Development of a Gas Stopper for Fusion-Evaporation Products
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Introduction
Fusion-evaporation reactions create products with 40-60 MeV of kinetic energy (Figure 1). For it to be possible to study the chemistry of these products, the products must be thermalized. Currently, transactinides (elements with Z ≥ 104) can only be produced with fusion-evaporation reactions. The chemistry of transactinides is of particular interest due to the relativistic effects, which may affect the periodicity of the elements.

LISE is a program that simulates the products of a nuclear reaction being filtered through MARS. MARS is used to filter the evaporated residues from the unwanted product and beam. Then they pass through a variable angle mylar degrader, which decreases the energy of the ions. After the degrader, the ions then travel through the RTC window and into the gas cell. The RTC window also serves as a way for the ions to lose more of their energy (Figure 4).

Hafnium is a homolog of rutherfordium, the first transactinide element. The reaction considered to produce Hf is a beam of 187Tl at 223 MeV and a target of 197Au, creating a compound nucleus of 384Hf [1]. This reaction is of interest since Hf can be produced also by a 197Tl beam and a target of 208Pb. The evaporation residue 158Hf was chosen because it is an alpha chamber (RTC) window, and a gas stopper to thermalize the ions for a chemistry experiment.

Designing a Gas Stopper
Our design is based on the gas stopper at Michigan State University (Figure 2) [2]. This device is used to thermalize ions through gas collisions for further investigation. The thermalization of the ions is due to the random gas collisions between the helium atoms and the hafnium ions. Also, the electrodes in the gas stopper are used to focus the ions into a tight beam at the end of the stopper.

The original design for our gas cell (Figure 3) includes six ring electrodes and four “flower petals” to funnel the ions into an extraction nozzle. Our ions are significantly heavier and slower than those in the MSU design, so results of potential differences are compared in Figure 9. The optimum voltage difference was determined to be 10 V.

After several iterations, a problem was noticed: due to the large spatial distribution in both the horizontal and vertical directions, too many ions were being stopped by the first electrode. In order to solve this, we expanded the dimensions of the gas stopper (Figure 10).

After simulating with the wider gas stopper, more problems occurred. A region of space unaffected by any electrodes now existed around the petals, causing a lack of focusing in the region of the petals. Due to the new width of the gas stopper, the ions experience a lack of focusing in the region of the petals.

SIMION is an ion simulation program that calculates trajectories of ions under the influence of electric fields. This program simulates the process entering the gas stopper. The ions enter the stopper with an energy of ~3 MeV and, when they reach the end of the stopper, their energy has decreased to ~5.1 eV. The optimum helium pressure was determined to be 0.3 atm, which is lower than the pressure used in the MSU gas stopper. This is because our ions are significantly heavier and slower. In each of these collisions, the hafnium ions lose some of their energy. The configuration of the electrodes is optimized along with the voltages applied to these electrodes.

Hafnium ions were simulated using three different sets of potential differences for the electrodes (Figure 8). The first simulation began with a voltage at the RTC window of 350 V, then decreased throughout the rest of the gas cell. The next two simulations followed the same pattern, except with 700 V and 1400 V, respectively. Our main goal was to have high survival percentage combined with a low kinetic energy once the ions reached the end of the gas cell.

Conclusion/Future Work
We have determined that a 115.5 mm gas stopper is adequate for thermalizing the ions, including 3 rings and 5 petals. The smaller design decreases the time of flight of the ions while still keeping the survival percentage close to 100%.

The gas cell needs to be tested for other elements, such as zirconium, that are homologs of Rf and could therefore provide information on the expected properties of Rf. The most important issue still remaining is to fabricate and test the gas cell. This will require all of the other components to be in place as well, like the variable angle degrader and the RTC window. We also have to optimize the gas flow in the cell and deal with the issues of the ions changing charge state.

References

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