Activation cross sections of α-particle-induced reactions on scandium in the energy range of 22–51 MeV†

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Titanium radioisotopes have important applications in medical diagnostics. The positron emitter ^{45}Ti ($T_{1/2}$ = 184.8 min) is utilized in positron emission tomography (PET).[1)] It can be produced in carrier-free form through charged-particle-induced reactions on calcium or scandium. Scandium, a monoisotopic element (^{45}Sc: 100%), may offer a distinct advantage for producing ^{45}Ti.

In this study, we focused on α-particle-induced reactions on scandium. A literature survey using the EXFOR database identified six experimental studies of α-particle-induced reactions on scandium. However, the available data are limited and inconsistent, with no prior studies addressing the ^{45}Sc$(\alpha, x)^{45}$Ti reaction. Therefore, we conducted a new experiment to provide reliable cross sections in the energy range of 22–51 MeV.

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

The stacked target comprised pure metallic foils of ^{45}Sc (99.9% purity, 7.71 mg/cm^2), ^{nat}Ti (99.5% purity, 9.13 mg/cm^2), and ^{27}Al (>99% purity, 4.99 mg/cm^2). Nine sets of Sc-Al-Ti-Al foils were arranged in a target holder that also functioned as a Faraday cup. The target stack was irradiated for 30 min with a 50.9-MeV α-particle beam at an average intensity of 201 electric nA (enA). The incident beam energy was determined using the time-of-flight method,[2)] while the SRIM code[3)] was used to estimate energy degradation and uncertainty propagation through the stacked foils. The beam intensity was determined from the charge collected by the Faraday cup.

The γ-ray spectra of each irradiated Sc foil and its corresponding Al catcher foil were recorded using a high-resolution HPGe detector (ORTEC GMX30P4-70, 30% relative efficiency). Five measurements were performed per foil to accommodate the different half-lives of the products. Nuclear reaction and decay data for γ-ray spectrometry were obtained from the online databases NuDat 3.0[4)] and LiveChart.[5)]

The ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction was used to assess and correct the primary beam parameters and target thicknesses. The derived cross sections for this reaction were compared with the IAEA-recommended values. To improve agreement with the reference values, corrections were applied to the measured parameters: the beam energy was adjusted by +0.2 MeV, the beam intensity by −2%, and foil thicknesses by −2% (Sc), −1% (Ti), and −1% (Al) within their respective uncertainties. The corrected parameters, beam energy (51.1 MeV), beam intensity (197 enA), and thicknesses (7.56 mg/cm^2 for Sc, 9.04 mg/cm^2 for Ti, and 4.94 mg/cm^2 for Al) were used for cross-section analysis.

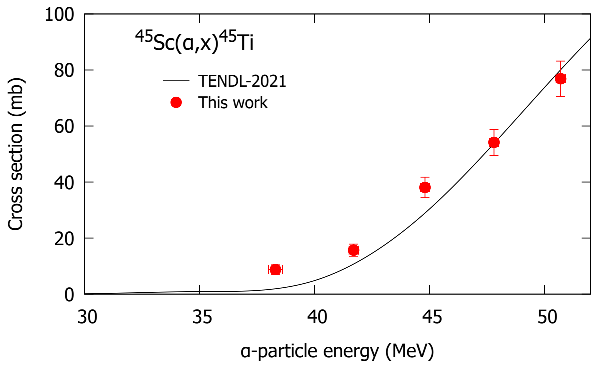

Fig. 1. Cross sections of ^{45}Sc$(\alpha, x)^{45}$Ti reaction.

Production cross sections of ^{45}Ti ($T_{1/2}$ = 184.8 min) were determined using 511-keV annihilation γ rays. In addition to direct formation, contribution by the indirect route through the decay of its parent nuclei, ^{45}V ($T_{1/2}$ = 547 ms), is possible. ^{45}V has decayed completely before the γ-ray measurements. Because the 511-keV γ rays are also emitted by co-produced, longer-lived positron emitters such as ^{48}V ($T_{1/2}$ = 15.974 d), ^{44g}Sc ($T_{1/2}$ = 3.97 h), and ^{43}Sc ($T_{1/2}$ = 3.891 h), their contributions to the photopeak were subtracted to obtain net counts from ^{45}Ti.

The cumulative cross sections, derived from the net counts in the spectra, are presented in Fig. 1 alongside TENDL-2021 predictions.[6)] No prior experimental data on this reaction have been found in the literature. The theoretical values show good agreement with our experimental results.

Production cross sections were also determined for ^{48}V, $^{47,46m+g,44m,44g,43g}$Sc, and ^{43,42}K in this work. The results are expected to contribute to the further development of nuclear medicine.

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