

Heavy Element Chemistry At TAMU: From Off-line to On-line

M.E. Bennett¹, M.C. Alfonso^{1,2}, C.M. Folden III¹

¹ Texas A&M University Cyclotron Institute, College Station, TX 77843

² Texas A&M University Chemistry Department, College Station, TX 77843

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 O Oxygen	9 18.998 F Fluorine	10 20.18 Ne 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 Iron	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 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton						
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.9 Y Yttrium	40 91.2 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	51 121.73 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.30 Xe Xenon						
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.9 La Lanthanum	72 178.4 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) Po Polonium	85 (210) At Astatine	86 (222) Rn Radon						
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.0 Ac Actinium	104 (261) Rf Rutherfordium	105 (262) Db Dubnium	106 (268) Sg Seaborgium	107 (262) Bh Bohrium	108 (263) Hs Hassium					112 (277) Cn Copernicium											
								109 (266) Mt Meitnerium	110 (271) Ds Darmstadtium	111 (272) Rg Roentgenium													
												113 (284) Fl Flerovium	114 (285) Fl Flerovium	115 (285) 115	116 (292) Lv Livermorium	117 (293) 117	118 (294) 118						

Z MM
 X
 Name

Z = proton number
 MM = natural mass*
 X = elemental symbol

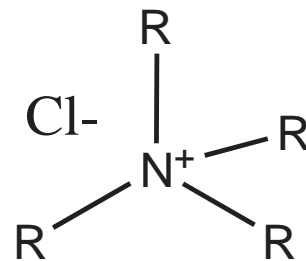
Gas, Liquid, Solid at 25°C
 *Parenthesis indicates mass of longest lived isotope

Lanthanides ▶	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.40 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.93 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium
Actinides ▶	90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 237.05 Np Neptunium	94 (244) Pu Plutonium	95 (243) Am Americium	96 (247) Cm Curium	97 (247) Bk Berkelium	98 (251) Cf Californium	99 (252) Es Einsteinium	100 (257) Fm Fermium	101 (260) Md Mendelevium	102 (259) No Nobelium	103 (262) Lr Lawrencium

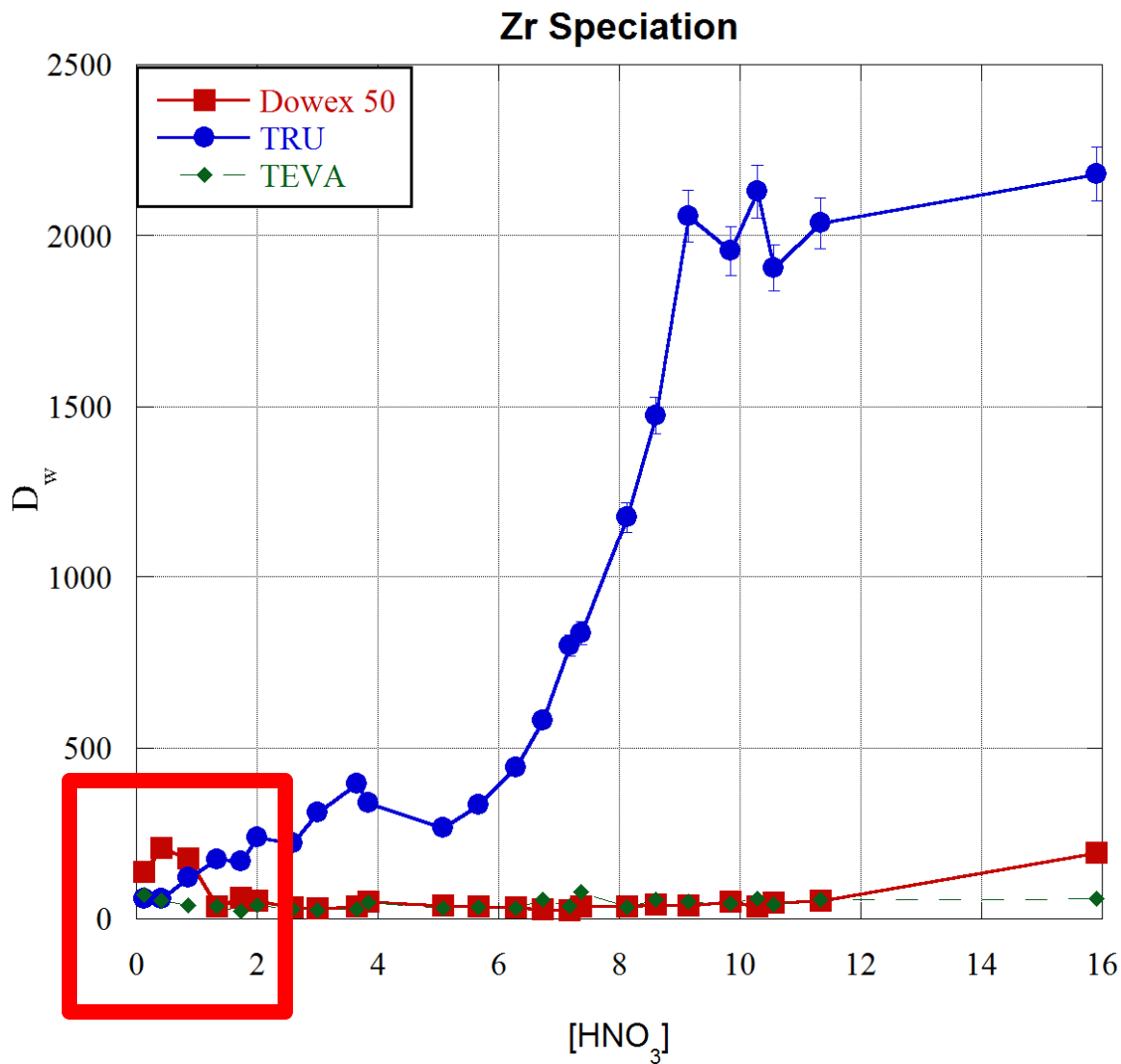
Off-Line Studies with TEVA Resin

- Performed in a traditional radiochemistry laboratory
- ~ 5 cps of ^{95}Zr ($t_{1/2}=64$ d) and ^{175}Hf ($t_{1/2} = 70$ d) per sample
- Want separation of Zr and Hf

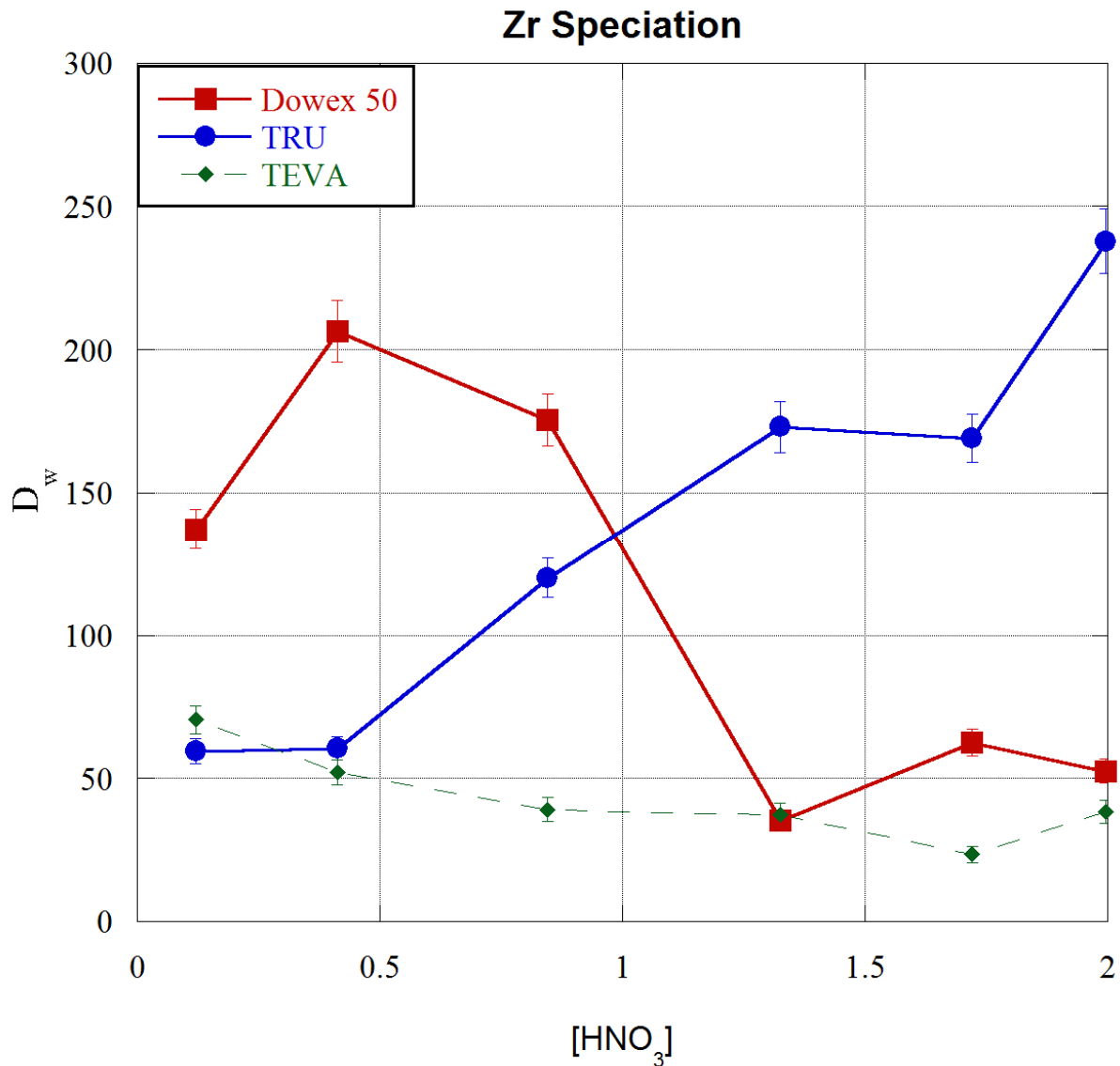
TEVA resin available from Eichrom International, INC.



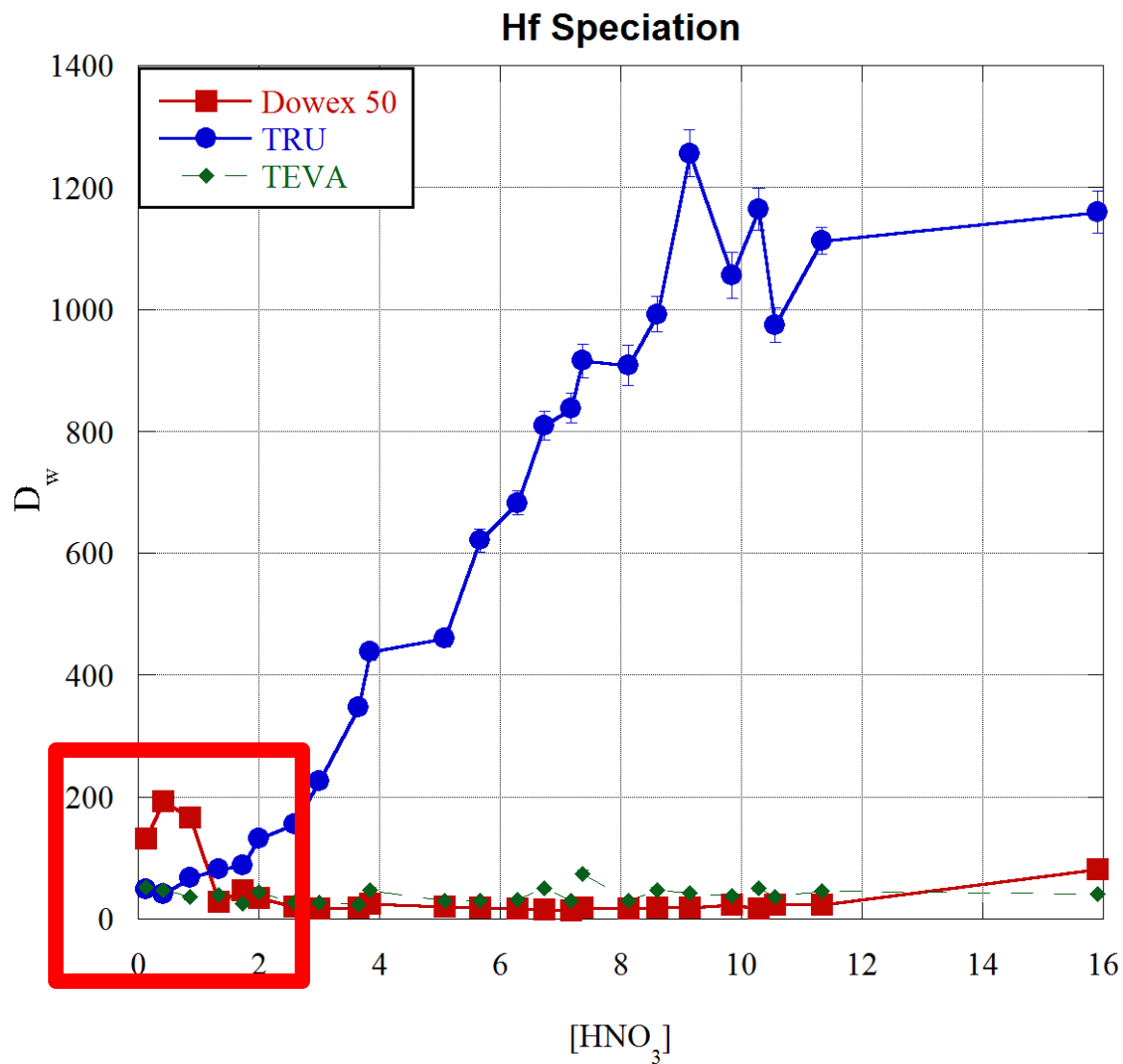
Speciation of Zr in HNO₃



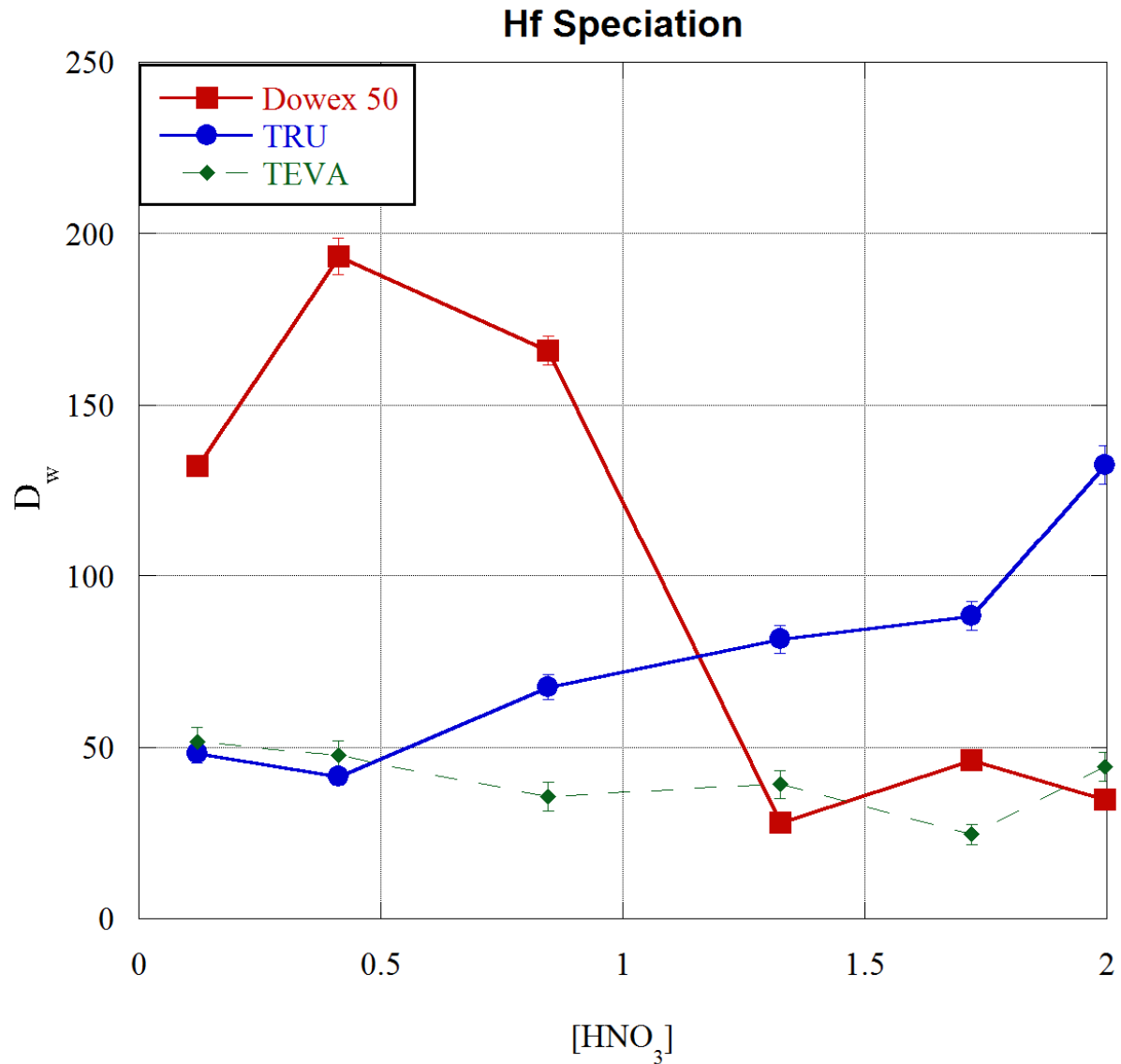
Speciation of Zr in HNO₃



Speciation of Hf in HNO₃



Speciation of Hf in HNO₃



The MIGS System

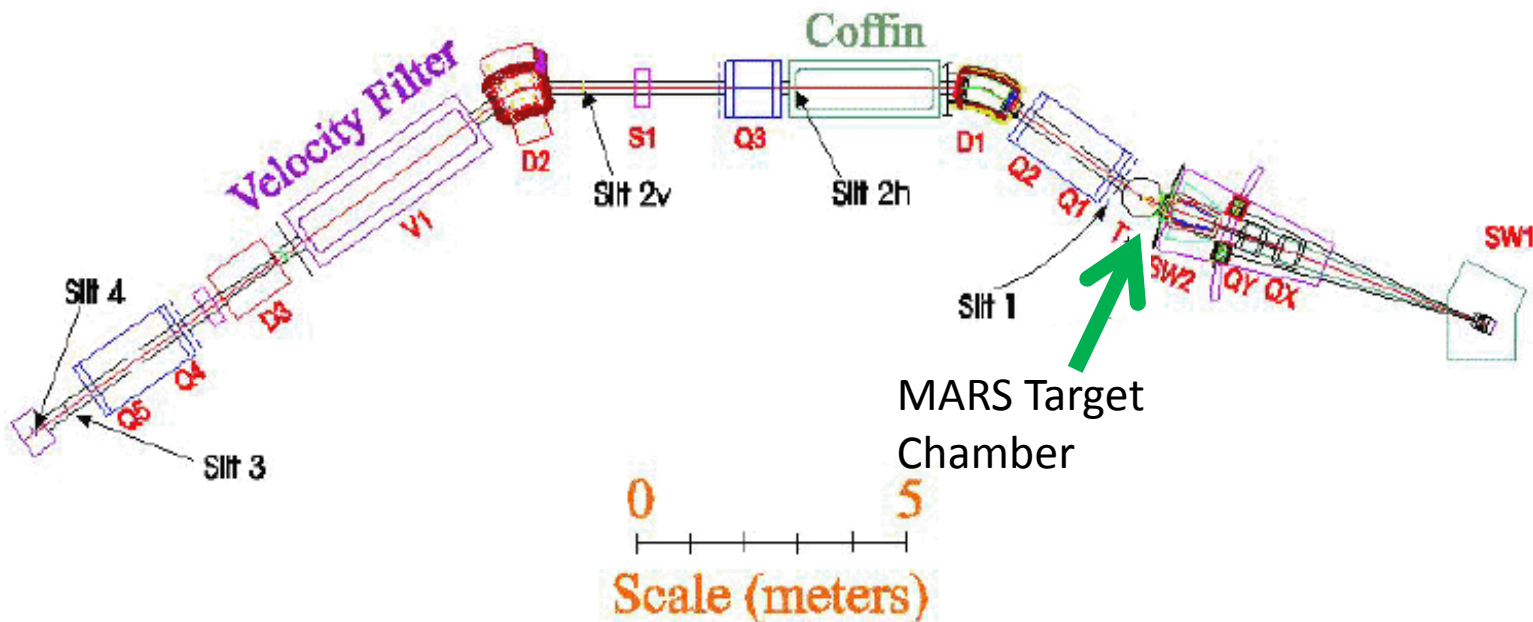
M: MARS (Momentum Achromat Recoil Spectrometer)

I: ICE (Ion Catching and Extraction)

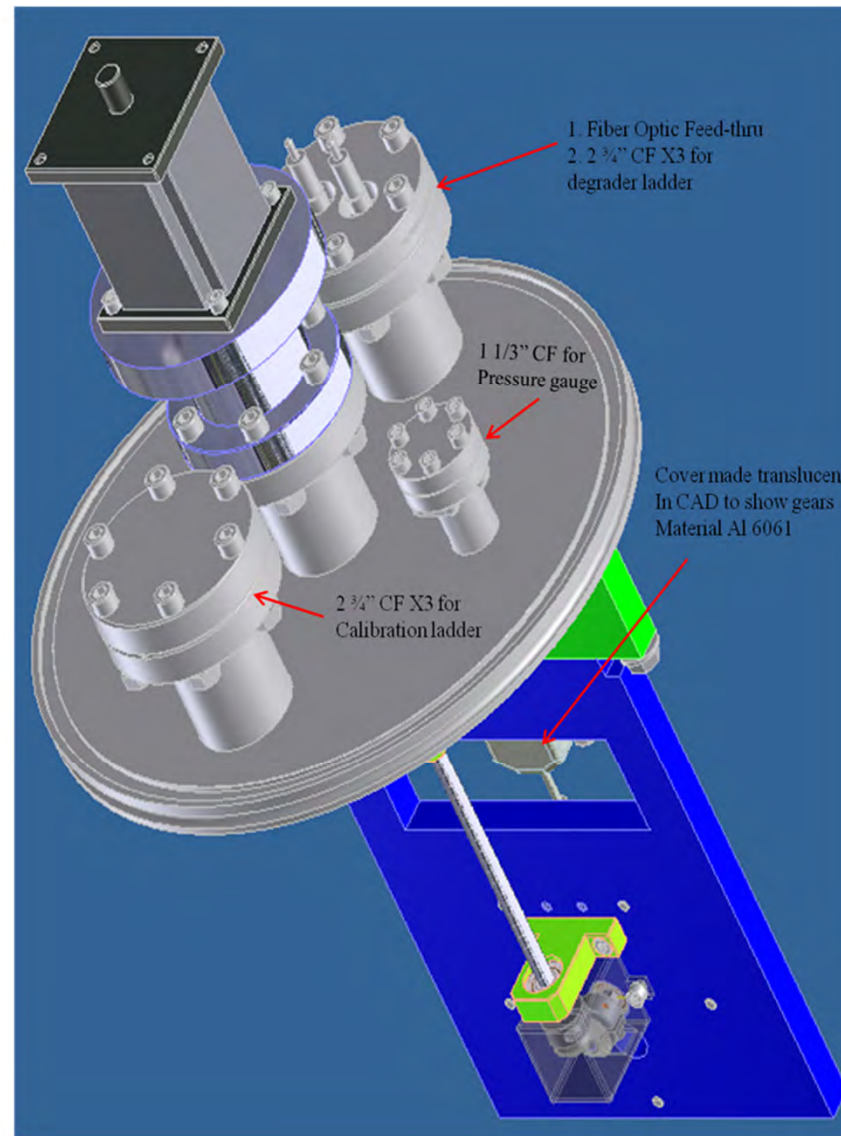
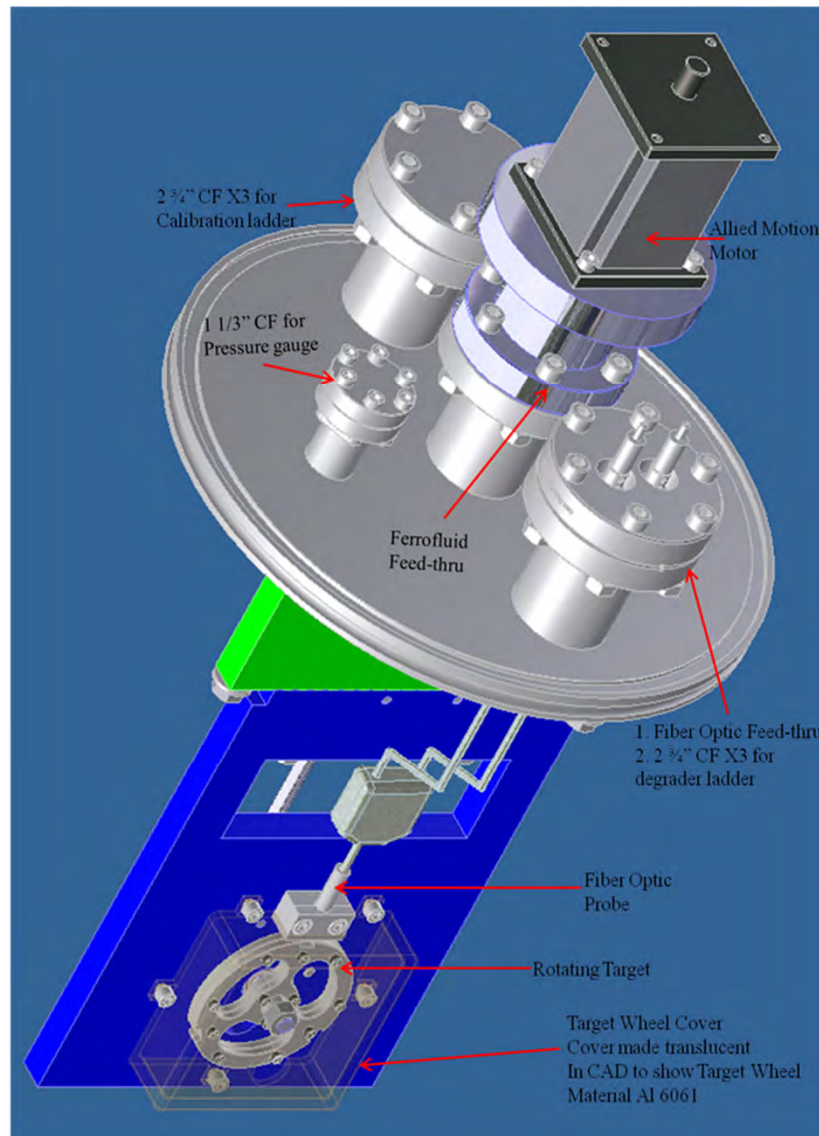
G: GLITTAR (Gas-Liquid Interface for Transactinide Transportation to Automated Radiochemistry)

S: SHELA (SuperHeavy Element Liquid Automation)

MARS: Momentum Achromat Recoil Spectrometer



MARS Targetry

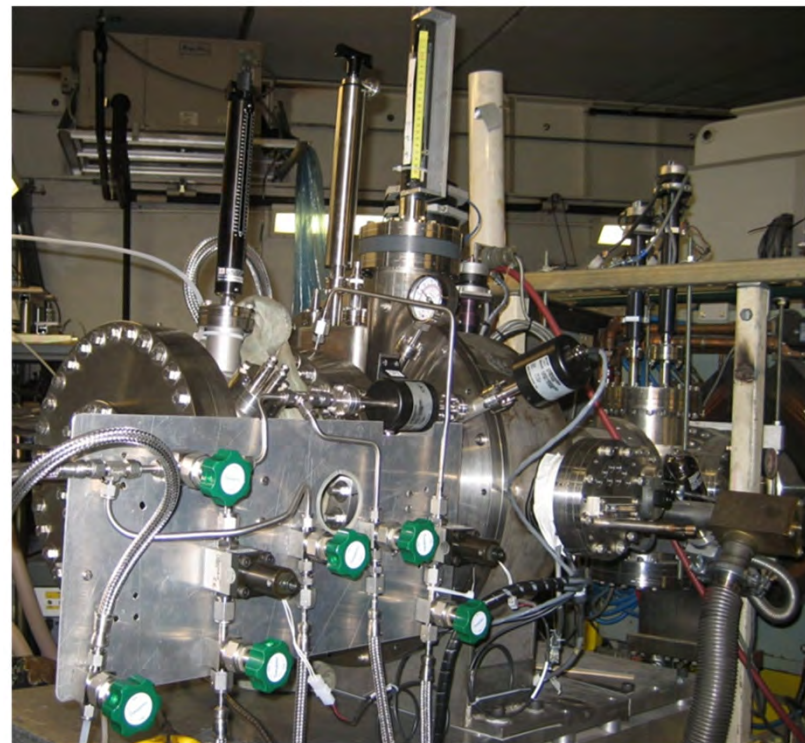
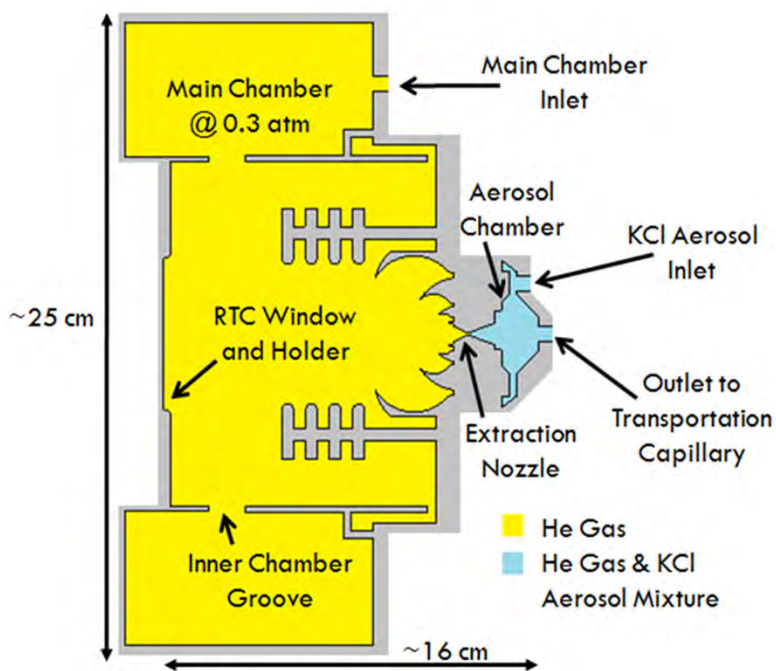


Mixed Metal Target

- ~300 nm ^{nat}Gd deposited on 1 μm Ti with e^- beam.
- ~300 nm ^{nat}Ge deposited on 1 μm Ti with thermal deposition.
 - Used to cover Gd to prevent oxidation

These targets will be used in a $^{nat}\text{Ge}, ^{nat}\text{Gd}(^{18}\text{O}, xn)$ $^{85}\text{Zr}, ^{169}\text{Hf}$ for accelerator based chemistry experiments, in late 2012/early 2013

ICE: Ion Catching and Extraction



The main chamber stops the recoil ions that come out of MARS and then transport them via a capillary tube to the radiochemistry laboratory, located ~8 ft behind the MARS cave

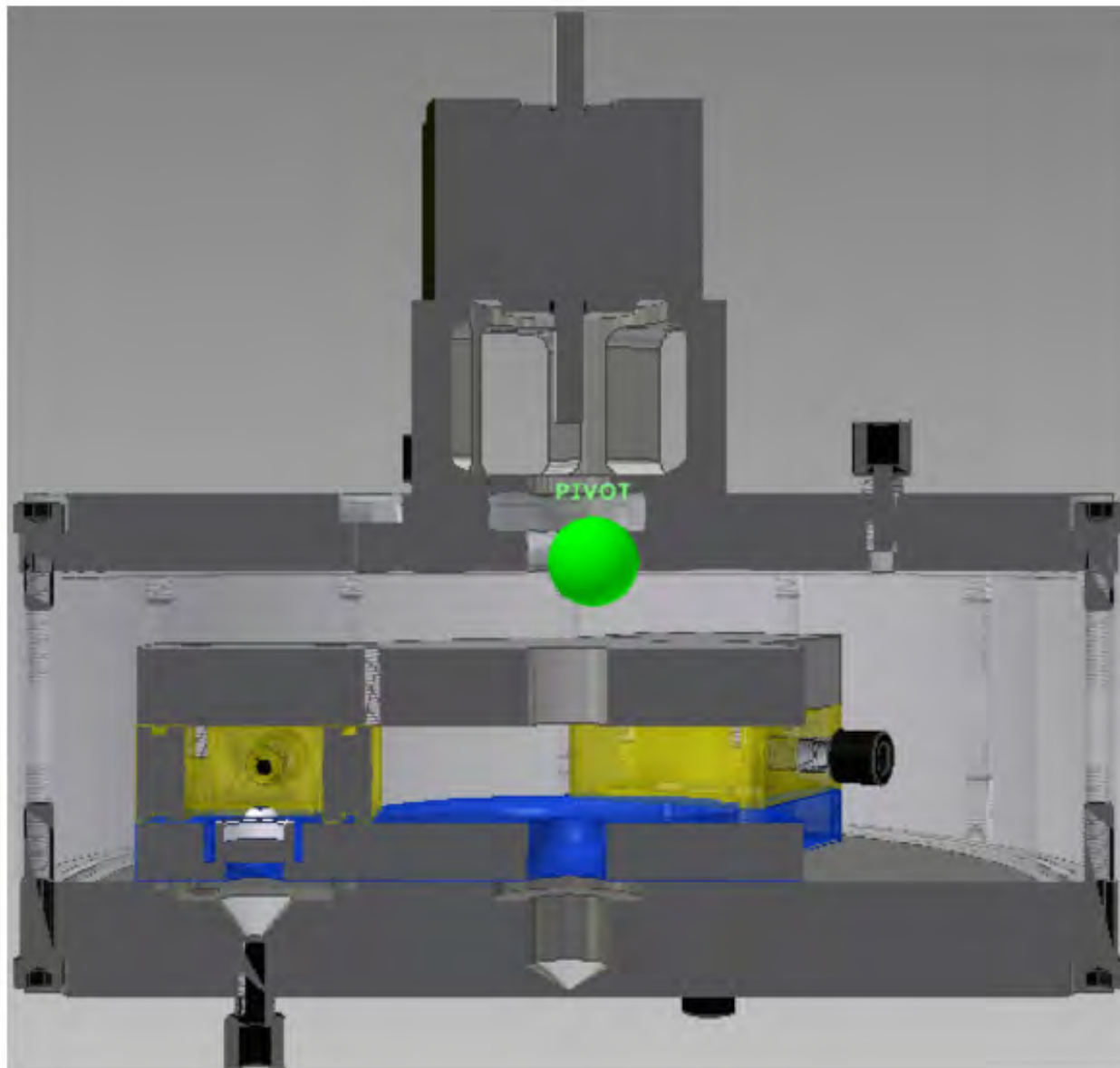
Radiochemistry Laboratory



Equipped with:

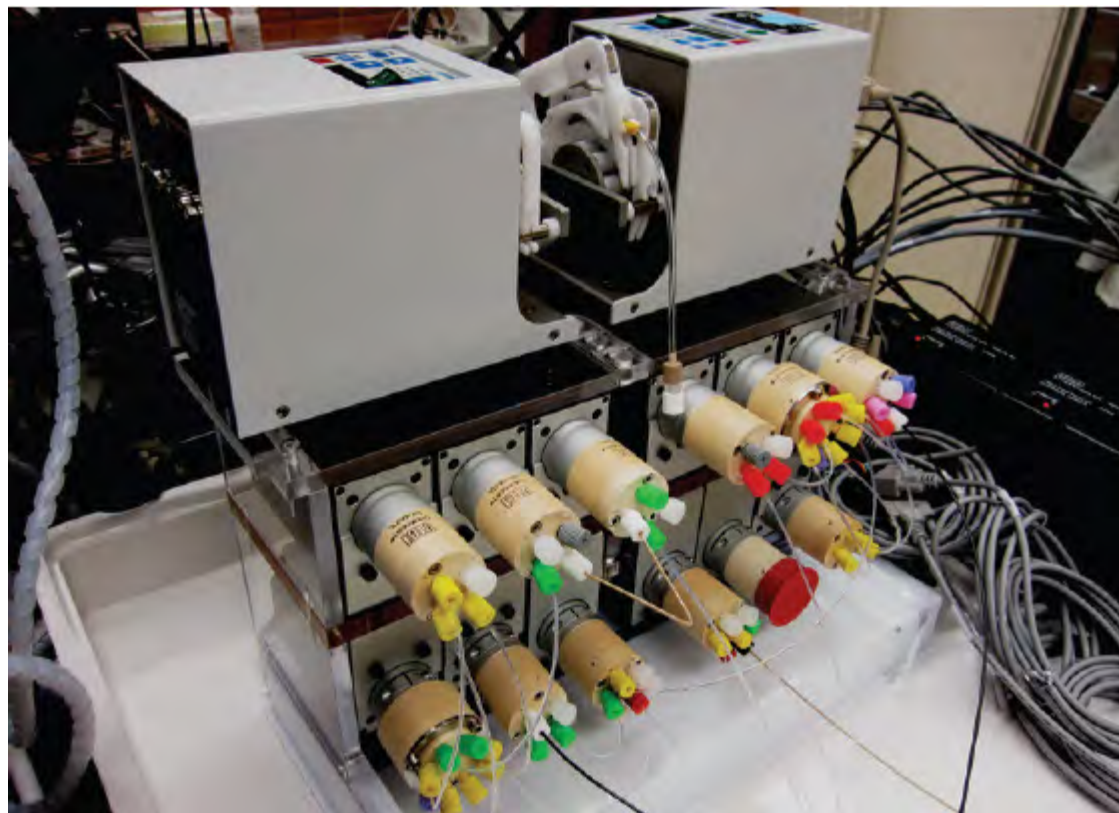
- ✓ 6 ft HF/HClO₄ fume hood
- ✓ Eyewash, safety shower
- ✓ Lab grade sink
- ✓ Isolated waste system
- ✓ Climate controlled
- ✓ Chemical/Fire resistant interior
- ✓ Non-slip flooring
- ✓ GFI 110/220 outlets
- ✓ Lab benches
- ✓ Chemical storage cabinets
- ✓ Moveable via crane, forklift, rolling
- ✓ Track lighting
- ✓ OSHA/State of Texas/NRC compliant

GLITTAR: Gas-Liquid Interface for Transactinide Transportation to Automated Radiochemistry



SHELA: SuperHeavy Element Liquid Automation

- LLNL has developed version 2 of the SHELA – Super Heavy Element Liquid Automation - chemistry system
- Improvements include better resistivity to acids, portability to accelerator facilities, integration with beam lines



Conclusions

- Assessment of chemical systems for Rf chemistry has been done
- New facilities are in place for on-line homolog studies
- Customized targets are available

Acknowledgements

CMF Group

Dr. Charles M. Folden III
Dr. Megan E. Bennett
Marisa C. Alfonso
Dmitriy A. Mayorov
Tyler A. Werke

LLNL

Dr. Dawn Shaughnessy
Dr. Ken Moody
Dr. Roger Henderson
Dr. Julie Gostic
Dr. Evgeny Tereshatov

ANL

John Greene

Cyclotron Institute

Operations staff
Accelerator Group

UNLV

Dr. Ralf Sudowe
John Despotopolus
Jeff Rolfes

