Characterization of a gas stopper for heavy element chemistry studies

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The chemical and physical properties of the heaviest elements are of particular interest because relativistic effects increase as Z^2 (proton number). Transactinides (Z>103), elements where this effect is expected to be the largest, do not exist naturally and are produced via a fusion-evaporation reaction. The product of this reaction must be degraded down to sub-eV energies for a chemical study to be possible. Previous experiments have used a combination of degraders and a gas cell, also known as a Recoil Transfer Chamber (RTC), to degrade and transport the fusion-evaporation reaction product to the appropriate chemistry set-up. Here at Texas A&M University, a RTC has been fabricated (see Fig. 1); the design of the device is described in detail in [1]. A laminar gas flow and a series of electrodes that create a potential gradient guide the ions through the extraction nozzle to the aerosol chamber for transportation to a future chemistry experiment.

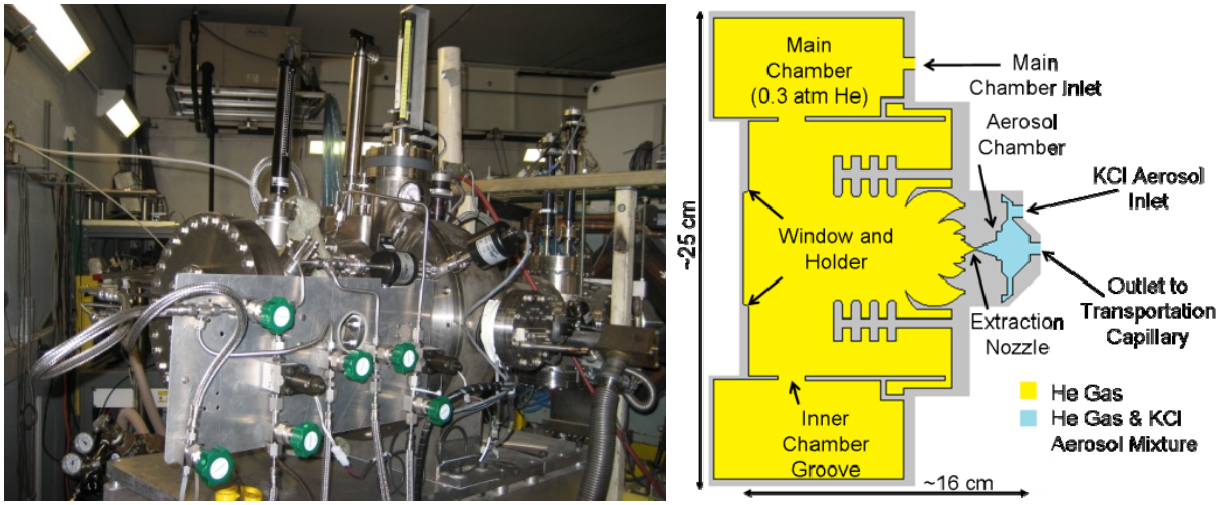

FIG. 1. Left: RTC attached to the end of the Momentum Achromat Recoil Spectrometer (MARS) beamline. Right: Schematic of the Texas A&M gas stopper.

The RTC was commissioned online using a high cross section fusion evaporation reaction, ^{118}Sn(^{40}Ar, 6n)^{152}Er, and preliminary results are presented here. A two-detector system was used to determine the extraction efficiency of the RTC; a detector was located directly after the RTC window and the extraction nozzle. Previous online experiments (see [2]) measured a peak extraction efficiency of approximately 40% with gas flow only (flow rate: 1.5-2.5 L/min). During an online experiment in March 2014, the potential gradient across the electrode system was optimized while the gas flow rate was held constant at 2.5 L/min. It was discovered that about a 22 V gradient across the entire device had the optimum extraction efficiency.

The angle of the rotating degrader upstream of the RTC window was then varied to better characterize the RTC extraction. The effective thickness of the rotating degrader increases with its angle, moving the stopped ^{152}Er distribution closer to the RTC window. Results for the extraction efficiency as

a function of degrader thickness are shown in Fig. 2. The RTC was run under two different modes during these measurements. One mode used only gas flow to transport the ions through the extraction nozzle, referred to as "gas flow only". The other mode used both gas flow and the optimum potential gradient across the electrode system to transport the ions through the extraction nozzle, referred to as "gas flow and electric field". The maximum measured extraction efficiencies are approximately 20% (gas flow only) and 35% (gas flow and electric field) (Fig. 2a). When the total degrader thickness was greater than 9 μm Mylar, ^{152}Er starts to "range-out" before reaching the end of the RTC window, and extraction efficiencies were corrected accordingly (Fig. 2b). The maximum "range-out" corrected extraction efficiencies are approximately 24% (gas flow only) and 43% (gas flow and electric field). The data suggest that ions thermalized too far into the device are defocused by the electric field, since extraction efficiency decreases with the addition of electric field at a degrader thickness less than 9 μm of Mylar. The difference in the centroid of the "gas flow only" results versus "gas flow and electric field" results implies that the gas flow works more effectively when the ions stop further into the RTC while the electric field works more effectively when the ions stop closer to the RTC window. Furthermore the broadening of the "gas flow and electric field" results, when corrected for "range-out", is evidence that the electric field can compensate when the ions stop too close to the window for the gas flow to be most effective.

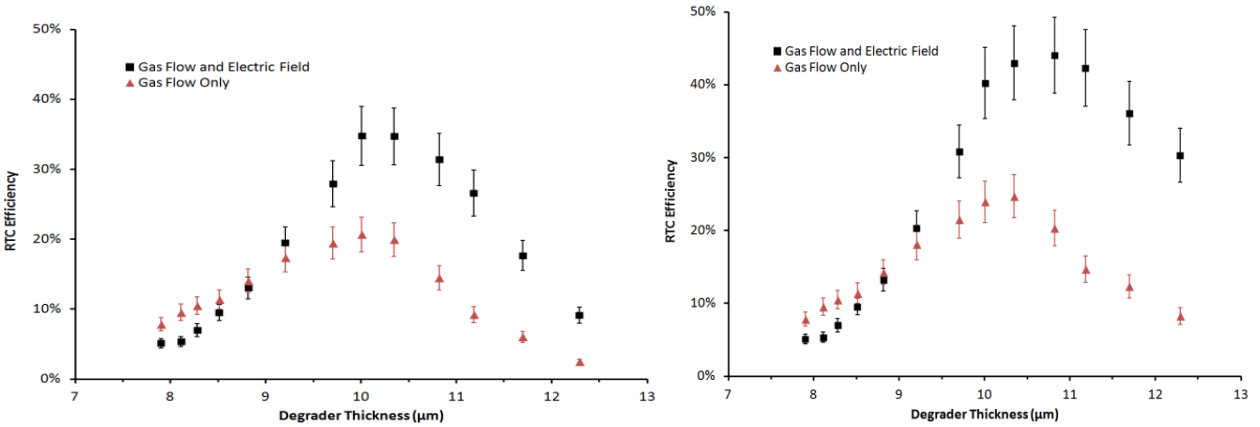

FIG. 2. Left: Extraction efficiency of the RTC as a function of the degrader thickness. Right: Extraction efficiency of the RTC as a function of the degrader thickness corrected for ions that "range-out" in the degraders. See main text for detailed discussion.

The transportation time of the device was determined to be 8.6 ± 1.0 s (gas flow only) and 6.9 ± 0.6 s (gas flow and electric field only), which is significant since the half life of ^{152}Er is 10.3 s. The extraction efficiencies corrected for decay loss were determined to be (44 ± 6)% (gas flow only) and (70 ± 9)% (gas flow and electric field). These extraction efficiencies are comparable to devices used worldwide [3-6]. Our device also has the advantage of a small emittance of the products exiting the extraction nozzle, and since this extraction efficiency can be achieved without the use of aerosols, a wider range of chemical systems can be studied using this RTC.

[1] M.C. Alfonso and C.M. Folden III, *Progress in Research*, Cyclotron Institute, Texas A&M University (2011-2012), p.II-46; http://cyclotron.tamu.edu/2012%20Progress%20Report/2%20Heavy%20Ion%20Reactions/II_46-51_development%20of%20a%20gas%20stopper.pdf.

[2] M.C. Alfonso *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2012-2013), p.II-6; http://cyclotron.tamu.edu/2013%20Progress%20Report/2%20Heavy%20Ion%20Reactions/II_6_characterization%20of%20a%20gas%20stopper.pdf

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