Production cross-sections of ^{52m}Mn in alpha-particle-induced reactions in natural vanadium

G. Damdinsuren,[*1,*2] M. Aikawa,[*1,*2,*3] Kh. Tegshjargal,[*4] N. Erdene,[*4] S. Ebata,[*5,*2] and H. Haba[*2]

The ground state of the ^{52m}Mn radioisotope has a half-life of $T_{1/2}$ = 5.6 days and decays via electron capture (70.6%) and positron emission processes (29.4%, $\langle E_{\beta+} \rangle$ = 242 keV). ^{52m}Mn can be used in positron emission tomography (PET) imaging to study biological and physiological processes with a time scale similar to its decay.[1)] The routes for ^{52m}Mn production include charged-particle-induced reactions. Among the possible reactions, we focused on the α-particle-induced reaction on natural vanadium targets. Eleven previous experimental studies were found in the EXFOR library.[2)] However, their data exhibited show large uncertainties and discrepancies. Therefore, we measured the excitation function of the ^{nat}V(α, x)^{52m}Mn reaction. The experimental result was compared with the literature data obtained from the EXFOR database and TENDL-2019 data.[3)]

The stacked-foil activation technique and high-resolution γ-ray spectrometry were used for cross-section measurements. The experiment target consisted of pure metal foils of ^{nat}V (25-μm thick, 99% purity), ^{nat}Ti (5-μm thick, 99.6% purity), and ^{27}Al (5-μm thick, 99.9% purity) from Nilaco Corp., Japan. ^{27}Al foils were inserted to sandwich ^{nat}V foils to separate the recoiled reaction products from ^{nat}V and ^{nat}Ti foils. ^{nat}Ti foils were used in the ^{nat}Ti(α, x)^{51}Cr monitor reaction to assess beam parameters and energy loss in the particles in the stack.

The target thickness was derived using the measured size and weight of the foils. The derived thickness of ^{nat}V, ^{nat}Ti, and ^{27}Al foils was 20.4, 2.24, and 1.22 mg/cm^2, respectively. These foils were then cut into 8 × 8 mm pieces to fit a target holder that served as a Faraday cup. Eleven sets of V-Al-Ti-Ti-Al foils were stacked into the target holder.

The stacked target was irradiated with a 50.6 ± 0.2 MeV alpha-particle beam for 30 min. The primary energy was measured by the time-of-flight method.[4)] Energy degradation in the stacked target was calculated using the SRIM code.[5)] The average beam intensity measured by the Faraday cup was 194 nA.

The γ-ray spectra of each irradiated foil were measured by a high-resolution HPGe detector (ORTEC GEM-25185-P) and analyzed using dedicated software (SEIKO EG&G Gamma Studio). Each ^{nat}V foil was measured with the following ^{27}Al catcher foil for the recoiled products. The distance between the detector and foils was arranged to ensure a dead time of less than 3%.

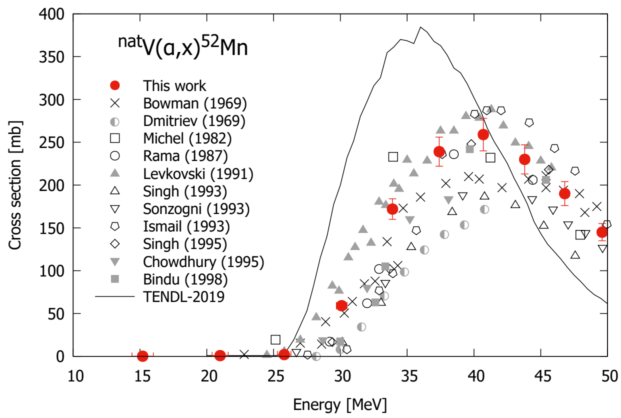

Fig. 1. Excitation function of the ^{nat}V(α, x)^{52m}Mn reaction.

The cross-sections of the ^{nat}Ti(α, x)^{51}Cr monitor reaction were derived to assess the beam parameters and target thickness. The γ line at 320.08 keV (I_γ = 9.91%) from the decay of ^{51}Cr ($T_{1/2}$ = 27.7025 d) in each low-energy foil of Ti-Ti pairs were measured. The derived cross-sections were compared with the IAEA recommended values.[6)] Our result was consistent with the recommended values and no corrections were adopted for data analysis.

Further, the cumulative cross-sections of the ^{nat}V(α, x)^{52m}Mn reaction were derived. The shorter-lived metastable state of the ^{52m}Mn ($T_{1/2}$ = 21.1 min) radionuclide decayed to the ground state ^{52m}Mn ($T_{1/2}$ = 5.591 d) and ^{52}Cr (stable) soon after the end of the bombardment. The γ line at 935.544 keV (I_γ = 94.5%) from the decay of ^{52m}Mn was measured after cooling for 17 days. The cumulative cross-sections were obtained from the net count of the γ line. Figure 1 shows the derived cross-sections in comparison to previous experimental studies and TENDL-2019 data.[3)] The present cross-section data exhibited a smooth curve and they were consistent with a part of previous experimental data. The peak position and amplitude of TENDL-2019 data were different from the experimental data.

G. Damdinsuren was granted a scholarship by the M-JEED project (Mongolian-Japan Engineering Education Development Program, J11B16).

References

1) F. Bianchi *et al.*, Appl. Radiat. Isot. **166** (2020).
2) N. Otuka *et al.*, Nucl. Data Sheets **120**, 272 (2014).
3) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).
4) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (2014), p. 3566.
5) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
6) F. Tárkányi *et al.*, IAEA-TECDOC-1211 (2007).

*1 Graduate School of Biomedical Science and Engineering, Hokkaido University
*2 RIKEN Nishina Center
*3 Faculty of Science, Hokkaido University
*4 School of Engineering and Applied Sciences, National University of Mongolia
*5 Graduate School of Science and Engineering, Saitama University