





Chemical Study of Heavy Elements ($Z \ge 104$)

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

1 1.01 H Hydrogen																	2 4.003 He Helium
3 6.94 Li Lithium	4 9.01 Be Beryllium											5 10.81 B Boron	6 12.01 C Carbon	7 14.01 N Nitrogen	8 15.999 Oxygen	9 18.998 F Fluorine	10 20.18 Neon
11 22.99 Na Sodium	12 24.31 Mg Magnesium											13 26.98 Al Aluminium	14 28.09 Si Silicon	15 30.97 P Phosphorus	16 32.06 S Sulfur	17 35.45 Cl Chlorine	18 39.95 Ar Argon
19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti _{Titanium}	23 50.94 V Vanadium	24 51.996 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Manganese	27 58.93 Co Cobalt	28 58.70 Ni Nickel	29 63.55 Cu _{Copper}	30 65.37 Zn _{Zinc}	31 69.72 Ga Gallium	32 72.59 Gee Germanium	33 74.92 As Arsenic	34 78.96 Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc Technetium	44 101.7 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.40 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.69 Sn _{Tin}	51 121.75 Sb Antimony	52 127.60 Te _{Tellurium}	53 126.90 I Iodine	54 131.30 Xee Xenon
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.91 La► Lanthanum	72 178.49 Hf _{Hafnium}	73 180.85 Ta _{Tantalum}	74 183.85 W Tungsten	75 186.21 Re Rhenium	76 190.20 Os Osmium	77 192.22 Ir Iridium	78 195.09 Pt Platinum	79 196.97 Au _{Gold}	80 200.59 Hg _{Mercury}	81 204.37 Tl Thallium	82 207.19 Pb Lead	83 208.98 Bi Bismuth	84 (209) Polonium	85 (210) At Astatine	86 (222) Rn Radon
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.03	Rf tutherfordium	Db Dubnium	Sg Seaborgium	Bh Bohrium	Hs Hassium	109 (266) Mt Meitnerium	110 (271) Ds Darmstadtium	111 (272) Rg Roentgenium	Cn Copernicium	113 (284) 113	114 (288) Fl Flerovium	115 (288) 115	116 (292) Lv Livermorium	117 (293) 117	118 (294) 118





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 MARS **Beam From Physical Pre-Separator** Cyclotron **RTC Window** Recoil Transfer Chemistry Variable Angle Chamber (RTC)Courtesy of Marisa Experiment Degrader

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

~25 cm

lons 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. lons 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.



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.

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

Recoil Transfer Chamber (RTC)



SIMION Simulations

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.

Experimental Results



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 $\approx 3\%$ 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

Many thanks and appreciation for the incredibly generous opportunity to work with Dr. Charles M. Folden III and his research group during Summer 2012. Sincere appreciation also goes to the PHY-1004780 National Science Foundation grant for making this research program possible.





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