Isotope Program
U.S. Department of Energy

Stable Isotope Portfolio

DOE Office of Science's Office Hours
June 10, 2024

Dr. April Gillens, PM for Stable Isotopes

Office of Science for Isotope R&D and Production
U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY

Statement of Commitment

The DOE Office of Science (SC) microsite on Diversity, Equity & Inclusion is now posted on the SC website.

The entirety of the statement can be found at:
https://science.osti.gov/sc-2/research-and-conduct-policies/diversity-equity-and-inclusion/

“The DOE Office of Science (SC) is fully committed to fostering safe, diverse, equitable, and inclusive work, research, and funding environments that value mutual respect and personal integrity. Effective stewardship and promotion of diverse and inclusive workplaces that value and celebrate a diversity of people, ideas, cultures, and educational backgrounds is foundational to delivering on the SC mission. The scientific community engaged in SC-sponsored activities is expected to be respectful, ethical, and professional.

The DOE SC does not tolerate discrimination or harassment of any kind, including sexual or non-sexual harassment, bullying, intimidation, violence, threats of violence, retaliation, or other disruptive behavior in the federal workplace, including DOE field site offices, or at national laboratories, scientific user facilities, academic institutions, other institutions that we fund, or other locations where activities that we support are carried out…”

The Faces of DOE IP

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Stable Isotope R&D

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Stable Isotope Facilities

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Isotope Program Initiatives

Jon Neuhoff
Isotope Reactor Facilities

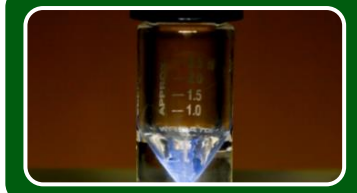
Julie Ezold
Technical Advisor

Past Office Hours

- Monday, March 11, 2024 – Introduction to the DOE Isotope Program and Mission. (Slides | Video)
- Monday, April 8, 2024 – Competitive DOE IP Funding Opportunities for R&D and Training. (Slides | Video)
- Monday, May 13, 2024 – Working with a Program Manager Before, During, and After an Award. (Slides | Video)
- https://science.osti.gov/Isotope-Research-Development-and-Production/officehours

Mission

DOE Isotope Program Mission



Produce and/or distribute radioactive and stable isotopes that are in short supply; includes by-products, surplus materials and related isotope services

Maintain the infrastructure required to produce and supply priority isotope products and related service

Conduct R&D on new and improved isotope production and processing techniques which can make available priority isotopes for research and application. Develop workforce.

Ensure robust domestic supply chains. Reduce U.S. dependency on foreign supply to ensure National Preparedness.

Stable Isotopes

Stable Isotopes are found naturally and do not decay.

Enriched stable isotopes are used in a variety of direct applications as well as to produce radioisotopes.

Samples enriched with a particular stable isotope are most desirable for applications. Enrichment technology emerged from the war-time era to enrich Uranium-235 and can be classified due to dual use technology.

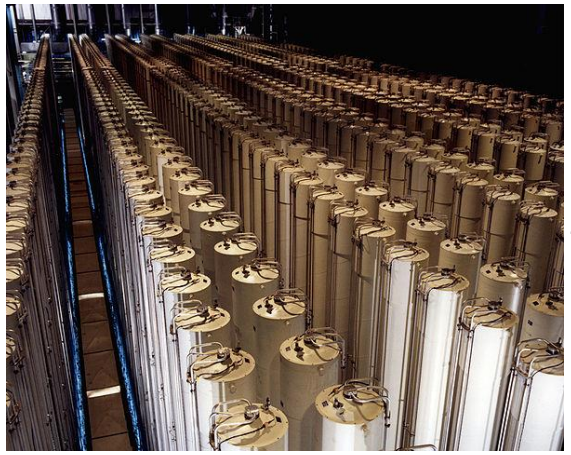
Three common methods to enrich isotopes:

Distillation: Effective if large mass difference between isotopes – often used to separate light elements.

Gas Centrifuge: Gas rotated in cylinder at high speed to separate different masses by centrifugal force. Requires a gaseous form of element or compound. Best for higher throughput, lower enrichment.

Electromagnetic Separation: Isotopes are separated by a strong magnetic field. Best for higher enrichment, lower throughput.

Manhattan project Calutrons that enriched uranium via electromagnetic separation – no longer operating



Gas centrifuges from Piketon Plant- no longer operating

National Stable Isotope Repository

- Stewardship of the DOE Isotope Program's National Stable Isotope Repository at ORNL is a DOE Office of Science mission-essential function that ensures a domestic supply of crucial isotopically and chemically purified materials for the government, academia, medicine, and industry.
- The repository consists of calutron-produced and purchased isotopes, and now also includes ORNL EMIS-enriched isotopes.
- All inventory additions/removals are directed by NIDC.
- Every batch is dispensed using ISO 9001:2015 registered processes to ensure delivery of a quality product to our customers.

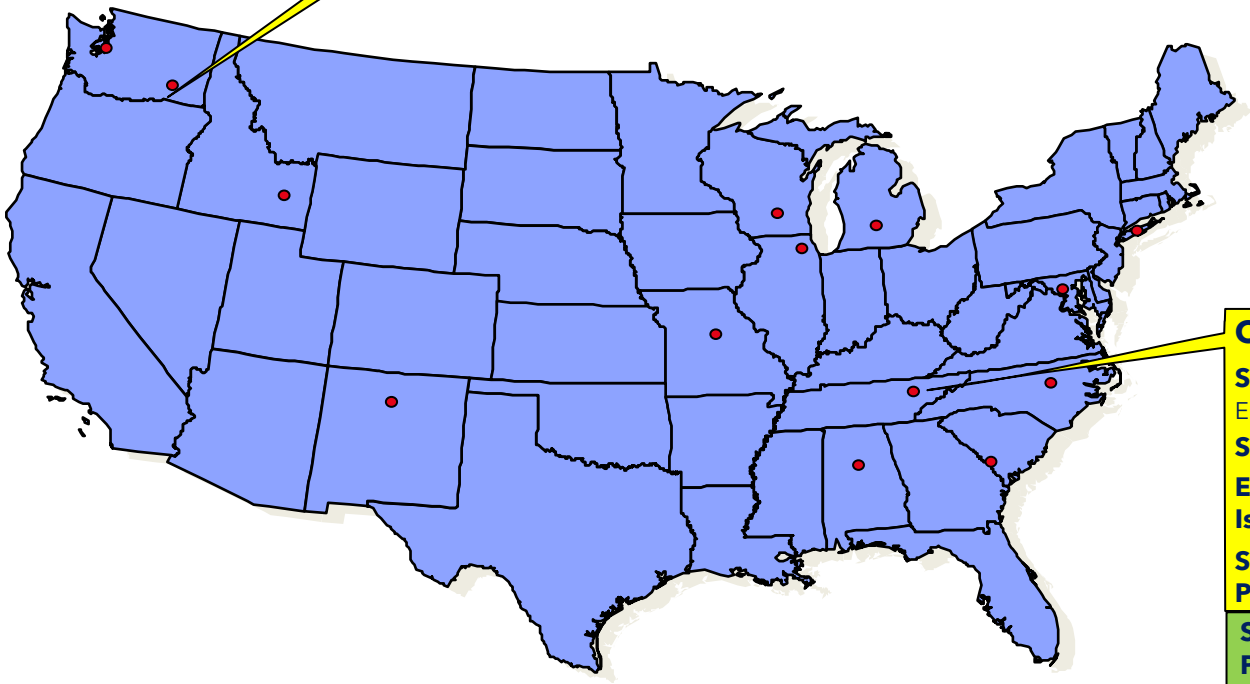
ORNL stewards an inventory that is an irreplaceable national treasure.

NIDC catalog offers
>3,500 quality-controlled batches
306 isotopes
79 elements

Group IA												IIIA	IVA	VA	VIA	VIIA	Inert Gases
H	IIA							VIII		IB	IIB						He 1
Li 2	Be 1											B 2	C 2	N 1	O 2	F	Ne 1
Na 1	Mg 3	IIIB	IVB	VB	VIB	VIIB						Al 1	Si 3	P	S 4	Cl 2	Ar 2
K 3	Ca 6	Sc	Ti 5	V 2	Cr 4	Mn	Fe 4	Co 1	Ni 5	Cu 2	Zn 5	Ga 2	Ge 5	As 2	Se 6	Br 2	Kr 5
Rb 2	Sr 4	Y 2	Zr 5	Nb	Mo 7	Tc 3	Ru 7	Rh	Pd 6	Ag 2	Cd 8	In 2	Sn 10	Sb 2	Te 8	I	Xe 6
Cs	Ba 7	La† 2	Hf 6	Ta 2	W 5	Re 2	Os 7	Ir 2	Pt 6	Au 1	Hg 7	Tl 2	Pb 4	Bi 1	Po 1	At 1	Rn
Fr	Ra 3	Ac‡ 2															

†	Ce 4	Pr	Nd 7	Pm	Sm 7	Eu 2	Gd 7	Tb	Dy 7	Ho 2	Er 6	Tm	Yb 7	Lu 2
‡	Th 2	Pa	U 5	Np 2	Pu 6	Am 2	Cm 4	Bk 1	Cf 2	Es	Fm	Md	No	Lr

DOE IP Stable Isotope Production Sites

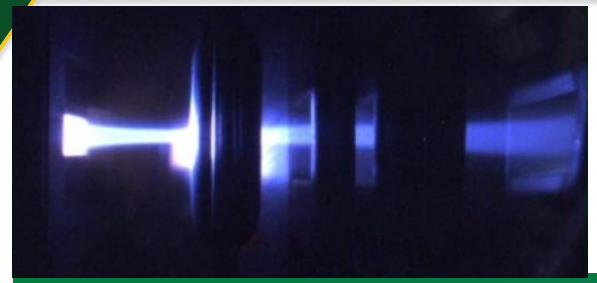


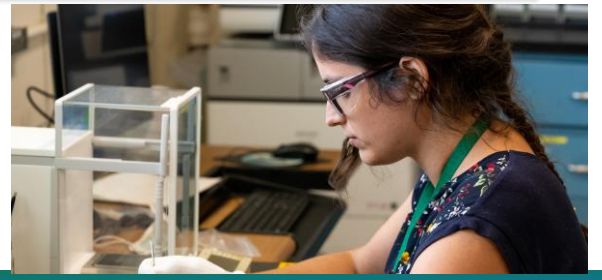
PNNL
TDIS -Thermal Diffusion Isotope Separation

ORNL
Stable Isotopes Inventory:
E.g., Ca-48, Ga-69, Rb-87, Cl-37
Stable Isotope Production:
ESIPP - Enriched Stable Isotope Pilot Plant
SIPF - Stable Isotope Production Facility

SIPRC - Stable Isotope Production and Research Center

Stable Isotope Research Areas





Plasma Science

- Ion Source Technology
- Plasma physics

Materials Science and Chemistry

- Isotope harvesting and processing
- Feedstock development
- Physical and chemical conversions for unique customer requirements

Enrichment Technology

- Electromagnetic Isotope Separation
- Gas Centrifuge Isotope Separation
- Thermal Diffusion Isotope Separation
- Atomic Vapor Laser Isotope Separation

Isotope-Specific Methodologies

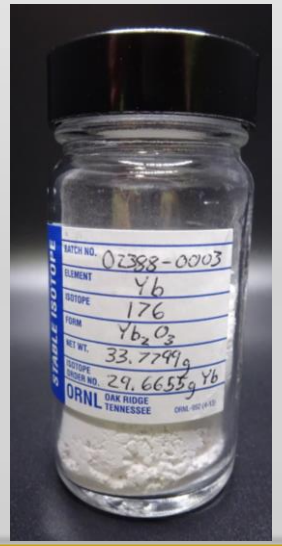
- Expanding suite of enriched stable isotopes in response to program priorities
- R&D for quotes to convert isotopes to unique customer specifications

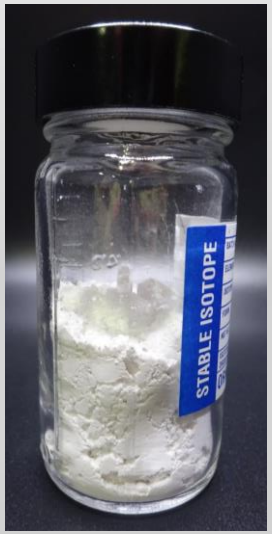
Third generation (E3) EMIS technology has achieved ^{176}Yb enrichment goal at scale!

- Highly enriched Yb-176 is critical to produce lutetium-177 for targeted cancer therapy.
- E3 EMIS meeting or exceeding product specs and production quantities.
- In November 2023, a nearly 30-gram batch of 99.7% enrichment Yb-176 was added to the national stable isotope sales inventory, the largest single batch of US-produced material since the calutrons halted production in 1998.
- The National Isotope Development Center (NIDC) has already received orders for this material.

and

- Simultaneous enrichment of <u>all</u> Yb isotopes





New EMIS E4 and E5 will be complete in Q2 FY25

- 90-degree EMIS units of the E3 design and located in the same space.
- Will be initially operated for Ni-64 enrichment.
- Tremendous opportunity to develop a deeper understanding of production-level, multi-machine operations with multiple elements and isotopes.
- Optimization of isotope processing chemistry.
- The overarching goal is highly-efficient production of critical stable isotopes from beginning to end of the isotope lifecycle:
  - scoping studies and proof of concept
  - pre-production R&D,
  - pilot production campaigns,
  - production demonstration, and
  - production with the product being processed to the National Stable Isotope Repository for customers.

Developing the 4th-Generation EMIS Device: Double Electromagnetic Isotope Separation (DEMIS)

Project Driver:
The U.S. needs a fully domestic supply chain of ultrahigh enriched isotopes

Project Description:
The DEMIS effort is developing and deploying 4th generation EMIS devices capable of enrichment on the order of 99.999+% starting from natural feedstock

The DEMIS R&D highly leverages ongoing ion source, collector and beam transport research and operations experience on the currently deployed 60-degree and 90-degree EMIS devices

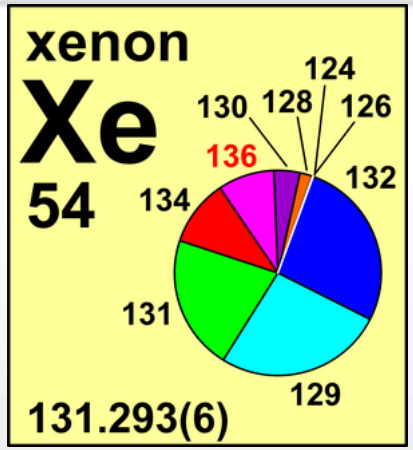
Project Scope:

1. Design a prototype Double Electromagnetic Isotope Separation (DEMIS) device (two 90D magnets)
2. DEMIS Procurement, Fabrication, Assembly, and Installation
3. Initial Commissioning with Argon Gas
4. Isotope-specific Commissioning
5. Baseline Performance Measurement

Gas Centrifuge

Develop and Deploy

- ORNL-developed gas centrifuge technology is currently being implemented in a first production cascade (SIPF).
- Stable isotope team works closely with ORNL colleagues in the NNSA Domestic Uranium Enrichment (DUE) Program on the latest centrifuge technology advancements.
- Multiple GCIS gas test stands have been constructed for specific isotopes.
- Initial enrichment of ^{129}Xe (SIPF) and ^{100,98}Mo (SIPRC)



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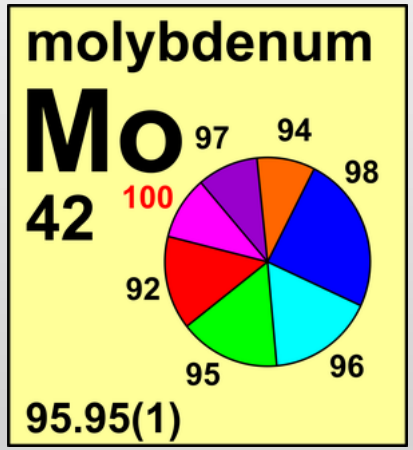


Stable Isotope Production Facility (SIPF)

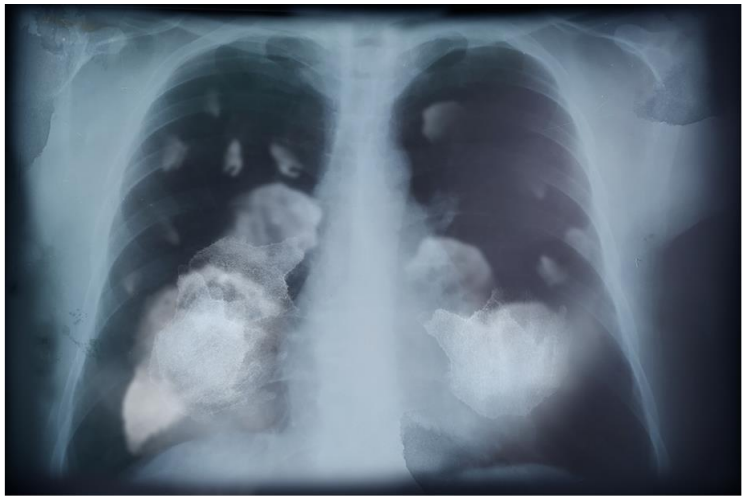
- **Scope:** design and construct a centrifuge machine and cascade for separation of ^{129}Xe.

- **Xenon-129 (^{129}Xe)** is used as a diagnostic tool to image the lungs. MRIs using the isotope can provide 3D images and assist in quantifying lung structure and function.
- US production of ^{129}Xe will mitigate dependence on foreign suppliers.

The Stable Isotope Production Facility (SIPF) is scheduled for completion in 2024 and will house DOE IP's GCIS technology.

Transition to Operations phase in parallel with project completion

This will be the first Gas Centrifuge production cascade for stable isotopes in the U.S.!



Xenon-129 is a novel isotope used primarily as a diagnostic tool to image the lungs.

Stable Isotope Production and Research Center
Strong U.S. Enrichment Capability

Isotope Program
U.S. Department of Energy

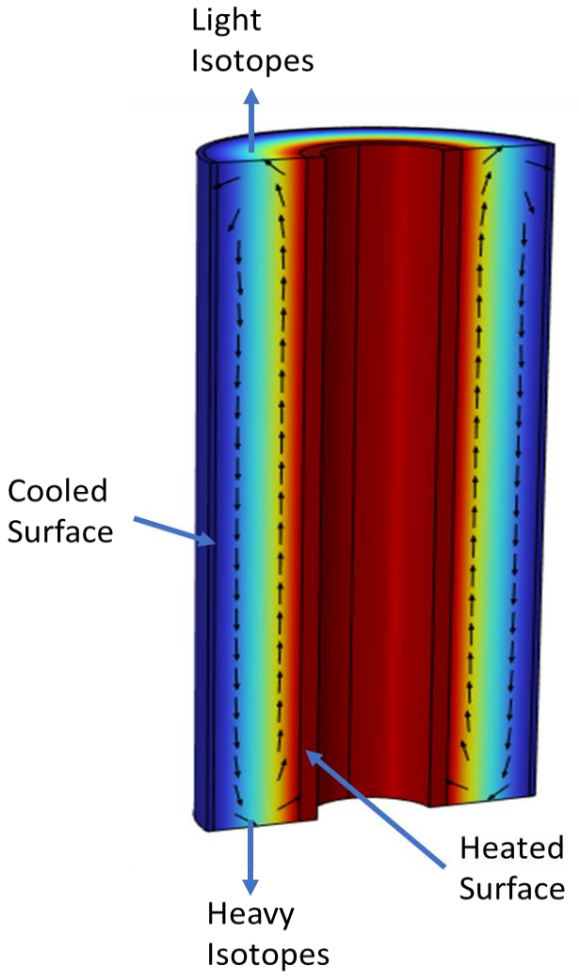
Stable Isotope Production and Research Center (SIPRC)

- **Expand our nation's ability to perform <u>multiple</u> isotope production campaigns at large scale production; mitigate foreign dependence; promote economic resilience.**
- DOE IP vision is to nurture core competencies in a broad suite of enrichment technologies

Groundbreaking Ceremony 10/22

Thermal Diffusion

- The radial thermal gradient moves heavier molecules toward the cold wall and lighter molecules toward the hot wall
- Natural convection circulating flow amplifies the small thermal diffusion separation to ~100X that observed in a two-bulb apparatus
- TDIS column separates isotopes with (usually) lighter masses moving up, and heavier masses moving down
- Multiple columns arranged in a cascade are used to achieve the desired enrichment and production rate



Setting Stable Isotope Priorities Process of Evaluation

Historical, calutron-era inventory managed by NIDC

Examining 5-year sales inventory
Includes depleted inventory
Includes procurements to replenish isotopes

Radioisotope Feedstock Assessment

Evaluate production capacity for radioisotopes
New, emerging radioisotopes

Surveys

Federal – Conducted biennially by DOE IP
Customer – Conducted annually by NIDC
Market Assessments – as requested from NIDC

Community Needs

Super Heavy Element, Federal Priorities, Quantum Information Science, Nuclear Forensics, Supply disruptions, Community queries

Stable Isotope R&D Topics

- Isotope R&D and Production FOA
  - Released biennially
  - Work in this area should advance basic research supporting current technologies in electromagnetic ion separation (EMIS), atomic vapor laser ion separation (AVLIS), thermal diffusion and novel enrichment approaches. Responsive work scope might explore, but are not limited to: the development of EMIS-based ion sources capable of greater than 20% ionization efficiency of the lanthanide and actinide series of elements at 1 mA intensity or greater; understanding the plasma chemistry and atomic physics effects associated with high intensity heavy ion plasma and ion sources; understanding the sputter physics of materials with energy and angular dependence; development of high efficiency, high purity magnetized radiofrequency driven ion source technology for EMIS-based enrichment; resolving the uncertainty around applying modern approaches to AVLIS isotope enrichment. In addition, the specifications for feed stock and resulting chemistry are often very process dependent. This can lead to material compatibility issues when working across different enrichment technologies. DOE IP is interested in applications focused on mitigating these material compatibility issues. Responsive work scope might explore, but is not limited to, plasma/ion formation of challenging feed material and chemistry, physics, or engineering based materials analyses. Studies aimed at the development of automated techniques to enhance the efficiency and safety of materials processing and enrichment (including uses of AI or ML, multi-physics modeling, and advanced manufacturing) are also encouraged. All applications should first be discussed with the Subprogram Contact.
- Annual Continuation of Solicitation for the Office of Science Financial Assistance Program (“The Open Call”)
  - Who can apply?
  - How does DOE IP use it?

Upcoming Events

- Isotope R&D and Production (DOE IP) DOE IP will hold virtual office hours on the second Monday of the month, 2-3pm ET. In cases where the second Monday falls on a federal holiday, the office hour will slide to the third Monday of the month. Upcoming topics include:
  - Monday, July 8, 2024, at 2pm ET – The FOA Application and Review Process
  - Monday, August 12, 2024, at 2pm ET – How to Become a Reviewer for DOE IP
- For more information on DOE IP office hours, including registration, upcoming topics, slides, and recordings, please visit https://science.osti.gov/Isotope-Research-Development-and-Production/officehours.
- We look forward to having you join our Office of Science network and office hours!

Thank You!