Production cross sections of ^{45}Ti via deuteron-induced reaction on ^{45}Sc

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The radionuclide ^{45}Ti ($T_{1/2}$ = 184.8 min) is a positron emitter ($E_{\beta+}$ = 439 keV, $I_{\beta+}$ = 84.8%) suitable for positron emission tomography (PET). This radioisotope can be produced in the deuteron-induced reaction on a scandium-45 target at cyclotrons. However, the quality of experimental data on the cross sections of the ^{45}Sc$(d,2n)^{45}$Ti reaction is not satisfactory. The main purpose of this study is, therefore, to measure the cross sections of the ^{45}Sc$(d,2n)^{45}$Ti reaction for ^{45}Ti production. In addition, the physical yield is derived from the measured cross sections.

The stacked-foil activation technique and γ-ray spectrometry were adopted to determine the cross sections. The stacked target consisted of metallic foils of ^{45}Sc (thicknesses of 7.71 mg/cm^2 and 76.0 mg/cm^2 with a purity of 99.0%), ^{27}Al (4.99 mg/cm^2, 99.6%), and $^{\mathrm{nat}}$Ti (9.13 mg/cm^2, 99.6%). The target was irradiated for 30 min with a 24-MeV deuteron beam from the RIKEN AVF cyclotron. The incident beam energy was measured by the time-of-flight method. The energy degradation in the stacked target was calculated using the SRIM code.[1)] The beam intensity was measured using a Faraday cup and cross-checked with the $^{\mathrm{nat}}$Ti$(d,x)^{48}$V monitor reaction.[2)] According to the cross checking, the intensity (175.2 nA) was corrected by a decrease of 3% from the measured value (180.3 nA). The γ-ray spectra of the irradiated foils were measured by a high-resolution and high-purity germanium (HPGe) detector. The detector was calibrated by a standard mixed γ-ray point source. The dead time was kept below 7% in the measurements.

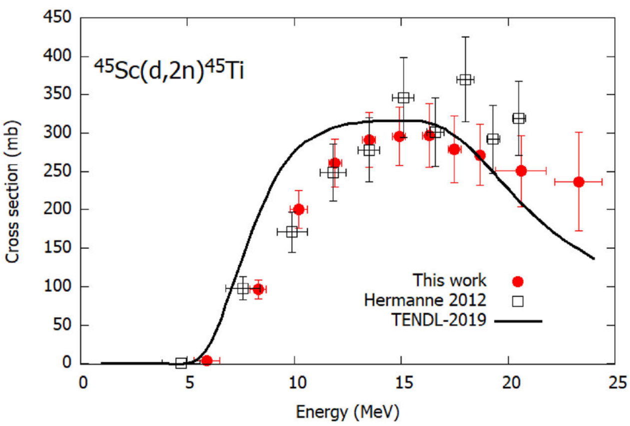

Fig. 1. Excitation function of the ^{45}Sc$(d,2n)^{68}$Ti reaction.

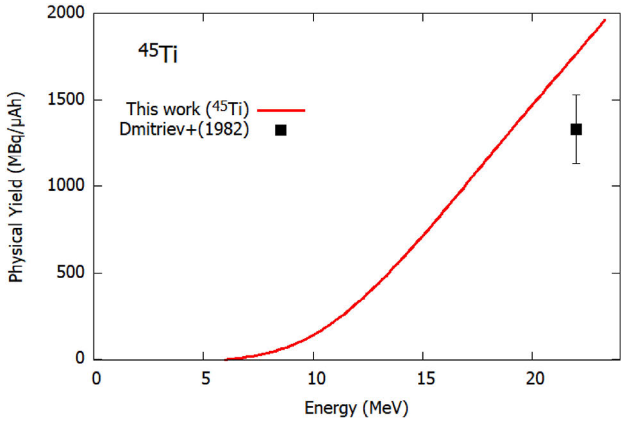

Fig. 2. Physical yield of ^{45}Ti.

The cross sections of the ^{45}Sc$(d,2n)^{45}$Ti reaction were derived from the measurement of the 719.6-keV γ-line (I_γ = 0.154%) associated with the ^{45}Ti decay. The excitation function of the ^{45}Sc$(d,2n)^{45}$Ti reaction is shown in Fig. 1 in comparison with previous experimental data[3)] and the theoretical estimation from TENDL-2017.[4)] The derived excitation function of the ^{45}Sc$(d,2n)^{45}$Ti reaction is consistent with the data reported by Hermanne *et al.*[3)] The peak position of the TENDL-2017 data is slightly shifted to a lower energy.

The physical yield of ^{45}Ti was deduced from a spline fitted curve of the measured excitation function and stopping power calculated from the SRIM code.[1)] The derived yield is shown in Fig. 2. The present yield curve of ^{45}Ti is slightly higher than the experimental data measured by Dmitriev *et al.*[5)] at 22 MeV. We confirmed that no radioactive impurities of titanium are produced in the energy range below 15 MeV, which is the threshold energy of ^{44}Ti production. Above 15 MeV and up to 24 MeV, the physical yield of ^{44}Ti is seven or more orders of magnitude less than that of ^{45}Ti and negligibly small. Thus, this reaction with chemical separation allows the production of high-specific-activity ^{45}Ti in this energy range.

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