Activation cross sections of α-particle-induced reactions on scandium

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Titanium-45 ($T_{1/2} = 184.8$ min) is a positron emitter that can be used for positron emission tomography.[1)] This medical radioisotope can be produced by charged-particle-induced reactions on its neighboring elements, *e.g.*, calcium and scandium. An example production reaction is the α-particle-induced reaction on the monoisotopic element scandium (^{45}Sc: 100%). No experimental study on the production cross sections of such reactions was found in a literature survey performed using the EXFOR library.[2)] Therefore, we conducted an experiment to obtain the cross sections to produce ^{45}Ti and other co-produced impurities.

The experiment was performed at the RIKEN AVF cyclotron. The stacked-foil activation technique and offline γ-ray spectrometry were used. The stacked target for the experiment was composed of thin metallic foils of ^{45}Sc (99.9% purity), ^{nat}Ti (99.5% purity), and ^{27}Al (>99% purity) (Nilaco Corp., Japan). The average thickness of each foil was estimated from the measured weight and size. The derived thicknesses of the ^{45}Sc, ^{nat}Ti, and ^{27}Al foils were 7.71, 9.13, and 4.99 mg/cm^2, respectively. The original foils were cut into a size adjusted for the target holder (8 × 8 mm). Nine sets of Sc-Al-Ti-Al foils and an additional two sets of Ti-Al foils were stacked in the target holder that served as a Faraday cup.

The stacked target was irradiated with a 50.9-MeV α-particle beam for 30 min. The beam energy was determined by the time-of-flight method.[3)] The energy degradation in the stacked-foil target was estimated using stopping powers derived from the SRIM code.[4)] The average beam current derived using the total charge collected by the Faraday cup was 201 nA.

γ-ray spectra of the irradiated foils were measured using a high-purity germanium detector (ORTEC GEM30P4-70) and dedicated analyzing software (SEIKO EG&G Gamma Studio). The γ-ray measurement of each foil was performed five times to follow the decay of radionuclides with largely different half-lives. To force the annihilation of the emitted positrons, copper plates (886 mg/cm^2) were used to sandwich the Sc foils. The attenuation of γ rays in the copper plates was estimated for correction of measured counts.

Cross sections of the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction were derived to assess the beam parameters and target thicknesses. The 320.08-keV γ rays ($I_\gamma = 9.91\%$) emitted with ^{51}Cr decay ($T_{1/2} = 27.7$ d) were used. The derived cross sections were compared with the International Atomic Energy Agency recommended values.[5)] Based on the comparison, the measured beam energy and current were corrected by +0.2 MeV and −2% within the uncertainties, respectively. The measured thicknesses of the Sc, Ti, and Al foils were also corrected by −2%, −1%, and −1% within the uncertainty, respectively. The corrected beam parameters, energy (51.1 MeV), beam current (197 nA), and foil thicknesses (Sc: 7.56, Ti: 9.04, and Al: 4.94 mg/cm^2) were adopted to deduce the production cross sections of the radionuclides in the ^{45}Sc targets.

Activation cross sections of ^{48}V, ^{45}Ti, ^{47,46g,44m,44g,43g}Sc, and ^{43,42}K were determined from the experiment. The production cross sections of ^{45}Ti were derived using 511-keV annihilation γ rays. γ rays were also emitted from the decay of several co-produced positron emitters. The contributions of ^{47}V ($T_{1/2} =$ 32.6 min) and shorter-lived radionuclides were neglected in cooling times longer than 4.8 hours. The other contributions of ^{48}V ($T_{1/2} = 15.9735$ d), ^{44g}Sc ($T_{1/2} = 3.97$ h), and ^{43}Sc ($T_{1/2} = 3.891$ h) were estimated and subtracted.

The cumulative cross sections using the corrected counts of the 511-keV γ rays are shown in Fig. 1 in comparison with the TENDL-2021 values.[6)] The TENDL-2021 values are consistent with our results. No literature data were found in the EXFOR library. The new data obtained in this study are expected to contribute to design a production target of ^{45}Ti for use in nuclear medicine.

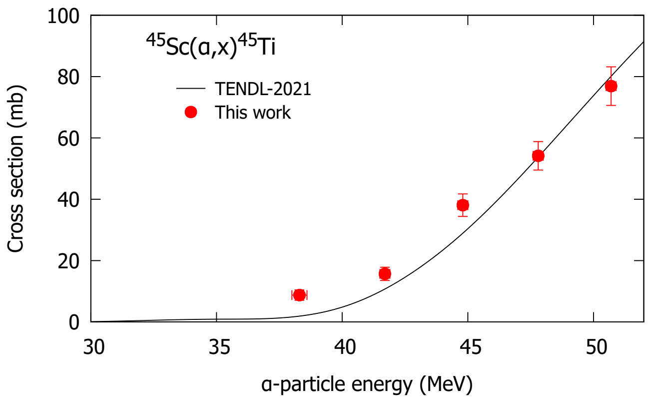

Fig. 1. Cross sections of the ^{45}Sc$(\alpha,x)^{45}$Ti reaction compared with theoretical calculation in the TENDL-2021 library.[6)]

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