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

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The radionuclide $^{45}\text{Ti}$ ($T_{1/2} = 184.8$ 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 $^{45}\text{Sc}(d,2n)^{45}\text{Ti}$ reaction is not satisfactory. The main purpose of this study is, therefore, to measure the cross sections of the $^{45}\text{Sc}(d,2n)^{45}\text{Ti}$ reaction for $^{45}\text{Ti}$ 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 $^{48}\text{Sc}$ (thicknesses of 7.71 mg/cm$^2$ and 76.0 mg/cm$^2$ with a purity of 99.0%), $^{27}\text{Al}$ (4.99 mg/cm$^2$, 99.6%), and $^{nat}\text{Ti}$ (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 $^{nat}\text{Ti}(d,x)^{48}\text{V}$ monitor reaction.3) 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.

The cross sections of the $^{45}\text{Sc}(d,2n)^{45}\text{Ti}$ reaction were derived from the measurement of the 719.6-keV γ-line ($I_\gamma = 0.154\%$) associated with the $^{45}\text{Ti}$ decay. The excitation function of the $^{45}\text{Sc}(d,2n)^{45}\text{Ti}$ reaction is shown in Fig. 1 in comparison with previous experimental data3) and the theoretical estimation from TENDL-2017.4) The derived excitation function of the $^{45}\text{Sc}(d,2n)^{45}\text{Ti}$ reaction is consistent with the data reported by Hermann et al.3) The peak position of the TENDL-2017 data is slightly shifted to a lower energy.

The physical yield of $^{45}\text{Ti}$ 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 $^{45}\text{Ti}$ 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 $^{44}\text{Ti}$ production. Above 15 MeV and up to 24 MeV, the physical yield of $^{45}\text{Ti}$ is seven or more orders of magnitude less than that of $^{45}\text{Ti}$ and negligibly small. Thus, this reaction with chemical separation allows the production of high-specific-activity $^{45}\text{Ti}$ in this energy range.

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References

Fig. 1. Excitation function of the $^{45}\text{Sc}(d,2n)^{48}\text{Ti}$ reaction.

Fig. 2. Physical yield of $^{45}\text{Ti}$.