# Activation cross sections of alpha-induced reactions on natural tungsten for $^{186}$Re and $^{188}$Re production

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Radioisotopes (RI) are used for diagnosis and therapy in nuclear medicine. $^{186}$Re is a $\beta$ emitter with a half-life of 3.72 days, a maximum $\beta$ energy of 1.07 MeV, average penetration ranges of 1.1 mm in soft tissue and 0.5 mm in bone, and a 9.47% $\gamma$-ray emission at 137 keV. $^{188}$Re is a $\beta$ emitter with a half-life of 17 hours, maximum $\beta$ energy of 2.12 MeV, and 15.61% $\gamma$-ray emission at 155 keV.[1,2] Both isotopes can be used for theranostics (therapy and diagnosis).

We focused on a process to produce $^{186,188}$Re through alpha-induced reactions of natural tungsten because we could find data for only one 43 MeV.[3] Therefore, we measured the excitation function of the $^{nat}W(\alpha, x)^{186,188}$Re reactions up to 51 MeV.

The excitation functions of the $^{nat}W(\alpha, x)^{186,188}$Re reaction were measured by the stacked-foil method, activation method and high-resolution $\gamma$-ray spectroscopy. $^{nat}$W foils (purity: 99%, Goodfellow Co., Ltd., UK) were stacked with $^{nat}$Ti foils (purity: 99%, Goodfellow Co., Ltd., UK) for monitoring the beam parameters and degrading the beam energy. The thicknesses of the W and Ti foils were 15.03 and 2.23 mg/cm$^2$, respectively.

The irradiation was performed at the RIKEN AVF cyclotron. A 51 MeV alpha beam with an average intensity of 209.7 pnA was irradiated on the target for 2 h. The incident beam energy was measured by the time-of-flight method using plastic scintillator monitors.[4] The beam energy degraded in the stacked target was calculated using the SRIM code available online.[5] The $\gamma$-ray spectra of the activated foils were measured by an HPGe detector. Nuclear decay data were taken from the online NuDat 2.7 database.[6]

From the net peak areas of the 137.16- and 155.04-keV $\gamma$-rays, the activation cross sections for the $^{nat}W(\alpha, x)^{186,188}$Re reaction were deduced using the standard activation formula

$$\sigma = \frac{T_\gamma \lambda}{\varepsilon_d \varepsilon_\gamma \varepsilon_t N_t N_b (1 - e^{-\lambda t_b}) e^{-\lambda t_c} (1 - e^{-\lambda t_m})}$$

where $N_\mathrm{t}$ denotes the surface density of target atoms; $N_\mathrm{b}$ the number of bombarding particles per unit time; $T_\gamma$ the number of counts in the photo-peak; $\varepsilon_\mathrm{d}$ the detector efficiency; $\varepsilon_\gamma$ the $\gamma$-ray abundances; $\varepsilon_\mathrm{t}$ the measurement dead time, which is the ratio of live time to real time; $\lambda$ the decay constant; $t_\mathrm{b}$ the bombarding time; $t_\mathrm{c}$ the cooling time; and $t_\mathrm{m}$ the acquisition time.

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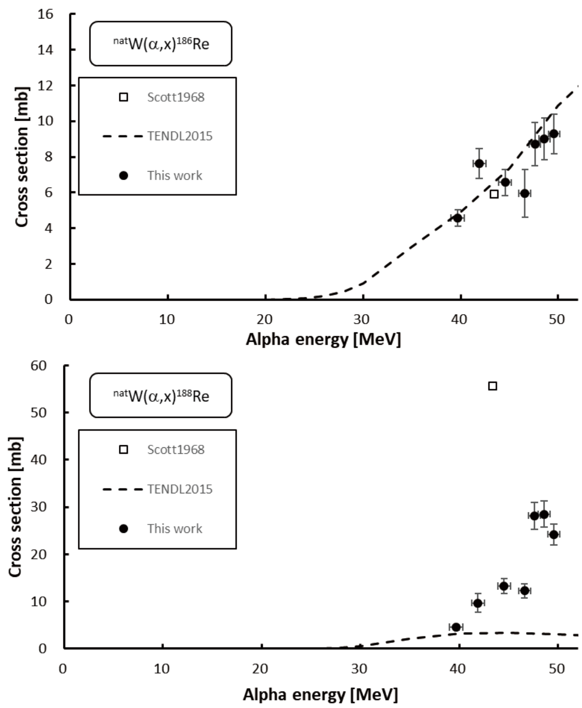


Fig. 1. Excitation functions of the $^{nat}W(\alpha, x)^{186,188}$Re reactions. The result is compared with a previous study[3] and TENDL-2015.[7]

We found that our $^{nat}W(\alpha, x)^{186}$Re result is in good agreement with previous data obtained by NE. Scott *et al.*[3] and the theoretical calculation (TENDL-2015).[7]

On the other hand, the $^{nat}W(\alpha, x)^{188}$Re result shows disagreements with the other data. TENDL-20157) underestimates the cross section at all energies.

References

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