Activation cross sections of alpha-particle-induced reactions on natural tungsten for osmium and rhenium radionuclides†

N. Ukon,[*1,*2] M. Aikawa,[*2,*3,*4] M. Saito,[*4] M. Hagiwara,[*5] H. Yashima,[*6] Y. Komori,[*2] H. Haba,[*2] S. Takács,[*7] F. Ditrói,[*7] and Z. Szücs[*7]

Rhenium radionuclides can be used in nuclear medicine.[1,2] ^{186g}Re, with a half-life of 3.7 d, decays with an emission of beta particles and gamma rays. The maximum energy of the beta particles is 1.07 MeV, which enables the beta particles to pass through average ranges of 1.1 mm in soft tissue and 0.5 mm in bone. ^{188g}Re is also a beta emitter. It has a half-life of 17 h and decays with emission of a higher-energy beta particle (2.12 MeV at maximum) and gamma rays. Both rhenium radionuclides can be used for theranostics, which is a combination of therapy and diagnosis. The radionuclides can be produced by charged-particle-induced reactions on tungsten. Among possible reactions, we observed on alpha-particle-induced reactions on tungsten. We found only two previous studies in a literature survey using the EXFOR library[3] and Nuclear Science References (NSR).[4] In addition, the literature cross sections differed significantly from each other. Therefore, reliable cross sections are required. We performed an experiment to measure activation cross sections of alpha-particle-induced reactions on natural tungsten, which consists of five isotopes, ^{180}W (0.12%), ^{182}W (26.50%), ^{183}W (14.31%), ^{184}W (30.64%), and ^{186}W (28.43%). We determined production cross sections of ^{186g,188g}Re and others. The measured cross sections are expected to contribute to search for the best production reactions of the radionuclides. The result was compared with the previous data and theoretical model calculation in the TENDL-2019 library.[5]

The stacked-foil activation technique and high-resolution gamma-ray spectrometry were used to measure the cross sections. We performed an experiment using a 50-MeV alpha-particle beam at the RIKEN AVF cyclotron. The stacked target was irradiated for 60 min with an alpha-particle beam collimated to a diameter of 3 mm. The average beam intensity measured by the Faraday cup was 189 nA. The stacked target consisted of thin and pure metallic foils of natural tungsten (^{nat}W) and titanium (^{nat}Ti). The ^{nat}W (99.95% purity) and ^{nat}Ti (99.6% purity) foils were purchased from Nilaco Corp., Japan. The ^{nat}Ti foil was used for the ^{nat}Ti$(\alpha,x)^{51}$Cr monitor reaction. The lateral size and weight of the foils were measured for the average thicknesses.

The measured average thicknesses of the ^{nat}W and ^{nat}Ti foils were 30.0 and 2.30 mg/cm^2, respectively. Fourteen sets of the W-Ti-Ti foils were stacked in the target holder. The second ^{nat}Ti foils were used for the monitor reaction under the assumption that the same amount of recoiled products from the second foils was compensated for by the first foils.

High-resolution gamma-ray spectrometry was performed using two high-purity germanium detectors and analysis software. Spectra of each irradiated ^{nat}W foil with the next ^{nat}Ti catcher foil were measured three times with different cooling times from 21 h to 4.8 d, respectively. The associated dead time was less than 6.9%.

Rhenium-186 has two metastable states, a shorter-lived ground state ^{186g}Re and longer-lived excited state ^{186m}Re ($T_{1/2} = 2.0\times10^5$ y). ^{186m}Re could be produced simultaneously but the contribution of the decay to ^{186g}Re was negligible because of the long half-life. The gamma line at 137.157 keV ($I_\gamma = 9.47\%$) was used to derive production cross sections of ^{186g}Re. The possible interference of 137.2 keV ($I_\gamma = 0.07\%$) from ^{181}Re was negligibly small because of the weak intensity.

The derived cross sections are shown in Fig. 1 with the theoretical prediction of TENDL-2019. The TENDL-2019 data are slightly different from our data. No experimental data were found in the literature survey.

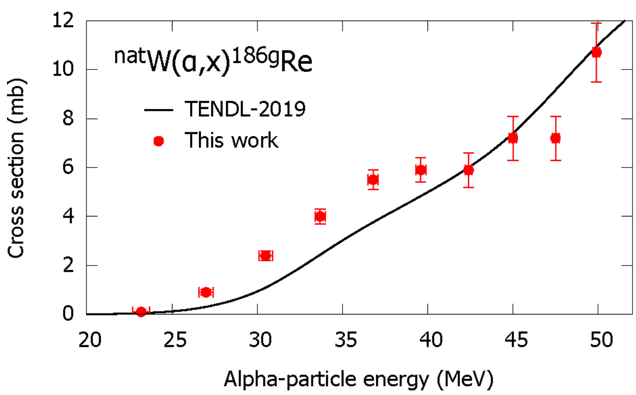

Fig. 1. Cross sections of the ^{nat}W$(\alpha,x)^{186g}$Re reaction with the TENDL-2019 value.

† Condensed from the article in Nucl. Instrum. Methods Phys. Res. B **539**, 95 (2023)

*1 Advanced Clinical Research Center, Fukushima Medical University
*2 RIKEN Nishina Center
*3 Faculty of Science, Hokkaido University
*4 Graduate School of Biomedical Science and Engineering, Hokkaido University
*5 High Energy Accelerator Research Organization (KEK)
*6 Institute for Integrated Radiation and Nuclear Science, Kyoto University
*7 Institute for Nuclear Research (ATOMKI)

DOI:10.34448/RIKEN.APR.57-154

References
1) I. G. Finlay *et al.*, Lancet Oncol. **6**, 392 (2005).
2) A. M. Denis-Bacelar *et al.*, Eur. J. Nucl. Med. Mol. Imaging **44**, 620 (2017).
3) N. Otuka *et al.*, Nucl. Data Sheets **120**, 272 (2014).
4) B. Pritychenko *et al.*, Nucl. Instrum. Methods Phys. Res. A **640**, 213 (2011).
5) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).