Measurement of production cross sections of Re isotopes in the ^{nat}W(d,x) reactions

Y. Komori,[*1] M. Murakami,[*1,*2] and H. Haba[*1]

Chemical characterization of superheavy elements is one of the most important and challenging subjects in the field of nuclear chemistry. We plan to conduct model experiments for chemical studies of element 107, Bh, using radiotracers of its homologs, Tc and Re. Long-lived ^{95m}Tc ($T_{1/2}$ = 61 d), ^{183}Re ($T_{1/2}$ = 70 d), and ^{184m,g}Re (m: $T_{1/2}$ = 169 d; g: $T_{1/2}$ = 35.4 d) are useful for the model experiments. These isotopes are producible in the deuteron-induced reactions on ^{nat}Mo and ^{nat}W (nat: natural isotopic abundance) using the RIKEN AVF cyclotron. Previously, we measured production cross sections of Tc isotopes in the ^{nat}Mo(d,x) reactions for quantitative production of ^{95m}Tc.[1)] In this work, we have measured the cross sections of Re isotopes in the ^{nat}W(d,x) reactions up to 24 MeV.

The cross sections were measured using a stacked-foil technique. The target stack consisted of twenty sets of ^{nat}W foils (99.95% purity, 40.7 mg/cm^2 thickness) and ^{nat}Ti foils (>99.6% purity, 4.7 mg/cm^2 thickness). The Ti foils were used to calibrate the beam current and the incident energy via the monitor reaction ^{nat}Ti(d,x)^{48}V.[2)] The size of all foils was 15 × 15 mm^2. The target stack was irradiated for 1 h with a 24-MeV deuteron beam supplied from the RIKEN AVF cyclotron. The average beam current was 0.18 μA. After the irradiation, each foil was subjected to γ-ray spectrometry with a Ge detector.

The excitation functions were measured for the ^{nat}W(d,x)^{181,182a,182b,183,184m,184g,186g}Re,^{187}W,^{182g,184}Ta reactions. Figure 1 shows the excitation function of the ^{nat}W(d,x)^{183}Re reaction. Our results are in good agreement with those of Tárkányi et al.[3)] and Duchemin et al.[4)] and slightly smaller than others.[5–7)] Figure 2 shows the excitation function of the ^{nat}W(d,x)^{184m}Re reaction. There are only two reports[4,5)] on the cross sections of ^{184m}Re and our data confirmed the results reported by Duchemin et al.[4)] It can be seen that the theoretical model code TALYS (TENDL-2014)[8)] reproduces well the experimental cross sections of ^{183}Re. However, the code significantly overestimates the excitation function of ^{184m}Re though it can reproduce the shape of the function. As for ^{184g}Re, our results are slightly smaller than those in the literature.[3–5)] The TALYS code slightly underestimates our excitation function of ^{184g}Re, though it reproduces the shape of the function. Thick-target yields of ^{183,184m,184g}Re were deduced from the measured cross sections. The deduced yields of ^{183,184m,184g}Re at 24 MeV are 1.7, 0.043, and 1.2 MBq/μA·h, respectively. Based on the present results, we produced ^{183,184m,184g}Re by typical irradiations of a 200 mg/cm^2-thick ^{nat}W target foil with the 24-MeV deuteron beam with 5-μA for 3 h. These Re isotopes were chemically separated as no-carrier-added forms from the target material and by-products by using anion-exchange and alumina columns. We are using these radiotracers to develop a rapid solvent extraction apparatus and to determine suitable experimental conditions to study the aqueous chemistry of Bh.[9)]

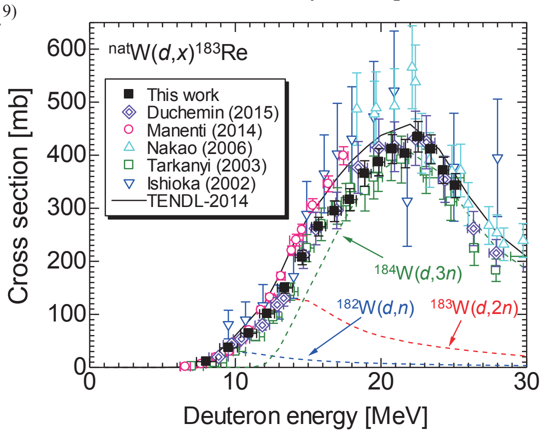

Fig. 1. The excitation function of the ^{nat}W(d,x)^{183}Re reaction. The errors of the cross sections were evaluated by propagating those of counting statistics in the radioactivity measurement, detector efficiency, and γ-ray intensity. The error in the deuteron energy corresponds to the energy degradation in each foil.

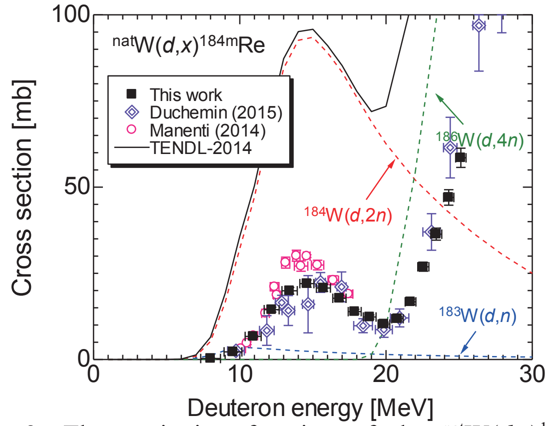

Fig. 2. The excitation function of the ^{nat}W(d,x)^{184m}Re reaction.

References

1) Y. Komori et al.: RIKEN Accel. Prog. Rep. **48**, 296 (2015).
2) IAEA: IAEA report IAEA-TECDOC-1211, 2001.
3) F. Tárkányi et al.: Nucl. Instrum. Meth. B **211**, 319 (2003).
4) C. Duchemin et al.: Appl. Radiat. Isot. **97**, 52 (2015).
5) S. Manenti et al.: Radiochim. Acta. **102**, 669 (2014).
6) M. Nakao et al.: Nucl. Instrum. Meth. A **562**, 785 (2006).
7) N. S. Ishioka et al.: J. Nucl. Sci. Technol. Suppl. **2**, 1334 (2002).
8) A. J. Koning et al.: TENDL-2014: TALYS-based Evaluated Nuclear Data Library, 2014.
9) Y. Komori et al.: Pacifichem 2015, Honolulu, Hawaii, U.S.A., Dec. INOR 1758, 2015.

*1 RIKEN Nishina Center
*2 Graduate school of Sci. and Technol., Niigata Univ.