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 β^- emitter with a half-life of 3.72 days. Its maximum β^- energy of 1.07 MeV has average penetration ranges of 1.1 mm in soft tissue and 0.5 mm in bone. It decays with the emission of γ-rays at 137 keV ($I_\gamma = 9.47\%$). ^{188}Re is also a β^- emitter with a half-life of 17 h and a maximum β^- energy of 2.12 MeV, and it decays with γ-ray emission at 155 keV ($I_\gamma = 15.61\%$).[1,2] Both isotopes can be used for theranostics investigations (therapy and diagnosis). We focused on processes to produce ^{186,188}Re through alpha-induced reactions on natural tungsten because only one previous work with one data point for both isotopes has been reported at an incident energy of 43 MeV.[3] Therefore, we investigated the excitation function of the $^{\rm nat}$W$(\alpha,x)^{186,188}$Re reactions up to 51 MeV.

The excitation functions of the $^{\rm nat}$W$(\alpha,x)^{186,188}$Re reactions were measured using the stacked-foil technique, activation method, and high-resolution γ-ray spectroscopy. $^{\rm nat}$W foils (purity: 99%, Goodfellow Co., Ltd., UK) were stacked with $^{\rm nat}$Ti foils (purity: 99%, Goodfellow Co., Ltd., UK) for monitoring the beam parameters and degrading the beam energy. The average thicknesses of the W and Ti foils were 29.99 and 2.29 mg/cm^2, respectively. The irradiation was performed at the RIKEN AVF cyclotron. The target was irradiated by an alpha-particle beam of 51 MeV with an average intensity of 189.1 pnA for 2 h. The incident beam energy was determined by the time-of-flight method using plastic scintillator monitors.[4] The energy loss of the beam in the stacked target was calculated using the SRIM code available online.[5] The γ-ray spectra of the activated foils were measured using a high-purity germanium (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 γ-rays, the activation cross sections for the $^{\rm nat}$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_t denotes the surface density of target atoms, N_b the number of bombarding particles per unit time, T_γ the number of counts in the photo-peak, ε_d the detector efficiency, ε_γ the γ-ray abundances, ε_t the measurement dead time, λ the decay constant, t_b the bombarding time, t_c the cooling time, and t_m the acquisition time.

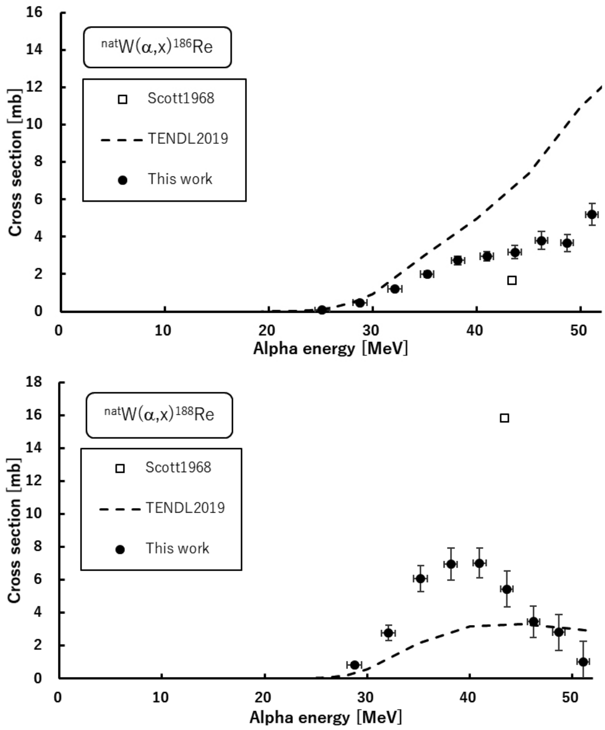

Fig. 1. Excitation functions of the $^{\rm nat}$W$(\alpha,x)^{186,188}$Re reactions. The results are compared with a previous study[3] and TENDL-2019.[7]

We found that the only previous data point obtained by Scott *et al.*[3] for the $^{\rm nat}$W$(\alpha,x)^{186}$Re reaction is approximately half of our data. In contrast, for the $^{\rm nat}$W$(\alpha,x)^{188}$Re reactions, the only data point of Scott *et al.*[3] is more than double our result. The TENDL-2019[7] predictions deviate considerably from the experimental data.

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