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

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Chemical characterization of superheavy elements is one of the 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. Relatively long-lived isotopes, ^{95m}Tc ($T_{1/2}$ = 61 d) and ^{184g}Re ($T_{1/2}$ = 35.4 d) are useful for tracer experiments. In the field of nuclear medicine, the isotope ^{99m}Tc, the daughter nuclide of ^{99}Mo, is the most widely used for diagnostic imaging. Recently, the direct production of ^{99}Mo/^{99m}Tc using an accelerator has attracted much attention. In this work, production cross sections of deuteron-induced nuclear reactions on ^{nat}Mo (nat: natural isotopic abundance) have been measured up to 24 MeV for the quantitative production of Tc isotopes. The results are discussed by referring to previously reported data and the theoretical model code TALYS.[1)]

The production cross sections were measured using a stacked-foil technique. Seventeen ^{nat}Mo foils (99.95% purity, 20.9 mg/cm^2 thickness), sixteen ^{nat}Ti foils (99.5% purity, 9.2 mg/cm^2 thickness), and sixteen ^{nat}Ta foils (99.95% purity,16.1 mg/cm^2 thickness) were stacked in the order ofMo/Ti/Ta. 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 Ta foils were used to attenuate the beam energy. The size of all foils was 15 × 15 mm^2. The target stack of the Mo/Ti/Ta foils was irradiated for 1 h with a 24-MeV deuteron beam supplied from the RIKEN AVF cyclotron. The average beam current was 0.17 μA. After the irradiation, each foil was subjected to γ-ray spectrometry with a Ge detector.

The excitation functions were measured for the ^{nat}Mo(d,x)^{93m,93g,94m,94g,95m,95g,96m,96g,97m,99m}Tc, ^{93m,99,101}Mo, ^{90g,92m,95m,95g,96g}Nb, and ^{89g}Zr reactions. Figure 1 shows the excitation function of the ^{nat}Mo(d,x)^{95m}Tc reaction. Our results are in good agreement with the previously reported data.[3–5)] It can be seen that the TALYS code (TENDL-2013) underestimates the cross sections at deuteron energies exceeding 10 MeV. For the other reactions, most of our results are in good agreement with those of previous studies. We measured the production cross section of ^{97m}Tc ($T_{1/2}$ = 91 d) in the deuteron energy range of 14–24 MeV for the first time. It was found that the TALYS code qualitatively reproduces the shape of these excitation functions, though there is little agreement between the experimental cross sections and the theoretical values.

Thick-target yields for all the investigated Tc, Mo, Nb, and Zr isotopes were deduced from the measured production cross sections. Figure 2 shows the thick-target yields of the Tc isotopes as a function of the deuteron energy. The deduced yield of ^{95m}Tc at 23.7 MeV is 0.36 MBq/μA·h. For ^{99}Mo and ^{99m}Tc, the deduced yields at 23.7 MeV are 9.6 and 40 MBq/μA·h, respectively. To increase the production yields of ^{99}Mo/^{99m}Tc and to reduce radioactivities from by-reaction products, the use of enriched ^{98}Mo and ^{100}Mo targets is favorable. Based on the present results, we will produce ^{95m}Tc for the model experiments on Bh chemistry. We will also develop a simple and efficient chemical separation scheme to obtain no-carrier-added Tc tracer from the Mo target.

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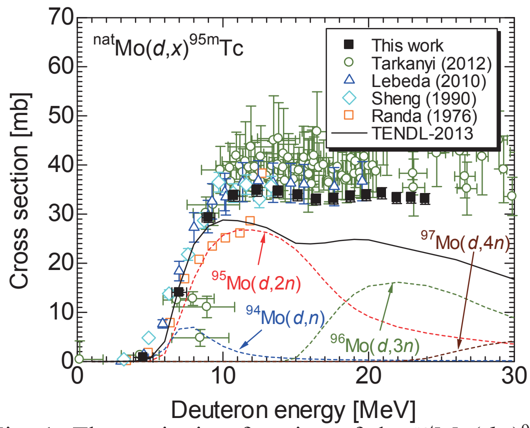

Fig. 1. The excitation function of the ^{nat}Mo(d,x)^{95m}Tc reaction.

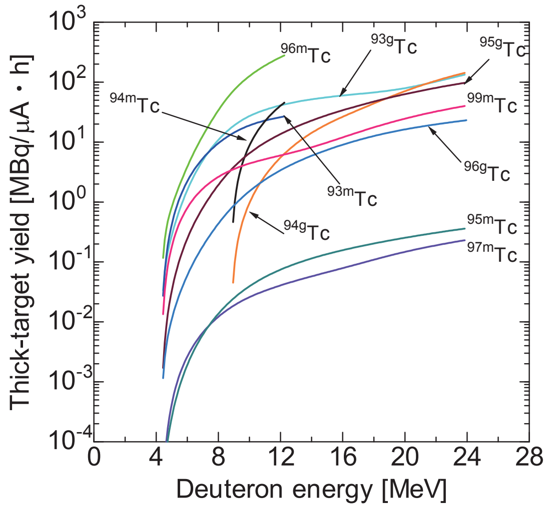

Fig. 2. Thick-target yields of the Tc isotopes expressed as radioactivities after 1-h irradiation with 1 μA.

References

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