Production cross sections of ^{48}V via α-particle-induced reactions on scandium below 29 MeV

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Vanadium-48 ($T_{1/2}$ = 15.974 d) is a positron emitter suitable for positron emission tomography (PET), with an average positron energy of 291 keV ($I_{\beta+}$ = 50.4%). This positron energy is comparable to that of ^{18}F and ^{64}Cu, making it promising for generating higher-quality images.[1)]

High specific activity of ^{48}V can be produced through charged-particle-induced reactions on titanium and scandium targets. To minimize the production of co-produced impurities, enriched targets are preferable. From the perspective of enrichment, scandium is advantageous owing to its monoisotopic nature. We focus on the α-particle-induced reactions on scandium. Although we have previously measured cross sections for the reactions, the energy range of 22–51 MeV did not cover the peak position.[2)] A literature survey using the EXFOR library revealed six earlier studies, including our previous one, that deviated around the peak position. Therefore, we performed an additional experiment to measure the cross sections of the ^{45}Sc$(\alpha, n)^{48}$V reaction near the peak position.

We conducted the experiment at the RIKEN AVF cyclotron, employing the well-established stacked-foil activation technique and γ-ray spectrometry to measure the cross sections of α-particle-induced reactions on ^{45}Sc. The stacked target consisted of thin, pure metallic foils of scandium (^{45}Sc), titanium (^{nat}Ti), and aluminum (^{27}Al). The ^{45}Sc foils were the same as those used in the previous study. The ^{nat}Ti foil was used for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction to assess the beam parameters and target thicknesses. The ^{27}Al foils served as catcher foils for recoiled products from the adjacent foils. The measured average thicknesses of the ^{45}Sc, ^{nat}Ti, and ^{27}Al foils were 7.71, 2.33, and 1.82 mg/cm^2, respectively. The foils were cut into 8 mm × 8 mm pieces to fit a target holder, which also served as a Faraday cup. Nine sets of Sc-Al-Ti-Al foils were stacked in the target holder. The stacked target was irradiated with a 29-MeV α-particle beam for 30 min. The beam energy of 29.0 MeV was measured using the time-of-flight method.[3)] Energy degradation in the stacked target was calculated using stopping powers derived using the SRIM code.[4)] The beam intensity measured using a Faraday cup was 200 electric nA (enA). γ rays emitted from the irradiated foils were detected using a high-purity germanium detector (ORTEC GMX30P4-70, 30% relative efficiency) calibrated with γ-ray point sources of known activity. Each Sc foil, along with the Al catcher foil, was measured four times to follow the different half-lives of the products. Necessary nuclear data were obtained from the online databases NuDat 3.0[5)] and LiveChart.[6)]

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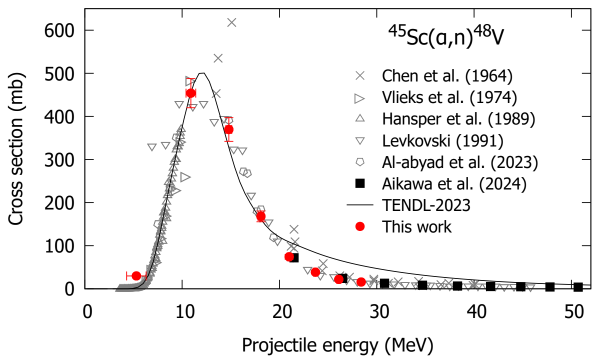

Fig. 1. Cross sections of ^{45}Sc$(\alpha, n)^{48}$V reaction.

Cross sections for the ^{nat}Ti$(\alpha, x)^{51}$Cr monitor reaction were used to assess the target and beam parameters. The cross sections obtained with the measured parameters were shifted slightly to the lower-energy region. Therefore, as in our previous study, the thickness of ^{45}Sc was corrected by −2%, resulting in better agreement with the recommended values.

The production cross sections of ^{48}V ($T_{1/2}$ = 15.9735 d) were determined using the intense γ line at 983.53 keV (I_ν = 99.98%). The results from all four-measurement series were consistent. Our result is presented in Fig. 1, along with comparisons against the results of various past studies and theoretical calculations. The current data show a smooth connection to our previous data in the overlapping energy region. Some data in the earlier studies deviate from our results, while the remaining data agree with ours. The theoretical predictions from the TENDL-2023 library[7)] are consistent with our result below 20 MeV but are larger above 20 MeV.

In addition to the production cross sections of ^{48}V, we also determined those of $^{47, 44m, 44g}$Sc up to 29 MeV. These results are found to be consistent with those of our previous study. The final results will be published as soon as possible.

References

1) B. A. Broder *et al.*, Appl. Radiat. Isot. **186**, 110270 (2022).

2) M. Aikawa *et al.*, Nucl. Instrum. Methods Phys. Res. B **550**, 165315 (2024).
3) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (IPAC) (2014), p. 3566.
4) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
5) National Nuclear Data Center, The NuDat 3.0 database, `http://www.nndc.bnl.gov/nudat3/`.
6) International Atomic Energy Agency, LiveChart of Nuclides, `https://www-nds.iaea.org/livechart/`.
7) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).