Results of first online tests of small ion-surfing RF carpet gas cell at GARIS-II

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As part of the SLOWRI project, we have begun development of a new low-energy experimental facility, SlowSHE, for use with radioactive isotopes (RI), such as Super Heavy Elements (SHE), that are created via fusion-evaporation reactions. This new facility utilizes a small gas cell[1)] placed after the GARIS-II separator to thermalize the ions before they are transported to a multi-reflection time-of-flight mass spectrograph[2)]. A very thin mylar film (2.4 μm thick) on a rotatable frame is placed before the gas cell for use as an adjustable degrader to remove, in combination with two thin (1.1 μm and 2.4 μm thick) mylar windows, a large fraction of the ions kinetic energy. The remaining kinetic energy is removed by collisions with He gas, which the cell is pressurized with upto 100 mbar.

In this first experiment, we desired to verify the combined stopping and extraction efficiency for a variety of chemical elements using isotopes with a wide range of half-lives. We first studied stopping and extraction of the long-lived ^{205}Fr ($T_{1/2}$=3.8 s), produced via the reaction ^{169}Tm(^{40}Ar,4n)^{205}Fr.

The degrader was initially replaced with a large silicon detector array to measure the incoming rate. The α-decay rate of ^{205}Fr was calibrated against the rate of elastically scattered incoming beam near the reaction target. The detector was then replaced by the degrader and the rate of α-decay on a silicon detector placed after the gas cell was measured as a function of the degrader angle. The result, shown in Fig. 1, featured a flat plateau with efficiency peaking near 30%.

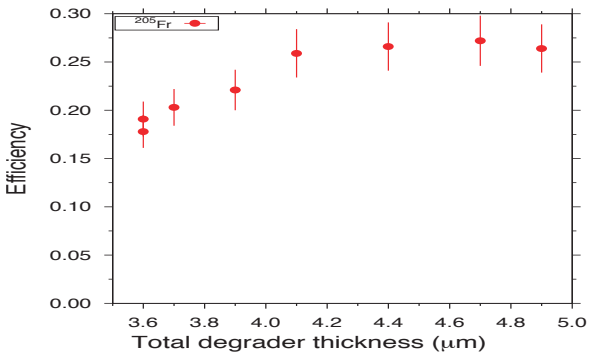

Fig. 1. Combined stopping and extraction efficiency for ^{205}Fr as a function of degrader thickness. The thickness was varied by rotating the degrader. Gas cell was operated at room temperature.

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Of perhaps greater interest was the stopping and extraction efficiency for shorter-lived isotopes. This was studied with a Tantalum target using the reactions ^{181}Ta(^{40}Ar,p4n)^{216}Th and ^{181}Ta(^{40}Ar,4n)^{217}Pa to produce species with $T_{1/2}$ of 26 ms and 3.5 ms, respectively. The α-decay spectra seen after the gas cell using a chopped beam and measuring decays during "beam off" are shown in Fig. 2. The red spectrum was measured by quickly pulsing the linac beam while the green spectrum was measured with longer period pulses. For the long period beam pulses, short-lived isotopes extracted during "beam on" decay prior to "beam off" and are suppressed.

For these beams, having higher-Z and lower energy than ^{205}Fr, the degrader was inoptimally thick. However, we were able to set lower limits on the stopping and extraction efficiencies. For the short-lived ^{216}Th, we were able to achieve ∼15% combined efficiency, while for the extremely short-lived ^{217}Pa ∼12%.

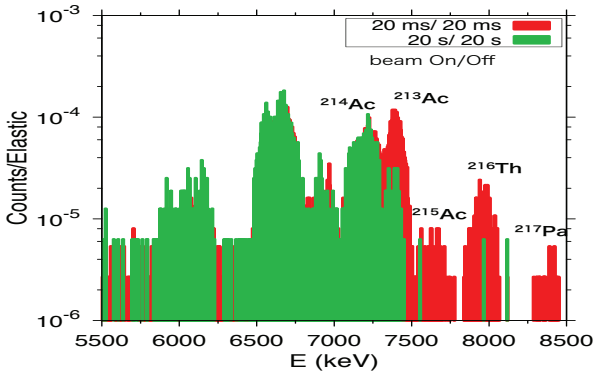

Fig. 2. α-decay spectra seen on silicon detector after the gas cell. Pulsing the linac beam with a short period, a strong suppression of short-lived isotopes was observed.

These results were obtained with the gas cell operated at room temperature; we believe that using cryogenic temperatures should provide further improvements by reducing the possibility of charge exchange with gas impurities and reducing the rate of diffusion of the ion cloud as it transits the length of the gas cell. Even with the efficiencies reported herein, it should be possible to perform precision mass measurements of even trans-Uranium isotopes with exceedingly low production rates. First such measurements are planned to take place within calendar year 2015.

References

1) F. Arai et al., this volume
2) P. Schury et al., Nuclear Instr. and Methods in Physics Research B 335 (2014) 39-53