Production cross-sections of dysprosium-159 radioisotope from alpha-particle-induced reaction on natural terbium up to 50 MeV

D. Ichinkhorloo,[*1,*2] M. Aikawa,[*2,*3,*4] Ts. Zolbadral,[*1,*2] S. Goto,[*2,*4] G. Damdinsuren,[*1,*2,*4] N. Ukon,[*2,*5] and H. Haba[*2]

Dysprosium-159 radioisotope ($T_{1/2}$ = 144.4 d) can be used for determination of bone mineral.[1)] ^{159}Dy can be produced by the charged-particle-induced reactions on a monoisotopic element target of terbium-159. In previuos work, we studied production cross sections of ^{159}Dy from the deuteron-induced reactions on ^{159}Tb up to 24 MeV.[2)]

In this work, the production cross sections of ^{159}Dy, ^{159}Ho, ^{160m}Ho, ^{161}Ho and ^{162}Ho, in the α-particle-induced reactions on ^{nat}Tb were studied. The cross sections for the ^{159}Dy production are presented with the TENDL-2021 data[3)] in Fig. 1. There are no previous experimental data found in our literature survey.

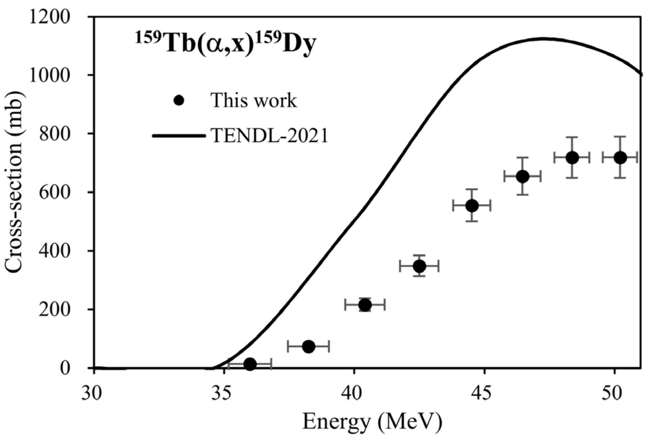

Fig. 1. Excitation function of the ^{159}Tb$(\alpha, x)^{159}$Dy reaction with the TENDL-2021 values.[5)]

The experiment was performed at the RIKEN AVF cyclotron using the stacked foil technique, activation method, and high-resolution γ-ray spectrometry to determine the activation cross-sections.

The stacked target foils of 8 × 8 mm were cut from a large ^{159}Tb foil (25 × 50 mm, 99.9% purity, Nilaco Corp., Japan), ^{27}Al (100 × 100 mm, 99.9% purity, Nilaco Corp., Japan), and ^{nat}Ti foils (50 × 100 mm, 99.6% purity, Nilaco Corp., Japan). The sizes and weights of the large Tb, Al and Ti foils were measured to derive the thicknesses, which were 19.1, 1.21 and 2.37 mg/cm^2, respectively. The ^{nat}Ti foils were used to confirm the beam parameters using the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction. The cut foils were stacked into the target holder which served as a Faraday cup.

The α-particles were accelerated to 50.9 MeV by the RIKEN AVF cyclotron. The beam energy was measured by the time-of-flight method.[4)] The stacked target was irradiated by the beam for 30 min with an average intensity of 200 nA. The beam intensity was derived using the total charge collected by the Faraday Cup. Energy degradation in the stacked target was calculated using the SRIM code.[5)]

The γ-rays emitted from irradiated foils were measured by a high-resolution high-purity germanium (HPGe) detector. The detector efficiency was calibrated using a multiple γ-ray emitting point source. The γ-ray spectra were analyzed by the Gamma Studio software (SEIKO EG&G).

The γ line at 58.0 keV (I_γ = 2.27%) from the ^{159}Dy decay ($T_{1/2}$ = 144.4 d) was measured to derive the cross sections of the ^{159}Tb$(\alpha, x)^{159}$Dy reaction. The measurements were performed after a cooling time of 2.3 days.

During the cooling time, the parent radionuclides ^{159m}Ho ($T_{1/2}$ = 8.30 s) and ^{159g}Ho ($T_{1/2}$ = 33.05 min) decayed to ^{159}Dy. The γ line had negligible interference with the X-rays of the lead shielding of the detector, which could be confirmed by no peaks found in the two foils at the energy below the threshold at the downstream of the beam. The mass attenuation coefficient adopted for the γ-ray line at 58.0 keV was 12.8 cm^2/g and calculated the correction factor is 1.007.[6)] The cumulative cross sections derived from the corrected activities for the ^{159}Dy production are compared with the TENDL-2021 data[4)] in Fig. 1. The TENDL-2021 data are much larger than our result.

In summary, we performed an experiment to measure the excitation functions of α-particle-induced reactions on ^{159}Tb targets up to 50.9 MeV at the RIKEN AVF cyclotron. The production cross-sections of ^{159}Dy, ^{159}Ho, ^{160m}Ho, ^{161}Ho and ^{162}Ho, were determined.

This work was supported by the Foundation for Science and Technology of Mongolia under grant number 2022/159.

References

1) D. V. Rao *et al.*, Med. Phys. **4**, 109 (1977).
2) D. Ichinkhorloo *et al.*, Nucl. Instrum. Methods Phys. Res. B **461**, 102 (2019).
3) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).
4) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (IPAC 2014), (2014), p. 3566.
5) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
6) Photon Interaction Database, National Institute of Standards and Technology, (2004), `https://physics.nist.gov/PhysRefData/XrayMassCoef/tab3.html`.

*1 Nuclear Research Center, National University of Mongolia
*2 RIKEN Nishina Center
*3 Faculty of Science, Hokkaido University
*4 Graduate School of Biomedical Science and Engineering, Hokkaido University
*5 Advanced Clinical Research Center, Fukushima Medical University

DOI:10.34448/RIKEN.APR.57-062