Excitation function of the ^{nat}Hf(α,x)^{182g}Ta reaction: Cyclotron production of a long-lived γ-ray emitter ^{182g}Ta

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We previously investigated the production of ^{179}Ta ($T_{1/2}$ = 1.82 y) in the proton- and deuteron-induced reactions on ^{nat}Hf[1,2] for basic chemical studies of the 105th element Db, which must be conducted at a single-atom scale. Although the long half-life of ^{179}Ta is convenient for such the chemical experiments, the decay characteristics of ^{179}Ta are less suitable: ^{179}Ta does not emit any γ ray in its EC decay, and it must be traced by measuring the characteristic X rays of Hf, which are often interfared by X or γ rays of other nuclides.

Another long-lived Ta isotope, ^{182g}Ta ($T_{1/2}$ = 114.74 d), is a γ-emitting isotope, and it has also been used as a radiotracer to explore the chemical behavior of Ta. ^{182g}Ta is usually produced by the ^{181}Ta(n_{th},γ) reaction with a high cross section of 20.5 ± 0.5 b.[3] However, the ^{182g}Ta radiotracer produced in this way is undesirable for basic studies of Db, because it is obtained with a macro amount of the target material of Ta.

Very recently, Tárkányi et al. measured the cross sections of W, Ta, and Hf isotopes in the ^{nat}Hf(α,x) reactions up to 40 MeV.[4] As shown in Fig. 1, they reported that the excitation function for the ^{nat}Hf(α,x)^{182g}Ta reaction increased with the beam energy. Because the ^{182g}Ta tracer with high specific radioactivity can be obtained with this reaction, we further studied the production of ^{182g}Ta in this reaction.

The excitation functions were measured by a stacked-foil activation technique. 11 pairs of thin metallic foils of ^{nat}Hf (97% chemical purity, 23 μm thickness) and ^{nat}Cu (99.9% chemical purity, 9 μm thickness) were stacked in an alternating sequence. The ^{nat}Cu foils were used for monitoring the beam current and energy by measuring the well-established ^{nat}Cu(α,x)^{67}Ga excitation function.[5] The size of the all foils was 15 × 15 mm^2. The stack was bombarded by a 50-MeV α beam supplied by the AVF cyclotron for 31 min. The beam was collimated within 9 mm in diameter and the average beam current was 0.23 μA. After the bombardment and the proper cooling duration, each foil was subjected to γ-ray spectrometry with a Ge detector.

The production cross sections were derived by the well-known activation formula.[6] The beam energies in the individual target foils were calculated with the SRIM-2008 program.[7] The experimental cross sections were compared with the calculated ones by the TALYS-1.6 code.[8]

In this work, independent cross sections were obtained for the ^{nat}Hf(α,x)^{176,177,178}W, ^{178,183}Ta, ^{179m2,181}Hf reactions, while cumulative ones were obtained for ^{nat}Hf(α,x)^{175,176,177,182g}Ta, ^{175}Hf. The measured cross sections of the ^{nat}Hf(α,x)^{182g}Ta reaction are shown in Fig. 1 along with the calculated ones. The cross sections in the energy range of 41–50 MeV were measured for the first time. The excitation function exhibits the maximum cross section of 8.3 ± 0.3 mb at 41.5 ± 1.2 MeV. The data of Tárkányi et al.[4] are consistent with the present data at ≥30.7 MeV, while that at 27.6 ± 0.7 MeV (0.2 ± 0.3 mb) is much smaller than the present one of 1.60 ± 0.08 mb at 27.2 ± 1.6 MeV. The cross sections calculated by the TALYS-1.6 code[8] show systematically lower values with a similar shape of the excitation function.

The physical thick-target yield was deduced from the measured cross sections and the calculated stopping power by the SRIM-2008 program.[7] The deduced yield of ^{182g}Ta was 5.2 kBq/μAh at 50 MeV.

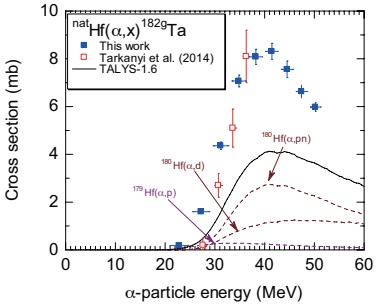

Fig. 1. Excitation function of the ^{nat}Hf(α,x)^{182g}Ta reaction. Dashed curves indicate the individual reaction channels evaluated by the TALYS-1.6 code.[8]

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