INL/CON-23-73479-Revision-1

INL Mass Separator Operations

April 2022

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INL Mass Separator Operations

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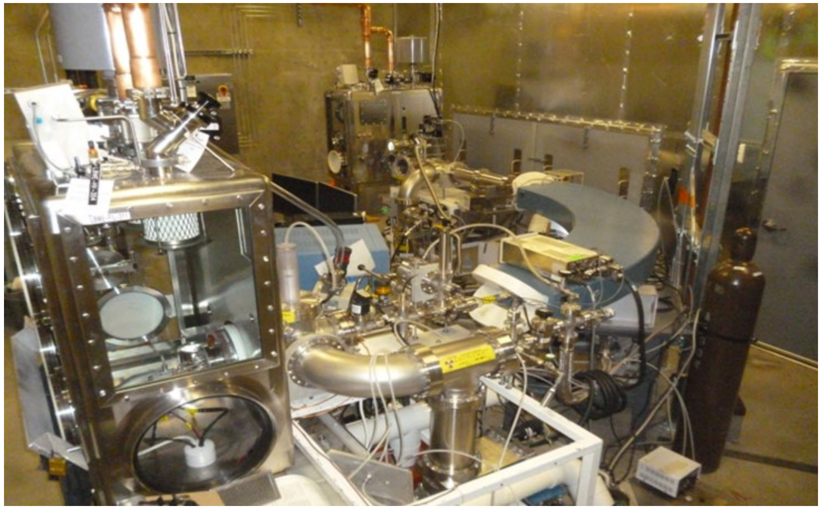
INL Separators

-Relocated and refurbished in 2009
-Used to produce Ba-134 spike standards
-tested with La, Sm, Pb starting materials
-noble gases including Ar, Kr, and Xe
-surrogate molecular charge demonstration for rad operations
-ion source testing



-Certified for radioactive isotope separations, 2015
-Gloveboxes are mated to source and collector ends
-Initial demonstrations Np-237, U-237, Xe, Ar feed
-Similar dimensions to stable separator
-Utilizes commercially available vacuum parts and upgraded magnetically-levitated turbo pumps

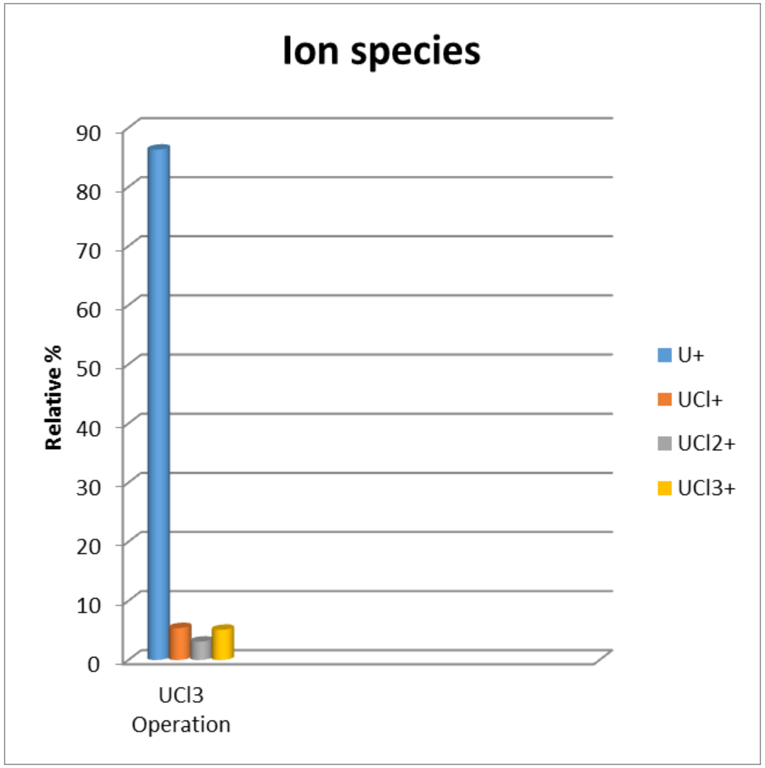
Ion Source Test Stand

- -Unit assembled in Longmont, CO, Beam Imaging Solutions INC.
- -Duplicate unit assembled at INL's Idaho Research Center (IRC).
- -Surrogate analysis performed on non-radioactive specimens; used to evaluate ion source designs, i.e., spark source, RF source
- -Various materials ionized including refractory metals (W, Th) and semi-volatile organometallic compounds

^{237}U enrichment by EMIS

Goal: Demonstrate the ability to isolate U-237 (~6 day half-life)

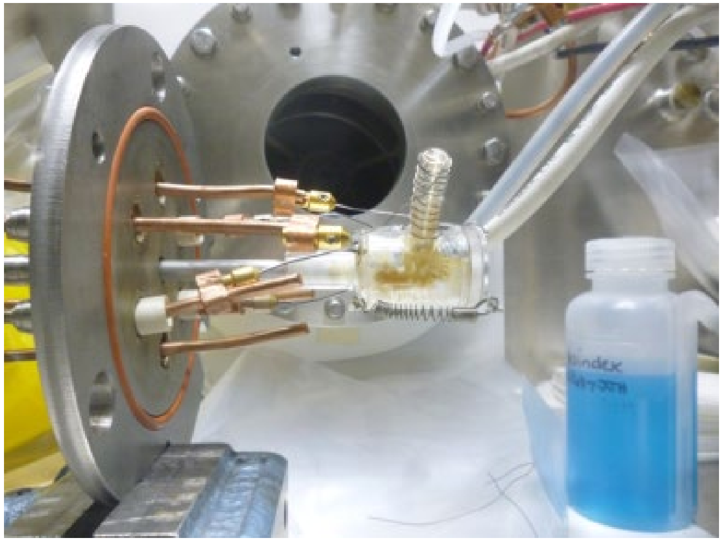
-Funded by DTRA post-det
-Side project from U-238 photo-fission product collection
-Approach: Thermal ionization using uranium analogues (i.e. UCl_3)
-Optimize beam to reduce molecular chlorides that reduce production rate (Beam current circa 100 nA on initial runs or about 300 ng / hr)
-Optimize chemistry to avoid oxy-chlorides



^{236g}Np enrichment by EMIS

Goal: Optimize Np^{+} ion beam with Np-237

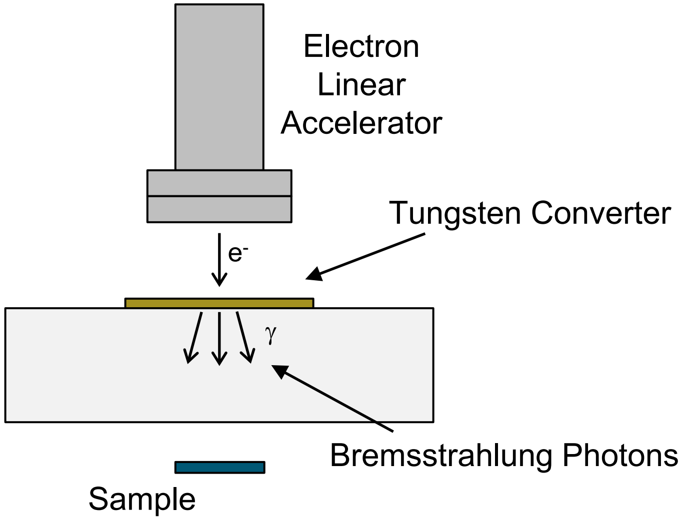
- $NpCl_3$ in thermal ion source
- Ion beam was produced but was not sustained for suitable optimization.



Thermal source loaded with $NpCl_3$

^{236g}Np Photonuclear Production ISU/INL

- Fission fragment production increases at increasing energies
  - cross sections obtained from the Evaluated Nuclear Data File
  - bremsstrahlung flux simulated with MCNP6



- Samples irradiated at Idaho Accelerator Center
- Electron interactions in tungsten produce bremsstrahlung photons
- As accelerator energy increases:
  - higher photon endpoint energy
  - Greater overlap with production cross sections

Photonuclear Production $^{236m/236g}Np$

Approach: Produce a sample of ^{236g}Np from photonuclear reactions on ^{237}Np target, purify Np from FP, Pu, U; isolate as volatile compound, electromagnetically separate Np isotopes

DHS TAR: Production non-fluorinated precursors for EMIS
Synthesize & Characterize B-diketones,
Vapor pressure, Spark Source for EMIS

DHS Ref. Chemical purification of irradiated Np from U, Pu, FP
Ref materials: Develop EMIS to enrich ^{236g}Np by electromagnetic isotope separation

DTRA: Photonuclear Production $^{237}Np(g,n)^{236g}Np$

38 MeV endpoint:

- 460 uCi per kW per hour per gram (est.)
- ~800 pg per kW per hour per gram (est.)
- 2.5 g Np-237 target irradiated for 100 hours, ~5 ug Np-236 produced

Results/Accomplishments

DHS TAR:

Production volatile compound precursors for EMIS.

- Inert Np synthesis: electrochemical bulk reduction
  - Produced crystals NpI_3 and NpI_4 ;
  - x-ray diffraction (WSU)
    - submitted for publication: Journal of Inorganic Chem.

Produce $NpCl_3$; FOD, TMHD compounds

- x-ray diffraction (WSU)
- Thermogravimetric analysis of FOD, TMHD compounds

Spark Source for EMIS (in progress):

Vapor pressure B-diketones (in progress)

DHS Ref Mat.:

- Chemical purification irradiated Np from U, Pu, FP
- Working on enrichment ^{236g}Np by EMIS

DTRA:

- Encapsulated NpO_2 (3 – 70 mg samples)
- Two Irradiations: one at 22 MeV and one at 38 MeV:

  inferred rate of ~800 pg/kW/h per gram

Publication: Inorganic Chemistry 2017 "Synthesis and Crystal Structures of Volatile Neptunium(IV) β-Diketonates" by A.T. Johnson, et al.

New Np compound: synthesis, crystallographic data, vapor pressure data, gas viscosity

Next Steps:

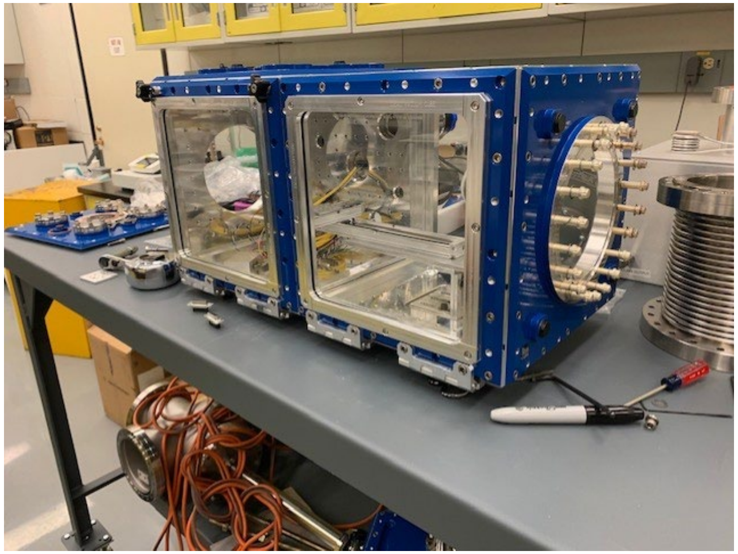
DOE Office of Science Isotopes Program: INL Isotope Separations

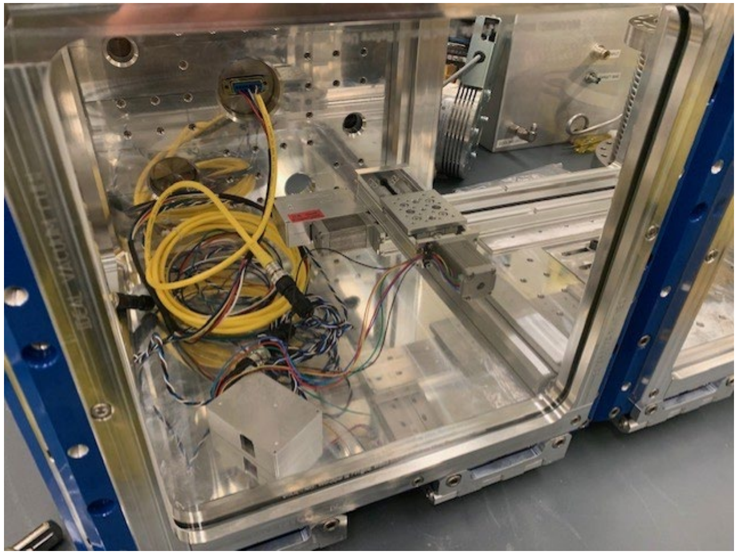
- Rad-EMIS stable operation with UCl_3 for many hours (>10),
- Refine collection/Faraday measurement cups
- $NpCl_3$ molecular fractionation, beam current and efficiency (TBD)
- Develop high efficiency ionization method to best utilize valuable starting materials (Electron bombardment source, Liquid metal ion source, RF source)

- Our Grand Challenge: obtaining gram Np target with sufficient Np to optimize instrument operation
    - Need 0.1% efficiency with targets containing ppm levels Np (efficient ion source, focusing optics and collection methods)
        - (ATR irradiated Np alloy fuel 30 ppm)
        - 100 - 500 hrs Np photonuclear production
        - LANL Np as feed?

- Future production efforts in addition to Np may include isotopes of Cm, Kr, Th, Pa, and Pu.

New collector chamber





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