Production cross sections of ^{47}Sc via deuteron-induced reactions on natural calcium

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Production of scandium radionuclides is of interest for practical use in nuclear medicine owing to the applicability of $^{43,\,44g}$Sc in positron emission tomography (PET) and ^{47}Sc in therapy.[1)] We systematically study production cross sections of the radionuclides via charged-particle-induced reactions on natural calcium. Preliminary results of the proton- and alpha-particle-induced reactions have been reported in previous studies.[2)] In this study, we focus on the deuteron-induced reactions on natural calcium, in which the isotopic ratio is ^{40}Ca: 96.941%, ^{42}Ca: 0.647%, ^{43}Ca: 0.135%, ^{44}Ca: 2.086%, ^{46}Ca: 0.004%, and ^{48}Ca: 0.187%. In our survey, we found only two experimental cross sections of the reaction below 25 MeV.[3,4)] In previous studies, however, cross sections for ^{47}Sc production were not presented. Therefore, we conducted an experiment to measure the production cross sections of scandium radionuclides with a special focus on ^{47}Sc.

The experiment was performed at the RIKEN AVF cyclotron. The stacked-foil activation technique and high-resolution gamma-ray spectrometry were employed.

The stacked target was prepared using ^{nat}Ca targets and ^{nat}Ti and ^{27}Al foils. Each ^{nat}Ca target was composed of two calcium-fluoride (CaF$_2$) layers (0.148 mg/cm^2 per layer) sandwiched between high-purity ^{27}Al backing foils (5.26 mg/cm^2, 99.999% purity, Goodfellow Co. Ltd., UK). The ^{nat}Ti (2.30 mg/cm^2, 99.6% purity, Nilaco Corp., Japan) and ^{27}Al foils (13.7 mg/cm^2, >99% purity, Nilaco Corp., Japan) were interleaved for monitoring the beam via the ^{nat}Ti$(d,x)^{48}$V monitor reaction and energy degradation of a deuteron beam, respectively. The average thicknesses were determined from the measured sizes and weights of the original foils. Once the thicknesses were determined, the original foils were cut into small pieces of 8 × 8 mm. Seventeen sets of a ^{nat}Ca target with Ti-Ti-Al foils were stacked in a target holder served as a Faraday cup.

The stacked target was irradiated for 60 min with a 24.2 ± 0.1-MeV deuteron beam. The average beam intensity measured by the Faraday cup was 105 nA. The energy degradation of the beam in the stacked target was calculated using stopping powers obtained from the SRIM code.[6)] Gamma rays emitted from the irradiated foils were measured without chemical separation using a high-purity germanium detector. Nuclear data required to determine activation cross sections were obtained from the online database, NuDat 3.0.[7)]

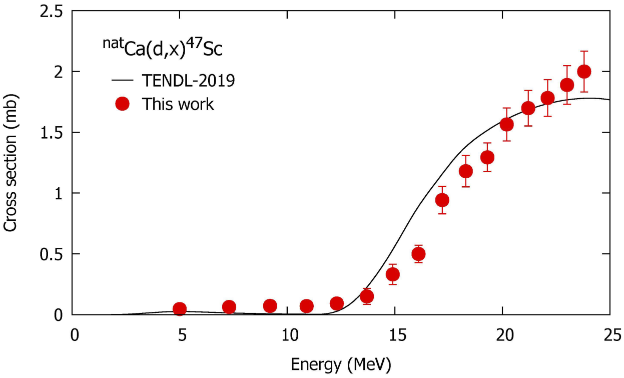

Fig. 1. Measured excitation function of the ^{nat}Ca$(d,x)^{47}$Sc reaction with a theoretical prediction of the TENDL-2019 values.[7)]

We determined the production cross sections of ^{47}Sc ($T_{1/2}$ = 3.35 d) via the deuteron-induced reactions on ^{nat}Ca. The cross sections were derived using the measured gamma line at 159.381 keV (I_γ = 68.3%) emitted with the decay of ^{47}Sc. The co-produced parent ^{47}Ca ($T_{1/2}$ = 4.54 d) also contributed to the production of ^{47}Sc. Our preliminary result, including the partial contribution of ^{47}Ca, is shown in Fig. 1. Below the threshold energy of the ^{48}Ca$(d,3n)^{47}$Sc reaction (E_{th} = 11.4 MeV), ^{47}Sc was dominantly formed from the reaction on ^{46}Ca. The result is compared with the cross sections of the ^{47}Sc direct production obtained from the TENDL-2019 library.[7)] The TENDL-2019 values show a slightly different shape from that of our result. Previously published experimental studies on this subject could not be found.

The measured spectra are analyzed in more detail, and the production cross sections of other scandium radioisotopes are determined. The results have potential implications for application in nuclear medicine.

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References

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