Activation cross sections of α-particle-induced reactions on ^{nat}Cu and ^{nat}Ti

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Radionuclides play a vital role in nuclear medicine, serving both therapeutic and diagnostic purposes. Their production relies on nuclear reactions with careful optimization of beam parameters to maximize yield while minimizing unnecessary by-products. Such optimization requires accurate monitor reactions. The International Atomic Energy Agency (IAEA) provides recommended values for the monitor reactions induced by protons, deuterons, ^{3}He, and α-particles.[1,2] These values are regularly updated based on the latest experimental data. The experimental data available in the EXFOR library[3] show significant scattering, as illustrated in Fig. 1 for example. Expert evaluators with extensive knowledge carefully selected relevant data to derive the recommended values.

In recent years, machine learning has emerged as a promising tool for the analysis of complex datasets. Motivated by this potential, we aim to explore the application of machine learning in refining recommended values. For this purpose, high-quality experimental cross-section data are essential to complement existing datasets. In this study, we conducted a new experiment to measure activation cross sections for α-particle-induced reactions on ^{nat}Cu and ^{nat}Ti up to 29 MeV. These data provide valuable input for advancing both traditional and machine-learning-based approaches to nuclear data analysis.

The experiment was conducted at the AVF cyclotron facility at RIKEN, employing stacked-foil activation combined with off-line γ-ray spectrometry. Thin metallic foils of natural copper (99.9% purity, 4.49 mg/cm^2) and natural titanium (99.6% purity, 2.33 mg/cm^2) were prepared as targets. The stacked target assembly comprised 20 sets of Cu-Cu-Ti-Ti foils cut in a size of 10 mm $\times$ 10 mm.

The target was irradiated for 30 min with a 29.0-MeV α-particle beam at an average intensity of 201 electric nA (enA), measured using a Faraday cup-like target holder. The incident beam energy was determined using the time-of-flight method,[4] while the energy loss of the projectiles as they traversed the foils was calculated based on stopping powers obtained using the SRIM code.[5]

γ rays emitted from the activated foils were measured using a high-purity germanium detector. We measured spectra from the ^{nat}Cu foils four times and those of the ^{nat}Ti foils twice for the different half-lives of the products. Reaction and decay data necessary for the γ-ray spectrometry were sourced from NuDat 3.0[6] and LiveChart.[7]

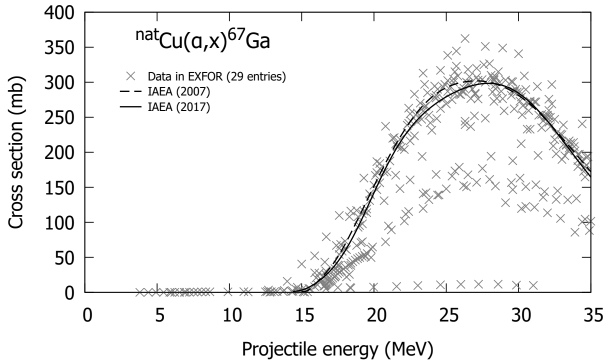

Fig. 1. Experimental data found in EXFOR library[3] and recommended values for ^{nat}Cu$(\alpha, x)^{67}$Ga reaction.[1,2]

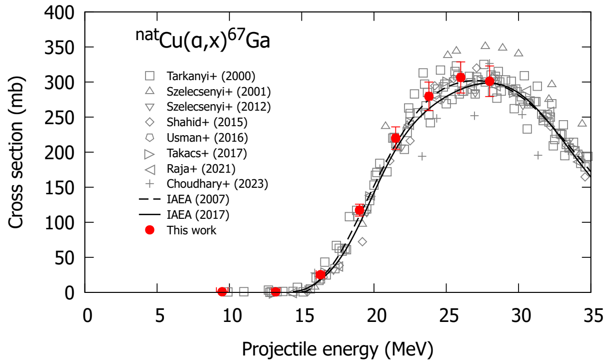

Fig. 2. Cross sections of ^{nat}Cu$(\alpha, x)^{67}$Ga reaction with experimental data published after 2000 and recommended values.[1,2]

The production cross sections of ^{67}Ga ($T_{1/2}$ = 3.2617 d) were determined using its intense γ line at 300.217 keV (I_γ = 16.64%). Potential interference from ^{67}Cu ($T_{1/2}$ = 61.83 h) to the same γ line (I_γ = 0.797%) was confirmed to be negligible.

The result is shown in Fig. 2 in comparison with those of various studies published after 2000 and the recommended values. Our data show better agreement with the recommended values published in 2007 than with those published in 2017.

The data analysis will be finalized, and updated results will be published in the near future. Additionally, we plan to further evaluate the experimental data

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DOI:10.34448/RIKEN.APR.58-021

and derive new recommended values using machine-learning techniques.

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