Cross sections of proton-induced reactions on ^{nat}W for ^{186g}Re production

M. Aikawa,[*1,*2] S. Ebata,[*3,*2] N. Ukon,[*4,*2] and H. Haba[*2]

Rhenium radionuclides can be used for theranostics, which is a combination of therapy and diagnosis.[1)] ^{186g}Re ($T_{1/2} = 3.7186$ d) decays with the emission of β^- particles and γ rays and can be used for nuclear medicine. Among possible reactions for ^{186g}Re production, we focused on proton-induced reactions on ^{nat}W. Eight experimental studies on the ^{nat}W$(p,x)^{186g}$Re reaction were found in the literature.[2–9)] However, the data of these studies were largely scattered. Therefore, we performed an experiment to measure reliable cross sections of proton-induced reactions on ^{nat}W (^{180}W 0.12%, ^{182}W 26.50%, ^{183}W 14.31%, ^{184}W 30.64%, and ^{186}W 28.43%). Among these isotopes, ^{186}W can contribute to the production of ^{186g}Re.

The experiment was conducted at the RIKEN AVF cyclotron. The stacked-foil technique, activation method, and γ-ray spectrometry were employed. The stacked target comprised pure metallic foils of ^{nat}W (25-μm thick, 99.95% purity) and ^{nat}Ti (5-μm thick, 99.6% purity), which were purchased from Nilaco Corp., Japan. The ^{nat}Ti foils were used for the ^{nat}Ti$(p,x)^{48}$V monitor reaction. The target thicknesses were derived on the bases of the measured size and weight of the foils. The derived thicknesses of ^{nat}W and ^{nat}Ti foils were 26.7 and 5.25 mg/cm^2, respectively. The original sheets were cut into a size of 10×10 mm to fit into a target holder, which served as a Faraday cup as well. Twenty sets of W-W-Ti-Ti foils were stacked as a target. For cross-section deduction, only the second foils downstream of each pair in the stack were used, accounting for recoiled products.

The stacked target was irradiated using a proton beam for 30 min. Proton energy determined using the time-of-flight method[10)] was 29.8 MeV. Energy degradation was calculated on the basis of the thicknesses and stopping powers derived from the SRIM code.[11)] The average beam current measured by the Faraday cup was 101 nA.

γ-ray spectra were measured using a high-resolution HPGe detector. The γ-ray spectra for each second ^{nat}W foil were measured five times 13 days after the end-of-bombardment. The associated dead time was less than 2.7%.

Cross sections of the ^{nat}Ti$(p,x)^{48}$V monitor reaction were derived using the γ line at 983.53 keV (I_γ = 99.98%) based on the decay of ^{48}V ($T_{1/2} = 15.9735$ d). The derived cross sections well agreed with the recommended values.[12,13)] No correction was necessary for the analysis.

The cross sections of the ^{nat}W$(p,x)^{186g}$Re reaction were determined. The long-lived excited state of ^{186}Re ($T_{1/2} = 2.0 \times 10^5$y) could not contribute to the ground state. The γ line at 137.15 keV (I_γ = 9.47%) emitted from the decay of ^{186g}Re was used to determine the cross sections. The possible interferences were γ lines at 136.28 keV (I_γ = 0.0311%) from ^{181}W ($T_{1/2}$ = 121.2 d) and 137.2 keV (I_γ = 0.07%) from ^{181}Re ($T_{1/2}$ = 19.9 h). Both contributions were negligible because of a longer half-life of ^{181}W and tiny branching ratios.

The independent cross sections shown in Fig. 1 are compared with the literature data[2–9)] and theoretical calculations in the TENDL-2021 library.[14)] Above 15 MeV, the data of Bonardi *et al.* (2011) and Tárkányi *et al.* (2007) agree with our data, although the peak amplitudes are slightly higher. Some data deviate from our result. The TENDL-2021 values agree with our results. Further analyses will be done to finalize the cross sections.

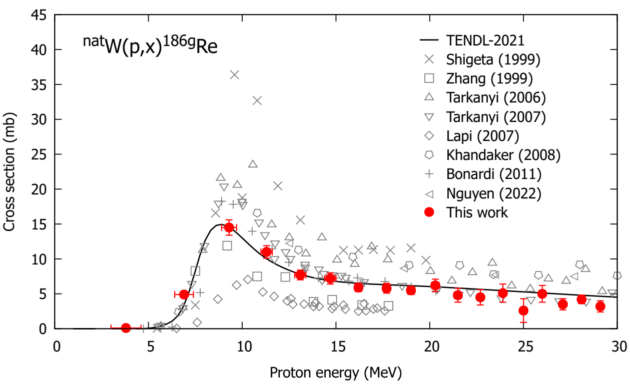

Fig. 1. Cross sections of the ^{nat}W$(p,x)^{186g}$Re reaction in comparison with the previous data[2–9)] and the TENDL-2021 values.[14)]

[*1] Faculty of Science, Hokkaido University
[*2] RIKEN Nishina Center
[*3] Graduate School of Science and Engineering, Saitama University
[*4] Advanced Clinical Research Center, Fukushima Medical University

DOI:10.34448/RIKEN.APR.57-029

References

1) I. G. Finlay *et al.*, Lancet Oncol. **6**, 392 (2005).
2) N. Shigeta *et al.*, J. Radioanal. Nucl. Chem. **205**, 85 (1996).
3) X. Zhang *et al.*, Radiochim. Acta **86**, 11 (1999).
4) F. Tárkányi *et al.*, Nucl. Instrum. Methods Phys. Res. B **252**, 160 (2006).
5) F. Tárkányi *et al.*, Nucl. Instrum. Methods Phys. Res. B **264**, 389 (2007).

6) S. Lapi *et al.*, Appl. Radiat. Isot. **65**, 345 (2007).
7) M. U. Khandaker *et al.*, Nucl. Instrum. Methods Phys. Res. B **266**, 1021 (2008).
8) M. Bonardi *et al.*, Radiochim. Acta **99**, 1 (2011).
9) T. H. Nguyen *et al.*, Radiat. Phys. Chem. **196**, 110145 (2022).
10) T. Watanabe *et al.*, Proc. 5th Int. Part. Accel. Conf. (IPAC), (2014), p. 3566.
11) J. F. Ziegler *et al.*, Nucl. Instrum. Methods Phys. Res. B **268**, 1818 (2010).
12) F. Tárkányi *et al.*, IAEA-TECDOC-1211 (2007).
13) A. Hermanne *et al.*, Nucl. Data Sheets **148**, 338 (2018).
14) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).