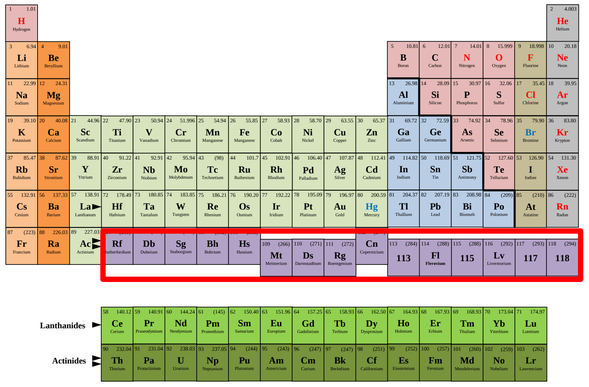
Optimization of the Extraction Efficiency of a Gas Stopper Using a Th-228 Source

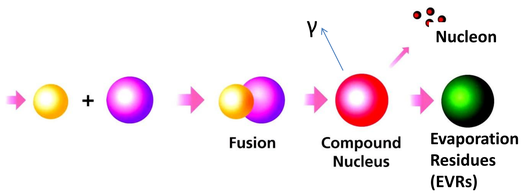
M. DeVanzo*¥, M. Alfonso*#, C.M. Folden III*

*The Cyclotron Institute at Texas A&M University, College Station, TX
¥Department of Physics, Astronomy, and Geosciences, Towson University, Towson, MD
#Department of Chemistry, Texas A&M University, College Station, TX

Chemical Study of Heavy Elements (Z ≥ 104)

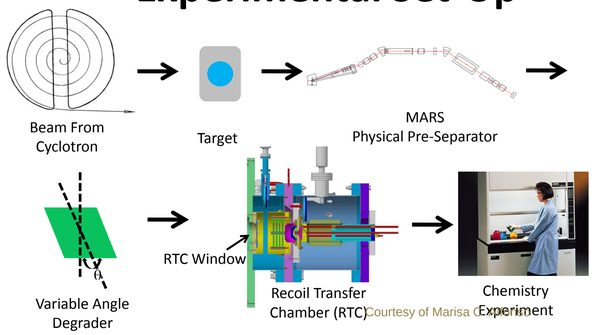
Heavy elements, especially the transactinides (Z ≥ 104), may have interesting chemistry due to relativistic effects [1]. Transactinides do not exist naturally and thus must be created via nuclear fusion-evaporation reactions.





Target and projectile atoms interact and fuse together forming a compound nucleus. The compound nucleus de-excites through emission of a nucleon and gamma radiation to a high-Z EVR.

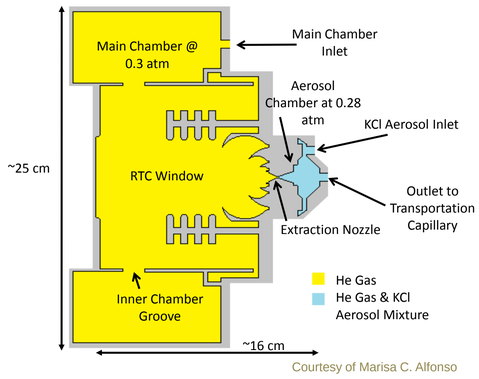
Experimental Set-Up



Courtesy of Marisa C. Alfonso

Fusion evaporation reactions are produced using accelerated particle beams from the cyclotron on thin-foil metal targets. Evaporation residues (EVRs), unwanted reaction products, and beam particles then travel through the physical pre-separator MARS which purifies the beam of EVRs. The Variable Angle Degrader and Recoil Transfer Chamber work in tandem to both thermalize and guide high-energy EVRs to the chemistry experiment. [2]

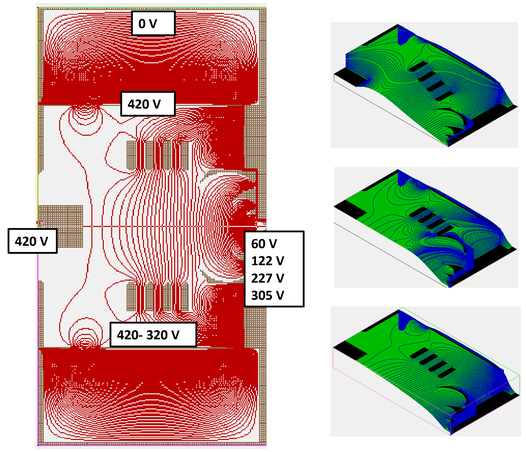
Recoil Transfer Chamber (RTC)



Courtesy of Marisa C. Alfonso

Ions enter the RTC window and are thermalized inside the RTC Main chamber. The position of this stopped distribution is approximately mid-way between the RTC and first ring electrode. Ions are then guided to and focused into the Extraction Nozzle by the ring and spherical electrodes, respectively. From the Extraction Nozzle, ions-aerosol clusters form in the Aerosol Chamber and are transported to an appropriate chemistry experiment through the Transportation Capillary.

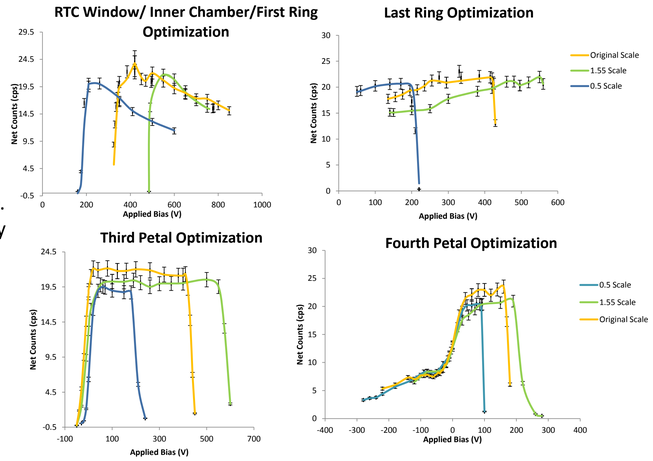
SIMION Simulations



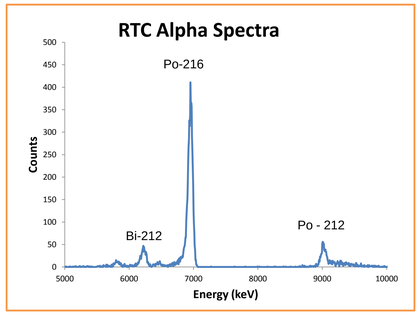
The figures above are 2D and 3D representation from SIMION of the electric field in the RTC's Main Chamber. The left figure shows the equipotential lines in the "Original Scale" configuration (Ions travel perpendicular these lines). The right figures display various potential energy surfaces with attributes that both positively and negatively affect ion transport.

Experimental Results

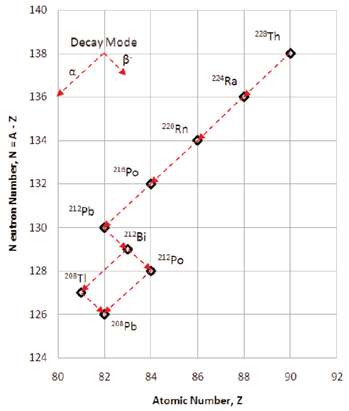
Po-216 recoils from a Th-228 source were used to mimic the transportation of EVR's through the Extraction Nozzle to the Aerosol Chamber. The electrode system was optimized by setting parameters for all electrodes and increasing and decreasing a single parameter until the observed count rate reduces to background. The tested parameter was then set to the voltage corresponding the to highest count rate observed. This was repeated for all parameters in the initial configuration as well as configurations scaled by 0.5 and 1.55 of the "Original Scale."



A silicon detector was used to measure the Po-216 that reached the Aerosol Chamber. By varying the voltage on the ring and spherical electrodes, the transport of EVRs through the Aerosol chamber was investigated. A maximum count rate of 21 ± 1 cps was observed. This count rate represents an efficiency of approximately 70% assuming 3% of all Rn-220 emanates form the source.



The observed alpha spectra from the Th-228 source displays predominantly Po-216 and its decay products only to Ra-220 emanating into the He-filled RTC Main Chamber.



Above is a figure of the Th-228 decay chain [3]. All recoils emitted from the Th-228 source are neutralized by electrons surrounding the source material, leaving them unaffected by the potential gradient. Rn-220, however, is gaseous and thus emanates out of the source material, allowing its daughter, Po-216 to remain positively charged after production. A Rn-220 emanation fraction of ≈3% was measured, which agrees with literature values [4].

Future Work

Currently the RTC window flange is being modified to allow for greater accessibility when changing the RTC window. In the near future, a mass flow controller will be added to RTC in time for a second commissioning experiment in late Aug. – early September. Plans are also in the works to replace the spherical electrodes with a radio-frequency (RF) carpet .

References

[1] P. Pyykko. ***Relativistic Effects in Structural Chemistry***, Chem. Rev. **1988**, *88*, 563-594.
[2] M. C. Alfonso, *et. al.* ***New Gas Stopper for Heavy Element Chemistry Research***, 2011 Cyclotron Institute Annual Report.
[3] Ortec
[4] A. Sakoda. ***A comprehensive review of radon emanation measurements fro mineral rock, soil, mill tailing and fly ash,*** Applied Radiation and Isotopes. **2011**, 69, 1422-1435.

Acknowledgements

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