Charge population investigation for the ^{248}Cm fission products extracted from a helium gas catcher

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We are developing a helium gas catcher using the RF ion guide technique and a multi-reflection time-of-flight mass spectrograph downstream of the ZeroDegree spectrometer, referred to as ZD MRTOF-MS.[1)] We aim to convert BigRIPS beams to ultra low energy beams and precisely measure the atomic masses of unstable nuclei.

After highly charged radioactive ion beams enter the gas cell, their energy deposition results in the ionization of helium atoms and even impurities, and they undergo charge exchange with the helium and impurities. The charge state that will be dominant depends on the ionization potentials of the elements, as discussed in Ref. 2). Although it is naively expected that charge exchange with helium would stop when the ionization potential falls below the first ionization potential of helium, the mechanism for determining the charge population is complex because it also depends on the level of impurities in the helium gas. For efficient online experiments, *a priori* knowledge of the element dependent charge population is essential. Recently, a ^{248}Cm fission source with a 2-μm-thick Ti degrader was installed outside the cryogenic gas cell (Fig. 1). The ^{248}Cm source has an activity of 10 kBq with branching ratios of 91.6% and 8.4% for alpha and spontaneous fission decays, respectively. The emitted alpha particles and the spontaneous fission products enter the gas cell through a 6-μm-thick Mylar window. This setup facilitates tests with a consistent and knowable intensity of ions under a fair approximation of online conditions.

We performed the charge population measurements for ^{100}Y, ^{100,103}Zr, ^{100,103,104}Nb, ^{103,104}Mo, and ^{104}Tc ions produced by spontaneous fission decay from the ^{248}Cm source offline. The cryogenic gas cell temperature was approximately 80 K, and the gas density was equivalent to 200 mbar at room temperature (293.15 K). Their count rates for the singly, doubly, and triply charged states were measured with the MRTOF mass spectrograph detector. Their fractional charge population is shown in Fig. 2 with their second and third ionization potentials. It is reasonable that the doubly charged states were predominantly extracted from the helium gas. The fraction of triply charged ions decreases consistently with the increase in the third ionization potential. In contrast, Zr and Y exhibited smaller triple charge fractions than that of Nb despite the third ionization potentials of Y and Zr being less than Nb. This result could imply a significant molecularization probability leading to the loss of atomic Zr and Y ions. The charge populations are expected to depend significantly on the gas cell conditions such as temperature, cleanliness, *etc.* Further investigations with various conditions and elements and the searching for the molecularized fission products are in progress.

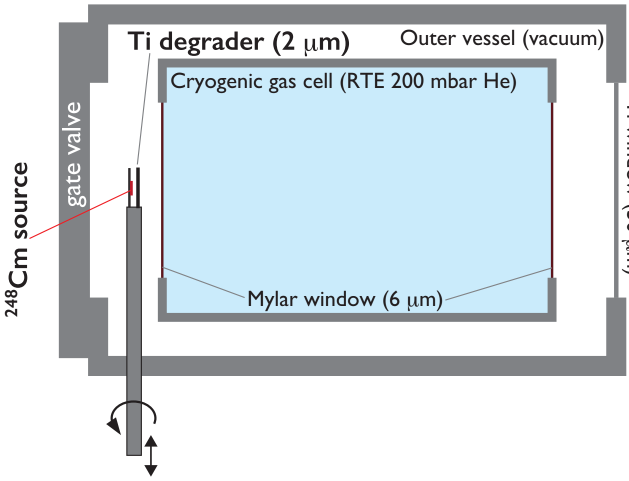

Fig. 1. Schematic of the gas catcher cell of the ZD-MRTOF (top view). The ions are transported upwards, out of the page. The fission source holder attached with the Ti degrader is movable and rotatable.

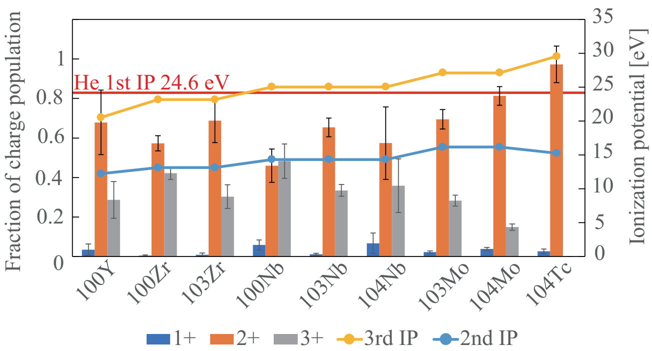

Fig. 2. Charge population of ^{100}Y, ^{100,103}Zr, ^{100,103,104}Nb, ^{103,104}Mo, and ^{104}Tc extracted from a helium gas cell. The 2nd and 3rd ionization potentials for Y, Zr, Nb, and Mo are plotted. The red line shows the first ionizaton potential of helium.

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