Production cross sections of ^{47}Sc via α-particle induced reactions on ^{nat}Ca†

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Scandium-47 ($T_{1/2}$ = 3.3492 d) is a potential radionuclide for therapy.[1] Owing to the relatively small abundance of ^{46}Ca (0.004%) and ^{48}Ca (0.187%) in natural calcium, its most possible production route for practical use is expected to be the α-particle-induced reaction on ^{44}Ca (2.086%).

In a literature survey, we found only one experimental study of the ^{44}Ca$(\alpha,p)^{47}$Sc reaction.[2] Therefore, we performed an experiment to provide more credible cross sections of the ^{nat}Ca$(\alpha,x)^{47}$Sc reaction. In addition to the production cross sections of ^{47}Sc, the activation cross sections for ^{46,44m,44g,43}Sc and ^{47}Ca were also determined simultaneously.

In the experiment, a 29-MeV α-particle beam was used to activate the targets at the AVF cyclotron in RIKEN. The stacked-foil activation technique and high resolution γ-ray spectrometry were adopted to perform the measurement.

Calcium-fluoride (CaF_2) was deposited on a high-purity ^{27}Al backing foil (Al_H, 99.999% purity, Goodfellow Co. Ltd., UK) and used as the ^{nat}Ca target. Metallic foils of ^{nat}Ti (99.5% purity) for the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reaction and low-purity ^{27}Al (Al_L, >99% purity) to catch recoiled products were purchased from Nilaco Corp., Japan and inserted into the stack. The average thicknesses of the Al_H, Al_L, and ^{nat}Ti foils were 2.57, 1.50, and 2.30 mg/cm^2, respectively, determined from the measured lateral sizes and weights of the foils. The thickness of the deposited CaF_2 layer was 0.135 mg/cm^2, which was derived from the measured deposited area and net weight. All foils were cut into a size of 10×10 mm to fit a target holder that also served as a Faraday cup. Each ^{nat}Ca target comprised two CaF_2 layers sandwiched between the Al_H backing foils. Twelve ^{nat}Ca targets were stacked with seven sets of ^{nat}Ti-Al_L foils in the target holder.

The stacked target was irradiated with an α-particle beam for 30 min. The measured average beam intensity and energy were 175 nA and 29.0 ± 0.2 MeV, respectively. The energy degradation in the stacked target was calculated using stopping powers obtained from the SRIM code.[3]

The high-resolution γ-ray spectrometry using a high-purity germanium detector was performed without chemical separation. The spectra of the ^{nat}Ca targets were measured with cooling times ranging from 3.2 h to 77 d.

The derived cross sections of the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reaction were compared with the IAEA recommended values[4] to assess beam parameters and target thicknesses. The beam intensity and thicknesses of both Al_H and Al_L foils were corrected within their uncertainties by +5.6% and −1%, respectively. The measured thicknesses of the ^{nat}Ti monitor foil and the CaF_2 layer were adopted without any correction.

^{47}Sc could be produced directly in the ^{44}Ca$(\alpha,p)^{47}$Sc reaction and indirectly by decay of the co-produced ^{47}Ca ($T_{1/2}$ = 4.536 d) and ^{47}K ($T_{1/2}$ = 17.50 s). The indirect contribution was at a negligible level because ^{47}Ca and ^{47}K can be formed only on the lower-abundant ^{46}Ca and ^{48}Ca isotopes. The activity of ^{47}Sc was determined by measuring the γ line at 159.381 keV ($I_\gamma = 68.3\%$) from the decay of ^{47}Sc. The derived cross sections of the ^{nat}Ca$(\alpha,x)^{47}$Sc reaction are shown in Fig. 1 compared with the literature data[2] and the theoretical values provided in the TENDL-2019 library.[5] The literature data on ^{44}Ca targets were normalized to those on ^{nat}Ca targets. The newly obtained data correspond to a smooth excitation function, in contrast to the literature data. The TENDL-2019 calculation overestimates both the experimental datasets. Thus, the data are expected to contribute to practical use in nuclear medicine and aid in improving the theoretical models.

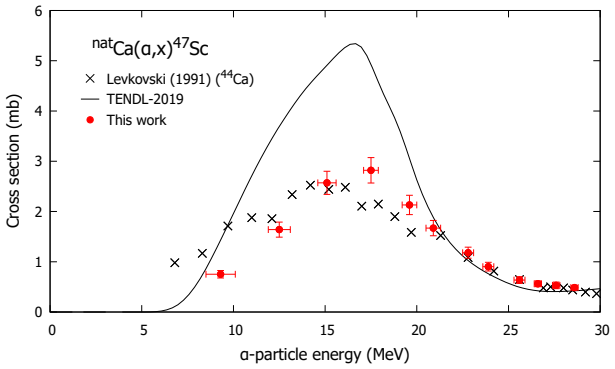

Fig. 1. Measured cross sections of the ^{nat}Ca$(\alpha,x)^{47}$Sc reaction with normalized literature data[1] and TENDL-2019 values.[5]

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