Production cross sections of titanium radionuclides via proton-induced reactions on scandium

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Titanium radionuclides can be used in nuclear medicine. ^{45}Ti ($T_{1/2} = 3.08$ h, $I_{\beta+} = 84.8\%$) and ^{44g}Sc ($T_{1/2} = 3.89$ h, $I_{\beta+} = 94.3\%$), which is the daughter of ^{44}Ti ($T_{1/2} = 59.1$ y), are positron emitters and suitable for positron emission tomography (PET).[1)] The two titanium radionuclides ^{44}Ti and ^{45}Ti can be produced via charged-particle-induced reactions, such as α-particle-induced reactions on calcium and proton- and deuteron-induced reactions on scandium in a no-carrier-added form. The former reaction on calcium requires enriched ^{42}Ca targets. However, the composition of this isotope in natural calcium is only 0.647%. For proton- and deuteron-induced reactions, the monoisotopic element scandium ^{45}Sc can be used as a target material. The proton- and deuteron-induced reactions on ^{45}Sc are thus promising for the production of both titanium radionuclides. We have previously studied the deuteron-induced reaction on ^{45}Sc.[2)] Subsequently, we focused on the proton-induced reaction on ^{45}Sc. In a literature survey and in the EXFOR library,[3)] we found four and ten experimental studies on the production cross sections of ^{44}Ti and ^{45}Ti isotopes, respectively. The cross sections reported in these previous studies are largely scattered. Therefore, additional and reliable cross sections of the proton-induced reactions on ^{45}Sc are required.

We performed an experiment at the RIKEN AVF cyclotron using well-established methods, namely, the stacked-foil activation technique and high-resolution γ-ray spectrometry. Pure metal foils of ^{45}Sc (99.0% purity, Goodfellow Co., Ltd., UK), ^{nat}Ti (99.6% purity, Nilaco Corp., Japan), and ^{27}Al (>99% purity, Nilaco Corp., Japan) were purchased and used for the stacked target. The ^{nat}Ti and ^{27}Al foils were used for the ^{nat}Ti$(p,x)^{48}$V monitor reaction and for catching recoiled products, respectively. The lateral size and weight of each foil were measured. The derived average thicknesses of the ^{45}Sc, ^{nat}Ti, and ^{27}Al foils were 30.5, 2.25, and 13.7 mg/cm^2, respectively. The foils were then cut into 10×10 mm pieces to fit a target holder that served as a Faraday cup. Twenty sets of Sc-Al-Ti-Ti-Al foils were stacked in the target holder. The stacked target was irradiated with a 30.1 ± 0.1MeV proton beam for 60 min. The initial beam energy was determined by the time-of-flight method.[4)] The average beam intensity measured by the Faraday cup was 203 nA. The energy degradation of the beam in the stacked target was calculated using stopping powers derived from the SRIM code.[5)] The γ-ray spectra from each irradiated foil were measured three times using a high-purity germanium detector (ORTEC GEM30P4-70). Nuclear decay data were obtained from the online database NuDat 3.0.[6)]

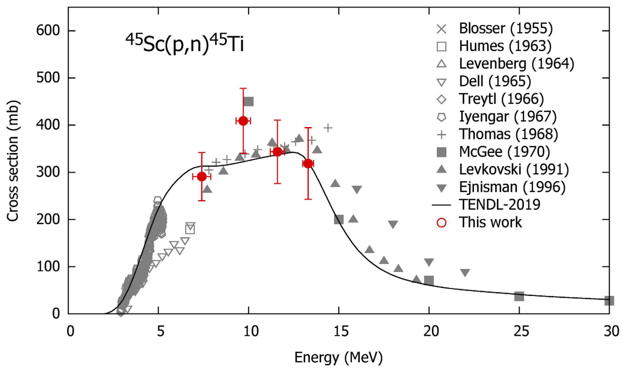

Fig. 1. Excitation function of the ^{45}Sc$(p,n)^{45}$Ti reaction in comparison with the previous data found in the EXFOR library[3)] and the TENDL-2019 values.[7)]

The weak γ line at 719.6 keV ($I_\gamma = 0.154\%$) emitted with the decay of ^{45}Ti was measured. Due to its low intensity, only four cross sections of the ^{45}Sc$(p,n)^{45}$Ti reaction, with large statistical uncertainties, at around the peak were determined. Our preliminary result in comparison with the earlier experimental data found in the EXFOR library[3)] and the TENDL-2019 values[7)] is shown in Fig. 1. The peak position and amplitude of our result are similar to the data obtained by McGee *et al.*[8)] The TENDL data are slightly smaller than our data at the peak.

Additional measurement after several months will be performed for the long-lived radioisotope ^{44}Ti. Production cross sections of scandium radioisotopes in the reaction will be also determined.

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