Production cross sections of ^{189g}Ir in α-particle-induced reactions on ^{nat}Re

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Iridium-189 has the ground state ^{189g}Ir ($T_{1/2} = 13.2$ d, ε: 100%) and two short-lived excited states ^{189m1}Ir and ^{189m2}Ir ($T_{1/2} = 13.3$ and 3.7 ms, IT: 100%). The radionuclide ^{189g}Ir is an Auger electron emitter and can be used for therapy in nuclear medicine.[1)] Charged-particle-induced reactions on osmium and rhenium are possible production routes of ^{189g}Ir. In this work, we focused on the α-particle-induced reactions on ^{nat}Re targets. In a literature survey, three experimental studies of the cross sections of the $^{nat}\mathrm{Re}(\alpha,x)^{189}$Ir reactions were found.[2–4)] The previous experimental data are significantly different in peak position and amplitude. Therefore, we performed an experiment to measure reliable cross sections of the $^{nat}\mathrm{Re}(\alpha,x)^{189}$Ir reaction. The result was compared with the experimental data published earlier and the TENDL-2021 values.[5)]

The experiment was conducted at the AVF cyclotron of the RIKEN RI Beam Factory. The stacked-foil technique, activation method, and high-resolution γ-ray spectrometry were used. The stacked target consisted of pure metallic foils of ^{nat}Re (12.5-μm thick, 99.99% purity), ^{nat}Ti (5-μm thick, 99.6% purity), and ^{27}Al (5-μm thick, 99.9% purity). All foils were purchased from Nilaco Corp., Japan. The ^{nat}Ti foils were used for the $^{nat}\mathrm{Ti}(\alpha,x)^{51}$Cr monitor reaction. The ^{27}Al foils were inserted to catch reaction products recoiled from the ^{nat}Re and ^{nat}Ti foils. The target thicknesses were derived from the measured size and weight of the foils. The derived thicknesses of ^{nat}Re, ^{nat}Ti, and ^{27}Al foils were 25.3, 2.24, and 1.22 mg/cm^2, respectively. The original foils were then cut into a size of 10 × 10 mm to fit in a target holder that served as a Faraday cup. Fifteen sets of Re-Al-Ti-Al foils were stacked in the target holder.

The stacked target was irradiated with a 50.6 ± 0.2 MeV α-particle beam for 30 min. The primary beam energy was measured by the time-of-flight method.[6)] Energy degradation in the stacked target was calculated using stopping powers derived from the SRIM code.[7)] The average beam intensity measured by the Faraday cup was 203 nA.

The γ-ray spectra were measured using a high-resolution HPGe detector (ORTEC GEM-25185-P) and analyzed using dedicated software (SEIKO EG&G Gamma Studio). The spectra of each ^{nat}Re foil and the following ^{27}Al catcher foil were measured several times. The distance between the detector and the foils was set to keep dead time below 1%.

To assess the beam parameters and target thicknesses, the $^{nat}\mathrm{Ti}(\alpha,x)^{51}$Cr monitor reaction cross sections were derived. The γ line at 320.08 keV (I_γ = 9.910%) from the decay of ^{51}Cr ($T_{1/2} = 27.7025$ d) was measured after a cooling time of 2 d.

The derived cross sections were compared with the IAEA-recommended values.[8)] Based on the comparison, the incident beam energy and thickness of the ^{nat}Re foil were corrected within the uncertainties by +0.2 MeV and −1%, respectively.

The measurement of the γ line at 245.1 keV (I_γ = 6.0%) emitted with the decay of ^{189g}Ir was performed after a cooling time of 36 d. The two short-lived excited states with shorter half-lives ($T_{1/2}$ = 13.3 and 3.7 ms, IT: 100%) decayed to ^{189g}Ir during the irradiation. The cumulative cross sections of the $^{nat}\mathrm{Re}(\alpha,x)^{189g}$Ir reaction were derived from measured net counts. The preliminary result of the cross sections of $^{189(g+m1+m2)}$Ir is shown in Fig. 1, together with the previous experimental data[2–4)] and the TENDL-2021 values.[5)] The experimental data of Singh and Gadkari[4)] are higher than our data, while the peak position is located at nearly the same energy. The data of Goncharov *et al.*[2)] and Ismail[3)] are largely different from ours in both peak amplitude and position. The TENDL-2021 values agree well with ours.

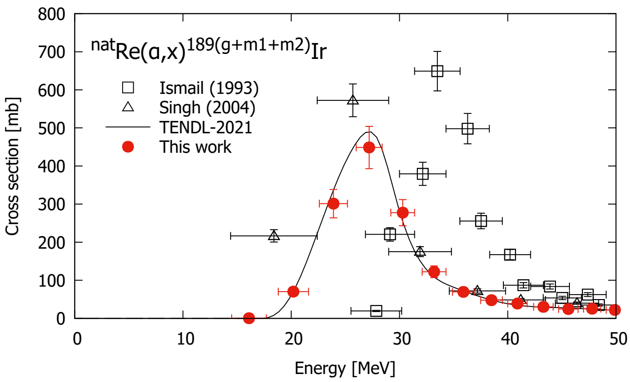

Fig. 1. Cumulative cross sections of the $^{nat}\mathrm{Re}(\alpha,x)^{189g}$Ir reaction.

The analyses to determine the final cross sections of ^{189g}Ir and other co-products are continued. The thick

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target yields of the products can be calculated using the measured cross sections. The finalized results are expected to contribute to the practical use of radionuclides in nuclear medicine.

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