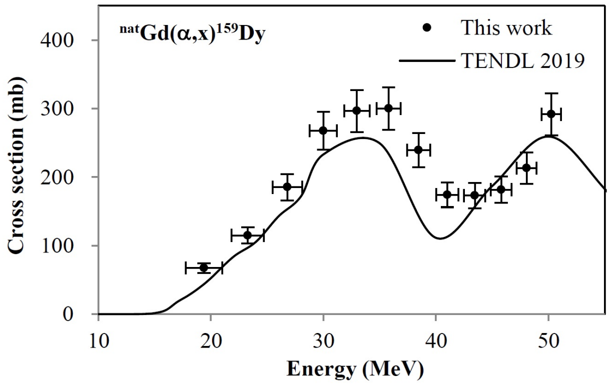

Fig. 1. Excitation function of the $^{\rm nat}$Gd$(\alpha, x)^{159}$Dy reaction compared to TENDL-2019 data.[4)]

The cross-sections of the $^{\rm nat}$Gd$(\alpha, x)^{159}$Dy reaction were determined using the γ-ray line at 58.0 keV (I_γ = 2.27%) from the ^{159}Dy decay ($T_{1/2}$ = 144.4 d). To reduce the γ-ray background from the short-lived radionuclides, the measurements were executed after cooling times of 25.4–28.8 d. The mass attenuation coefficient adopted for the γ-ray line at 58.0 keV was 12.8 cm^2/g.[7)] The correction factor using Eq. (1) of Ref. 8) is 1.17. The cross-sections of the ^{159}Dy production derived from the corrected activities are presented with the TENDL-2019 data[4)] in Fig. 1. Our experimental data show peaks at approximately 35 and above 50 MeV. The peak amplitudes and positions in the TENDL-2019 data agree with our results. Reported experimental data were no found in our literature survey.

Production cross-sections of ^{155,157}Dy, ^{153,155,156g,160,161}Tb, and ^{153}Gd were also determined. The results of this study are expected to contribute to the research and development of nuclear medicine.

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