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

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The radionuclide ^{189g}Ir, an Auger electron emitter, is suitable for therapy in nuclear medicine.[1] It has three isomeric states: the ground state ^{189g}Ir ($T_{1/2}$ = 13.2 d, ε: 100%) and two short-lived excited states ^{189m1}Ir ($T_{1/2}$ = 13.3 ms) and ^{189m2}Ir ($T_{1/2}$ = 3.7 ms), both of which decay to the ground state via isomeric transition (IT: 100%).

Possible routes for ^{189g}Ir production are p- and d-induced reactions on ^{nat}Os or enriched ^{189}Os and ^{188}Os targets. Alternative production routes are α-particle-induced reactions on ^{nat}Re and enriched ^{187}Re targets. In this work, we focused on the α-particle-induced reactions on ^{nat}Re. Our literature survey found two experimental studies on ^{189g}Ir production via α-particle-induced reactions on rhenium.[2,3] Their experimental data show significant differences in both peak position and amplitude. Therefore, we measured the excitation functions of α-particle-induced reactions on ^{nat}Re up to 50 MeV and compared the results with experimental data from past studies and the TENDL-2021 library.[4]

The experiment was conducted at the AVF cyclotron of RIKEN RI Beam Factory using stacked-foil activation and γ-ray spectrometry. 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% purity). The ^{27}Al foils were used to catch the recoiled reaction products from the ^{nat}Re and ^{nat}Ti foils. The ^{nat}Ti foils in the stack were used to evaluate the beam parameters and target thickness via the ^{nat}Ti $(\alpha,x)^{51}$Cr monitor reaction. The average target thicknesses, determined from the measured sizes and weights of the foils, were 25.3 ± 0.2, 2.24 ± 0.01, and 1.22 ± 0.02 mg/cm^2 for ^{nat}Re, ^{nat}Ti, and ^{27}Al, respectively. The foils were then cut into a size of 10 mm × 10 mm to fit 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 for 30 min with a 50.5 ± 0.2 MeV α-particle beam. The primary beam energy was measured via the time-of-flight method.[5] The energy degradation in the stacked target was calculated using the SRIM code.[6] 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 together. The distance between the detector and the foils was arranged such that the dead time was kept to less than 3%.

Cross sections of the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reaction were derived using the γ-line at 320.08 keV (I_γ = 9.91%) from the decay of ^{51}Cr ($T_{1/2}$ = 27.7025 d). The derived cross sections were compared with the IAEA-recommended values.[7] Based on the comparison, the incident beam energy and average thickness of the ^{nat}Re foil were corrected within the uncertainties by +0.2 MeV to 50.7 ± 0.2 MeV and 1% to 25.0 ± 0.4 mg/cm^2, respectively. The deduced excitation function of the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reaction using the corrected parameters was consistent with the recommended values published in 2007.

Cumulative cross sections of the ^{nat}Re$(\alpha,x)^{189g}$Ir reaction were derived from measurements of the 245.1-keV γ-line (I_γ = 6%) emitted with ^{189g}Ir decay ($T_{1/2}$ = 13.2 d) after a cooling time of 37 days. By that time, the two metastable states ($T_{1/2}$ = 13.3 and 3.7 ms, IT: 100%) had decayed to the ground state. Figure 1 shows the cumulative cross sections of ^{189g}Ir compared with past experimental data[2,3] and the TENDL-2021 data.[4]

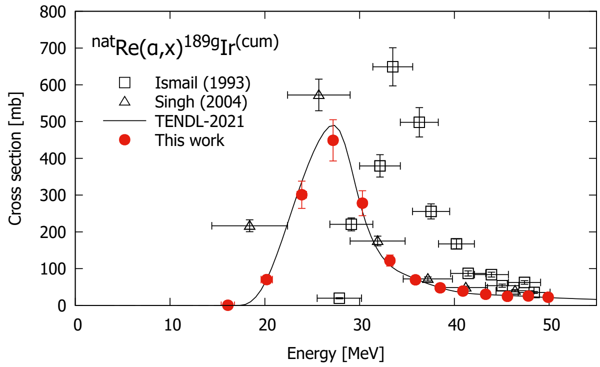

Fig. 1. Cumulative cross sections of ^{nat}Re$(\alpha,x)^{189g}$Ir reaction with experimental data from literature[2,3] and the TENDL-2021 values.[4]

† Condensed from the article in Appl. Radiat. Isot. **213**, 111486 (2024)

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DOI:10.34448/RIKEN.APR.58-018

The energy position of the peak is near ours, although the amplitudes obtained by Singh and Gadkari (2004) are higher. The data of Ismail (1993) are much different from ours in terms of the peak amplitude and position. The TENDL-2021 values agree well with ours. ^{nat}Re is more abundant and cheaper than osmium. The ^{nat}Re(α, x) reaction can produce a high yield of ^{189g}Ir with less contamination than is obtained with Os-based reactions. The results can contribute to the optimization of ^{189g}Ir production and improvement of theoretical model calculation codes.

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