Activation cross sections of alpha-induced reactions on natural ytterbium up to 50 MeV†

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Many radioisotopes can be used for medical diagnosis and therapy. One candidate radioisotope is ^{177g}Lu ($T_{1/2} = 6.647$ d).[1)] This radioisotope decays with emissions of a β-particle and γ-rays, which are useful for therapy and diagnosis. For practical use of ^{177g}Lu, the best production reaction should be selected. Among the possible production reactions, we focused on the ^{nat}Yb$(\alpha, x)^{177g}$Lu reaction in this study. Only one experimental study on this reaction was found in a literature survey.[2)] The study reported the production cross sections of ^{177g}Lu up to 37.7 MeV. We investigated the cross sections of the reaction up to 50 MeV.

The experiment was performed at the RIKEN AVF cyclotron. The stacked foil activation method and high resolution γ-ray spectrometry were used. The stacked target consisted of pure metallic foils of ^{nat}Yb (99% purity, Goodfellow Co., Ltd., UK) and ^{nat}Ti (99.6% purity, Nilaco Corp., Japan). The sizes and weights of the Yb (3 pieces of 25×25 mm^2) and Ti (1 piece of 50×100 mm^2) foils were measured for determination of the target thicknesses. The average thicknesses of the foils were found to be 16.60, 16.32, and 17.11 mg/cm^2 for the Yb foils and 2.40 mg/cm^2 for the Ti foil. The foils were cut into small pieces of 8×8 mm^2 to fit a target holder that also served as a Faraday cup. The target was irradiated with a 51.0-MeV α beam for 2 hours. The incident beam energy was measured by the time-of-flight method.[3)] Energy degradation in the target was calculated by the SRIM code.[4)] The average beam intensity measured by the Faraday cup was 414 nA. The γ-ray spectra of each irradiated foil were measured by a high-resolution HPGe detector without chemical separation. Reaction and decay data were taken from NuDat 2.7 for the data analysis.[5)]

The excitation function of the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction was derived from measurements of the 320.08-keV γ rays emitted after decay of ^{51}Cr ($T_{1/2} =$ 27.7025 d). The derived cross sections were compared with the IAEA recommended values.[6)] According to the comparison, the adopted beam intensity was 379 nA, a decrease of 8.4% from the measured value.

Production cross sections of ^{177g}Lu ($T_{1/2} = 6.647$ d) were derived from measurements of the γ line at 208.37 keV ($I_\gamma = 10.36\%$) after a cooling time of 3.1 days. Its parent radionuclide ^{177}Yb ($T_{1/2} = 1.911$ h) decayed during the cooling time. The contribution of ^{177m}Lu ($T_{1/2} = 160.44$ d) was estimated using the measurement series after a cooling time of 143 days and was found to be negligibly small. The cumulative cross sections of the ^{nat}Yb$(\alpha, x)^{177g}$Lu reaction were derived and compared with the previous study[2)] and the TENDL-2017 data,[7)] as shown in Fig. 1. The experimental data are in good agreement with each other, but the TENDL-2017 data are much lower than the previous and our experimental ones.

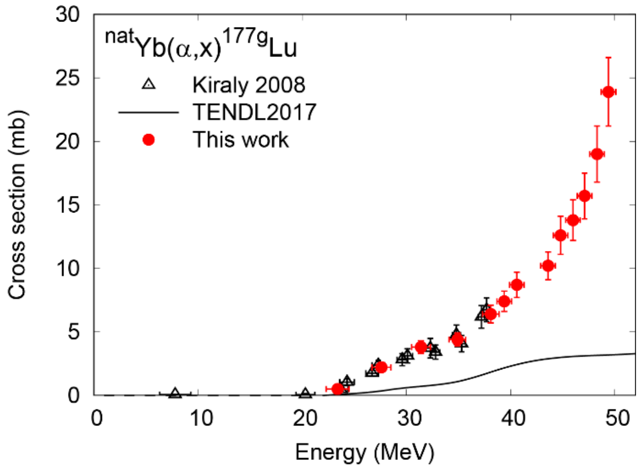

Fig. 1. Excitation function of the ^{nat}Yb$(\alpha, x)^{177g}$Lu reaction in comparison with previous experimental data[2)] and the TENDL-2017 data prediction.[7)]

In addition to ^{177g}Lu, production cross sections of co-produced radionuclides $^{170, 171, 172, 173, 175}$Hf, $^{171g, 172g, 173}$Lu, and ^{169g}Yb were determined. The results are useful to evaluate radionuclidic impurities of ^{177g}Lu for its practical application.

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