Excitation functions of α-particle-induced reactions on ^{nat}Cr up to 50 MeV†

N. Ukon,[*1,*2] M. Aikawa,[*2,*3] Y. Komori,[*2] H. Haba,[*2] S. Takács,[*4] and F. Ditrói[*4]

The radionuclide ^{52g}Fe has a half-life of 8.275 hours and decays with EC and β^+ decay modes via emitting an intense γ ray at 849.43 keV (I_γ = 100%).[1] The β^+ particle generates annihilation γ rays at 511.0 keV. These γ lines can be used for medical diagnostic imaging such as single-photon emission computed tomography (SPECT) and positron emission tomography (PET), the latter of which is particularly used for bone marrow imaging.[2,3] ^{52g}Fe is thus a valuable radionuclide and production routes must be investigated for optimizing its production. Several possible reactions produce ^{52g}Fe. We focused on the ^{50}Cr$(\alpha,2n)^{52}$Fe reaction. We measured the cross-sections of the ^{nat}Cr$(\alpha,x)^{52}$Fe reaction. Only the ^{50}Cr$(\alpha,2n)^{52g}$Fe reaction contributes to the cross-sections of the ^{nat}Cr$(\alpha,x)^{52}$Fe process below the threshold energy of the ^{52}Cr$(\alpha,yn)^{52}$Fe reaction (39.8 MeV). Thus, the cross-sections measured on natural chromium can be normalized to those of ^{50}Cr.

An experiment was conducted to measure the activation cross-sections of the α-particle-induced reactions on ^{nat}Cr at the AVF cyclotron of RIKEN. The standard stacked foil activation technique and high-resolution γ-ray spectrometry were used to determine the cross-sections. Nickel-chromium (NiCr) alloys were used as targets because chromium is difficult to process into a foil structure. Nickel metal foils were also created in same stack in to compare them with the nuclides produced from the nickel in the NiCr alloy foils, together with titanium-foils which were used for monitoring the reaction. All foils were cut in 10 × 10 mm to fit into the target holder. The target holder also served as a Faraday cup. The ^{nat}Ti$(\alpha,x)^{51}$Cr monitoring reaction was used to check the beam parameters (energy and intensity) and validate the energy scale deduced from the calculated energy loss of the α particles throughout the layered target. The stacked target was irradiated with a 51.2 ± 0.2-MeV α-particle beam. The incident energy of the α particles was measured using the time-of-flight method. The energy degradation in the target was calculated using SRIM code.[4] The duration of the irradiation with an average beam intensity of 209.8 nA was 2 hours. The beam intensity was recorded every minute to verify beam stability during irradiation. The γ-ray spectra of the irradiated foils were measured with an HPGe detector (ORTEC GEM-25185-P) and analyzed using dedicated software (SEIKO EG&G Gamma Studio). The detector was calibrated with a standard γ-ray point source containing a mixture of radioisotopes.

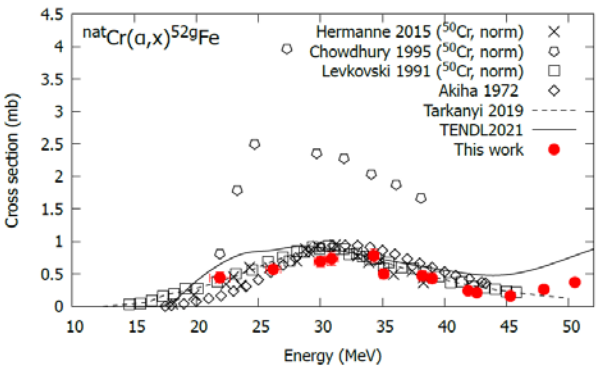

Fig. 1. Cross-sections of the ^{nat}Cr$(\alpha,x)^{52g}$Fe reaction in comparison with previous data,[6–9] the recommended values, and the TENDL-2021 result.[10] The values in the figure were normalized yo the abundance of ^{nat}Cr.

The ^{52}Fe radionuclide is metastable and has a short half-life ($T_{1/2}$ = 45.9 s). The ^{52m}Fe metastable state decays almost 100% to ^{52g}Mn (EC + β^+: 100%) and in minor part to ^{52g}Fe (IT: <4.0E-3%).

The contribution of ^{52g}Fe to populating the ^{52g}Fe state is negligibly small, and the independent cross-sections of the ^{nat}Cr$(\alpha,x)^{52g}$Fe reaction was obtained by measuring the 168.688 keV γ line (I_γ = 99%) from the decay of ^{52g}Fe ($T_{1/2}$ = 8.275 h). The measurement series started after a cooling time of 23 hours to reduce the effect of background radiation on the cross-section. Our result was compared with the experimental data,[6–9] and the recommended values and the TENDL-2021 data[10] are shown in Fig. 1.

We determined the activation cross-sections of the α-particle-induced reactions on ^{nat}Cr. A stacked target, the activation technique, and high-resolution γ-ray spectrometry were used. The cross-sections were deduced for the ^{nat}Cr$(\alpha,x)^{52g}$Fe, ^{52g,54}Mn, ^{48,51}Cr, and ^{48}V reactions. The newly measured data were compared with previous experimental data, and the results of the TALYS model calculation were obtained from the TENDL database. Our results were generally consistent with the previous experimental data. The cross-sections were deduced for the ^{nat}Cr$(\alpha,x)^{52g}$Fe, ^{52g,54}Mn, ^{48,51}Cr and ^{48}V reactions, but only the result for ^{52g}Fe is reported.

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*1 Advanced Clinical Research Center, Fukushima Medical University
*2 RIKEN Nishina Center
*3 Faculty of Science, Hokkaido University
*4 Institute for Nuclear Research (ATOMKI)

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