Production cross sections of ^{169}Yb in deuteron-induced reactions on ^{169}Tm

M. Saito,[*1,*2] M. Aikawa,[*1,*2] Y. Komori,[*2] H. Haba,[*2] and S. Takács[*3]

Radioactive isotopes (RI) are used in many application fields such as engineering and medicine. The medical RI ^{169}Yb ($T_{1/2}$ = 32.018 d, EC = 100%) is an Auger electron and X-ray emitter suitable for use in brachytherapy.[1,2] The proton-,[3–5] deuteron-,[6–8] and α-induced reactions[9] on a monoisotopic ^{169}Tm target were investigated by several research groups. Based on the experimental cross-section data, the deuteron-induced reaction on ^{169}Tm is one of the best candidates for the production of ^{169}Yb owing to the large cross section of the (d,2n) reaction.[6–8] However, the experimental cross-section data for the ^{169}Yb production by deuteron-induced reactions show relatively large uncertainties and scattering; therefore, the excitation function has not been defined properly yet. In this paper, we report cross-section data of the ^{169}Tm(d,2n)^{169}Yb reaction using thin metallic thulium foils to reduce the uncertainty of the experimental data.

The excitation function of the deuteron-induced reactions on ^{169}Tm were measured by the stacked-foil activation method using high-resolution γ-ray spectroscopy to assess the activity of the irradiated target foils. ^{169}Tm metallic foils (purity: 99%, Goodfellow Co., Ltd., UK) were stacked with ^{nat}Ti (purity: 99.9%, Goodfellow Co., Ltd., UK) and ^{27}Al foils (purity: >99.95%, Nilaco Corp., Japan) for monitoring the beam parameters and for degrading the beam energy. The average thicknesses of Tm, Ti, and Al foils were determined by measuring the surface area and weight of a larger piece of each foil and found to be 28.65, 4.95, and 13.44 mg/cm^2, respectively. The irradiation was performed at the AVF cyclotron of the RIKEN RI Beam Factory. The target was irradiated in a Faraday-cup with a deuteron beam of 24.36 MeV and an average beam intensity of 135.6 nA for 75 min. The beam intensity was increased by 6.4% in agreement with the ^{nat}Ti(d,x)^{48}V monitor reaction. The incident beam energy was measured by the time-of-flight method using plastic scintillator monitors.[10]

Nuclear decay data of ^{169}Yb are taken from the online NuDat 2.6 database.[11] The energy-dependent cross sections of the ^{169}Tm(d,2n)^{169}Yb reaction were derived from the γ-line at 177.21 keV (22.28%). Results are shown in Fig. 1 together with the previously measured experimental data[6–8] and the extracted result of the TALYS calculation (TENDL-2015[12]). The lowest measured cross section was 0.20 mb at 5.1 MeV while the highest measured cross section was 682.8 mb at 13.5 MeV. This peak energy is in good agreement with the previous data,[6–8] although the present cross sections are slightly higher.

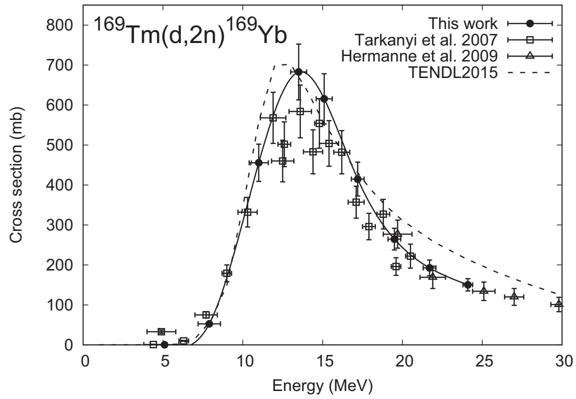

Fig. 1. The excitation function of the ^{169}Tm(d,2n)^{169}Yb reaction is shown with a spline fit over our experimental data. The result is compared with the previous experimental data[6–8] and TENDL-2015.[12]

In summary, we have measured the cross sections of the deuteron-induced reactions on ^{169}Tm to produce ^{169}Yb by using the stacked foil activation method. Thin metallic Tm foils were irradiated by a 24.36-MeV deuteron beam, and the activity of the produced radioisotopes was determined by high-resolution γ-ray spectrometry. The obtained excitation functions were compared with the earlier experimental data,[6–8] and good agreements were found in general.

References

1) F.H. DeLand et al., J. Nucl. Med. **12**, 683 (1971).
2) G. Lymperopoulou et al., Med. Phys. **33**, 4583 (2006).
3) C. Birattari et al., Nucl. Phys. A **201**, 579 (1973).
4) I. Spahn et al., Appl. Radiat. Isot. **63**, 235 (2005).
5) F. Tárkányi et al., Appl. Radiat. Isot. **70**, 309 (2012).
6) F. Tárkányi et al., Appl. Radiat. Isot. **65**, 663 (2007).
7) A. Hermanne et al., Nucl. Instr. Meth. B **267**, 727 (2009).
8) A. Hermanne et al., Nucl. Instr. Meth. B **383**, 81 (2016).
9) A.V. Mohan Rao et al., Pramana - J. Phys. **38**, 279 (1992).
10) T. Watanabe et al., Proc. 5th Int. Part. Accel. Conf. (IPAC2014), 3566 (2014).
11) National Nuclear Data Center: the NuDat 2 database, http://www.nndc.bnl.gov/nudat2/.
12) A.J. Koning et al.: TENDL-2015: TALYS-based evaluated nuclear data library.

*1 Graduate School of Science, Hokkaido University
*2 RIKEN Nishina Center
*3 MTA ATOMKI, Hungarian Academy of Sciences