Production cross sections of ytterbium and thulium radioisotopes in alpha-induced nuclear reactions on natural erbium†

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Radionuclides are used in nuclear medicine for therapy and diagnosis. The production reactions of such medical radionuclides should be investigated for practical use. The best route of their production can be discussed based on cross sections of possible nuclear reactions. The radionuclide ^{169}Yb ($T_{1/2}$ = 32.018 d) is a candidate of medical radionuclide. It decays with emission of Auger electrons and X-rays, which can be used for brachytherapy.[1] There are several charged-particle-induced reactions to produce ^{169}Yb. In this study, we focused on alpha-induced reactions on ^{nat}Er. Four previous studies of the ^{nat}Er$(\alpha,x)^{169}$Yb reaction[2–5] were found in a literature survey. However, the experimental data published earlier are rather inconsistent with each other. Therefore, we measured the excitation functions of the alpha-induced reaction on ^{nat}Er. The cross sections of byproducts, ^{166}Yb, and ^{165,166,167,168,170,173}Tm, were also determined.

The experiment was performed at the RIKEN AVF cyclotron. The stacked foil activation method and gamma-ray spectrometry were used. The stacked target consisted of ^{nat}Er (99% purity, Goodfellow Co., Ltd., UK) and ^{nat}Ti (99.6% purity, Nilaco Corp., Japan). The ^{nat}Ti foils were used for the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reactions to assess beam parameters and target thicknesses. The sizes and weights of both foils were measured to estimate their thicknesses. The derived thicknesses of ^{nat}Er and ^{nat}Ti were 20.06 mg/cm^2 and 2.26 mg/cm^2, respectively. The measured foils were cut to 10 × 10 mm^2 to fit a target holder. The target holder also served as a Faraday cup. The stacked target was irradiated for 1 hour with a 50.9-MeV alpha-beam. The energy was measured by the time-of-flight method.[6] The energy degradation in the stacked target was calculated using stopping powers obtained with the SRIM code.[7] The beam intensity measured by the Faraday cup was 200.3 nA. These beam parameters were assessed by the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reactions. According to the comparison, we corrected the thickness of ^{nat}Er decreased by 1% within the uncertainty.

The cross sections of the ^{nat}Er$(\alpha,x)^{169}$Yb reaction were derived. The radionuclide ^{169}Yb has a metastable state with a short half-life ($T_{1/2}$ = 46 s, IT: 100%), which decays only to the ground state ^{169g}Yb soon after the irradiation. The 177.21-keV gamma (I_γ = 22.28%) associated with the decay of ^{169g}Yb was measured after a cooling time of 11 days. The cross sections were obtained from the net counts of the gamma peak and are shown in Fig. 1. The results were compared with those of previous studies[2–5] and the TENDL-2017 data.[9] Both data of Király *et al.* (2008) and TENDL-2017 have nearly the same peak position as ours at approximately 35 MeV while the amplitudes are different. The other experimental data differ significantly from our results in both the shape and amplitude.

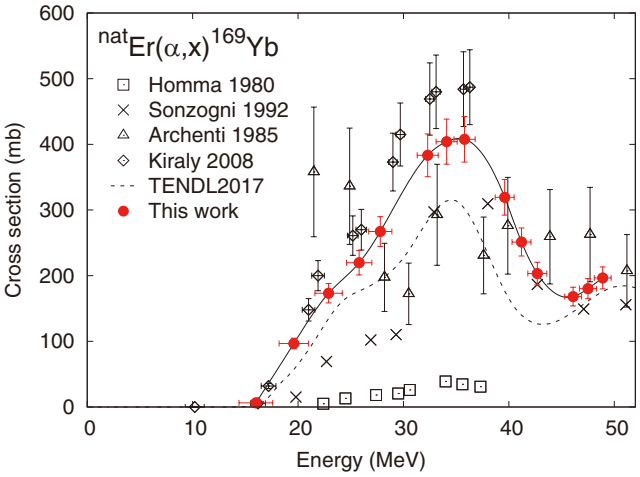

Fig. 1. Excitation function of ^{nat}Er$(\alpha,x)^{169}$Yb compared with previous data[2–5] and TENDL-2017.[9]

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