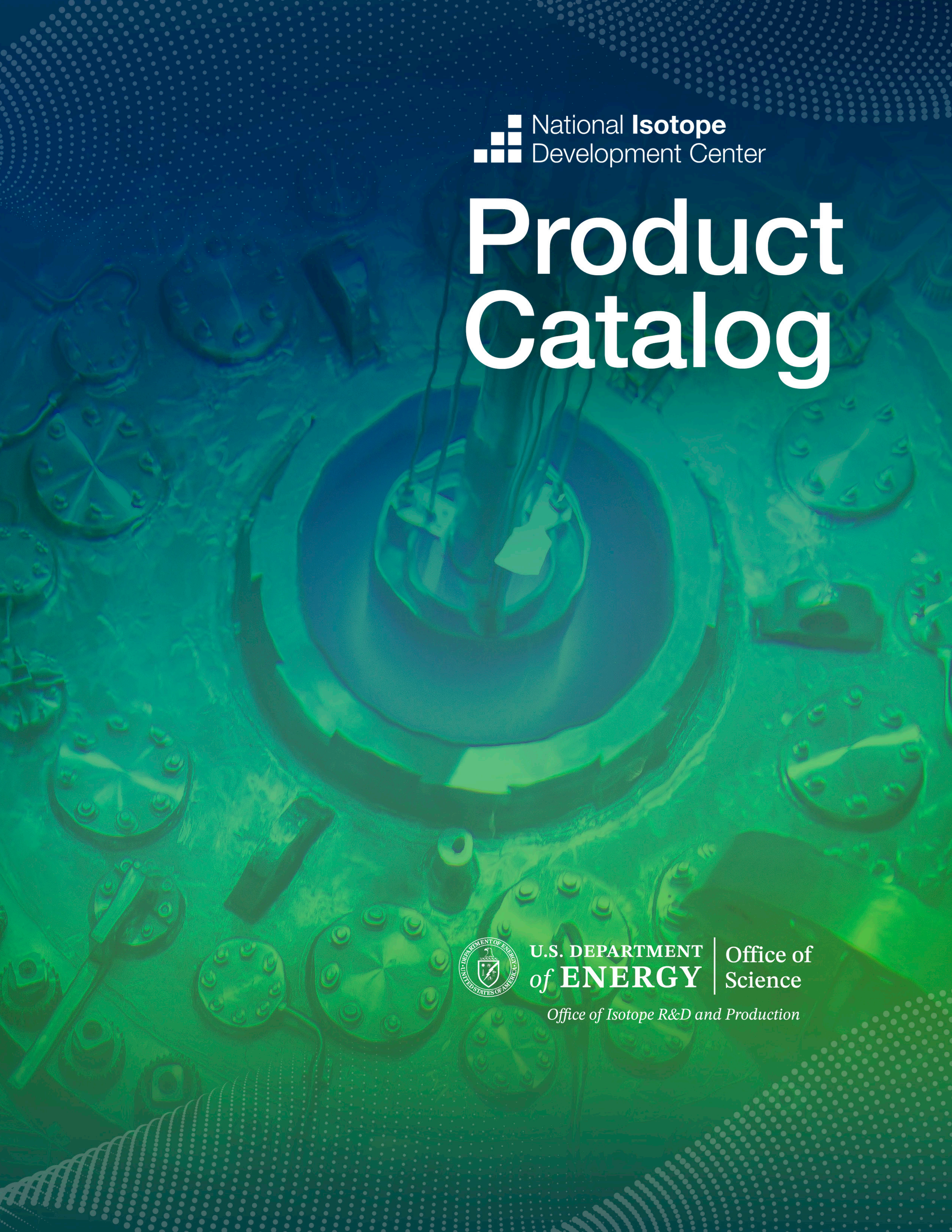

National **Isotope** Development Center

Product Catalog

U.S. DEPARTMENT of ENERGY | Office of Science

Office of Isotope R&D and Production

Providing the Nation with Critical Isotopes

The U.S. Department of Energy's Office of Isotope R&D and Production (DOE IRP) provides a wide range of isotope products and services to customers worldwide. Continuing a long tradition within the DOE and its predecessor organizations, we are committed to producing and distributing radioisotopes and enriched stable isotopes for research and development (R&D) purposes, medical diagnoses and therapy, industrial, homeland security, agricultural, and other useful applications in the national interest.

The DOE IRP is centrally managed from DOE Headquarters in Germantown, Maryland. Currently, the IRP maintains isotope production facilities at Argonne, Brookhaven, Idaho, Los Alamos, Oak Ridge, and Pacific Northwest National Laboratories. These facilities produce stable and radioactive isotopes in short supply using nuclear reactors, linear accelerators and other methods.

The office also partners with universities to invest in R&D and to develop production capabilities. Not only do these universities present unique infrastructure capabilities and expertise, but they are also essential to workforce development.

The DOE IRP established the National Isotope Development Center (NIDC) as an organization that interfaces with the user community and provides corporate services to the IRP.

For ordering isotopes or for additional information on isotope products and services, please contact the NIDC or visit our online catalog at www.isotopes.gov.

National Isotope Development Center

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www.isotopes.gov

Products and Services

Products that are offered for sale are listed in this catalog. Materials either exist in inventory or can be scheduled to be produced at one or more facilities. Isotopes are sold in forms suitable for incorporation into diverse pharmaceuticals, generator kits, irradiation targets, radiation sources, or other finished products. Stable enriched isotopes may be purchased or leased for nonconsumptive use.

Services are available based on the DOE's extensive expertise derived from many years of isotope R&D, and production operations. These services include chemical processing, target and source irradiations, R&D and testing capabilities, chemical form conversions, and source encapsulations.

To order, contact the National Isotope Development Center (NIDC) or request a quote on the NIDC website (www.isotopes.gov). Buyers will be required to provide documentation and reason for purchase. Buyers can obtain order forms, instructions, and assistance necessary for a transaction from the NIDC.

Availability of products and services described in this catalog varies, and distribution of some products may not be feasible at some times. However, the DOE is eager to work with current and potential customers to establish new means of production and new products as warranted by demand and national need. If specific products and services are not listed, inquiries are welcome and encouraged.

Prices, terms, and other conditions of purchase are established by the DOE. Price changes may be necessary at any time. However, confirming a purchase order ensures that the stated prices will apply for the term of the order. Price estimates can be obtained from the NIDC. Firm quotations are developed during the ordering process.

Isotope Availability

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	**He**
Li	**Be**											B	C	**N**	**O**	F	**Ne**
Na	**Mg**											**Al**	**Si**	P	**S**	**Cl**	**Ar**
K	**Ca**	Sc	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Ge**	**As**	**Se**	**Br**	**Kr**
Rb	**Sr**	**Y**	**Zr**	Nb	**Mo**	**Tc**	**Ru**	Rh	**Pd**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Te**	I	**Xe**
Cs	**Ba**		**Hf**	**Ta**	**W**	**Re**	**Os**	**Ir**	**Pt**	**Au**	**Hg**	**Tl**	**Pb**	**Bi**	**Po**	**At**	Rn
Fr	**Ra**		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
		La	**Ce**	Pr	**Nd**	**Pm**	**Sm**	**Eu**	**Gd**	Tb	**Dy**	**Ho**	**Er**	Tm	**Yb**	**Lu**	
		Ac	**Th**	Pa	**U**	**Np**	**Pu**	**Am**	**Cm**	**Bk**	**Cf**	**Es**	**Fm**	Md	No	Lr	

isotopes.gov/catalog

Elements shown in blue indicate that isotopes are available for quotation. To request a quote visit isotopes.gov/catalog or scan the QR code.

Report a Supply Chain Concern

isotopes.gov/supply-chain-concern

We closely monitor international isotope supply and demand. We routinely assess our production capabilities and take measures to support production for critical isotopes if a shortage should occur. If you have concerns about the stability of an isotope supply chain, please bring these to our attention.

Radioactive Isotopes

ISOTOPE	HALF-LIFE/DAUGHTER	CHEMICAL FORM	RADIONUCLIDIC PURITY
Actinium-225 (Th-229 Decay Product)	9.920 days to francium-221	Solid actinium nitrate	>98% Ac-225; <2% Ra-225
Actinium-227	21.772 years to thorium-227	Solid actinium nitrate	≥99%
Aluminum-26	7.17×10^5 years to magnesium-26	Aluminum(III) in 1 N HCl	>99%
Americium-241	432.6 years to neptunium-237	Oxide powder	>99%
Americium-243	7.364×10^3 years to neptunium-239	Oxide powder	>99%
Arsenic-73	80.30 days to germanium-73	Arsenic(V) in 0.1 N HCl	>99% (exclusive of As-74)
Astatine-211	7.214 hours to polonium-211 and bismuth-207	Astatide as Na salt in NaCl	>99.9%
Barium-133	10.551 years to cesium-133	Nitrate in dilute HNO_3	>99.9%
Berkelium-249	330 days to californium-249	Nitrate or chloride solid	>98%
Beryllium-7	53.22 days to lithium-7	Beryllium(II) in 0.5–5.0 N HCl	>95%
Bismuth-207	31.55 years to lead-207	Bismuth(III) in ≥4 M HNO_3	>99%
Bromine-77	57.0 hours to selenium-77	Ammonium bromide in 0.1 M NH_4OH	>99.5%, <0.5% Br-76 at shipment
Cadmium-109	461.4 days to silver-109	Cadmium(II) in 0.1 N HCl	>99% (excluding Cd-113m and Cd-115m)
Californium-249	351 years to curium-245	Nitrate or chloride solid	>98%
Californium-252	2.645 years to curium-248	Solution or custom form	>60–80 atom %
Cerium-134	3.16 days to lanthanum-134	Ce(III) in 0.1 M HCl	> 99.8% (excluding Ce-135, Ce-137m, Ce-139 and La daughters), Ce-135 < 1%, Ce-137m <5%, Ce-139 <3%
Cerium-139	137.641 days to lanthanum-139	Cerium (III) in 0.5 N HCl	>99%
Cobalt-55	17.53 hours to iron-55	Cobalt(II) in 0.05 N HCl	>99.9%
Cobalt-60	1925.28 days to nickel-60	Nickel-plated pellets (1 mm × 1 mm)	>99%
Curium-244	18.11 years to plutonium-240	Nitrate solid	Variable; analysis provided

*Now available from domestic producers

ISOTOPE	HALF-LIFE/DAUGHTER	CHEMICAL FORM	RADIONUCLIDIC PURITY
Curium-248	3.48×10^5 years to plutonium-244	Nitrate or chloride solid	>96%
Gadolinium-148	71.1 years to samarium-144	Gadolinium(III) in 0.1 N HCl	>95%
Germanium-68*	270.93 days to gallium-68	Germanium(IV) in <1 N HCl	Product commercially available, contact the NIDC with supply concerns
Gold-199	3.139 days to mercury-199	Chloride solution (0.5 M HCl)	Contact NIDC for details
Holmium-166m	1.20×10^3 years to erbium-166	Oxide powder	>98%
Iron-55	2.744 years to manganese-55	Chloride solution (0.5 N HCl)	Determined on each lot
Iron-59	44.5 days to cobalt-59	Chloride solution (1 to 2.5 N HCl)	Contact NIDC for details
Lead-203	51.7 hours to thallium-203	$PbCl_2$ in <500 µL HCl	>98%
Lutetium-177	6.647 days to hafnium-177	Chloride solution (0.05 N HCl)	≥99%
Magnesium-28	20.915 hours to aluminum-28	Magnesium chloride in 0.1 N HCl	No gamma emitters detected (<0.5%)
Manganese-52	5.591 days to chromium-52	Manganese (II) in 0.1 M HCl	<1% Mn-54
Manganese-54	312.2 days to chromium-54	Chloride solution (0.5 M HCl)	Contact NIDC for details
Mercury-194	444 years to gold-194	2 N HNO_3	>99%
Neptunium-236	1.53 x 106 years to uranium-236 and plutonium-236	0.5 M HCl solution	Contact NIDC for details
Neptunium-237	2.144×10^6 years to protactinium-233	Oxide powder	>99%
Nickel-63	101.2 years to copper-63	Chloride solution (0.1 M HCl) or dried chloride solid	>99%
Plutonium-238	87.7 years to uranium-234	Oxide powder	>99%
Plutonium-239	2.411×10^4 years to uranium-235	Oxide powder	>99%
Plutonium-240	3.6319 days to radon-220 6,561 years to uranium-236	Oxide powder	>99%
Plutonium-241	14.329 years to uranium-237	Nitrate or chloride solid or oxide powder	80–93%
Plutonium-242	3.73×10^5 years to uranium-238	Oxide powder or nitrate or chloride solid	>99%

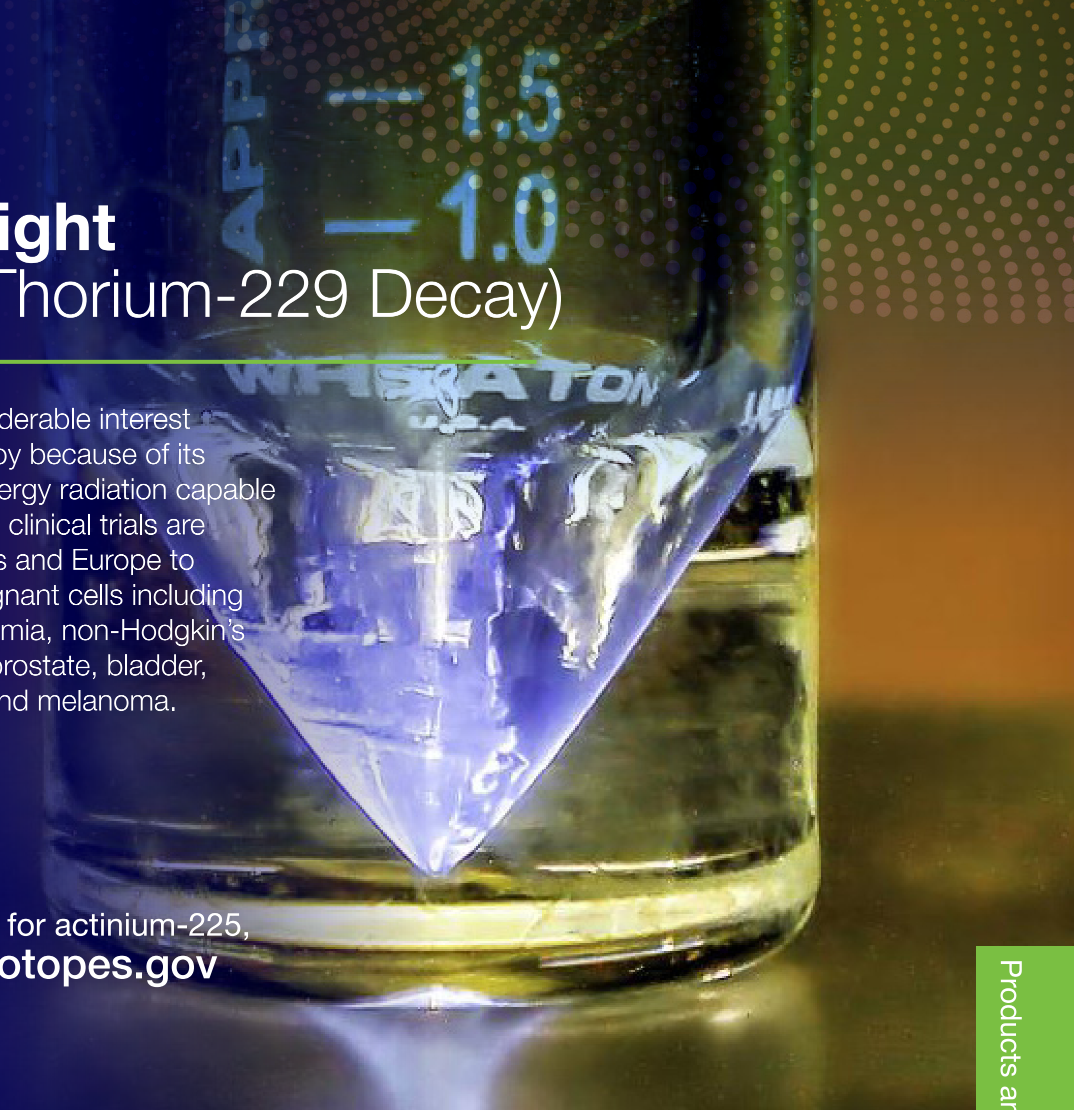
*Now available from domestic producers

ISOTOPE	HALF-LIFE/DAUGHTER	CHEMICAL FORM	RADIONUCLIDIC PURITY
Polonium-209	124 years to lead-205	5 M HNO_3 solution	>99%
Promethium-147	2.62 years to samarium-147	Solid Chloride (PmCl3) or Nitrate (Pm(NO3)3) Salt	99.99%
Radium-223	11.43 days to radon-219	Nitrate solid	≥99.9%, not including decay products
Radium-224	3.6319 days to radon-220	Radium chloride in 1 M HCl solution or solid radium nitrate	>99.9% Ra-224; <0.1% Th-228
Radium-224/ Lead-212 Generator	Radium-224: 3.6319 days to radon-220; Lead-212: 10.64 hours to bismuth-212	Ra-224 absorbed on AG MP-50 resin	>99.9% Ra-224; <0.001% Th-228
Radium-225	14.9 days to actinium-225	Nitrate solid	>99%
Radium-226	1,600 years to radon-222	Radium carbonate or radium nitrate salt	>99%
Selenium-72	8.40 days to arsenic-72	Selenium(IV) in 0.5–5.0 N HCl_3	Determined on each lot
Selenium-75	119.78 days to arsenic-75	Selenium(IV) in 6 N HNO	High purity. TBD after inital processing
Silicon-32	153 years to phosphorus-32	Silicon(IV) in 0.1 N NaOH	>99.9%
Sodium-22	2.6018 years to neon-22	Sodium chloride in H_2O	>99%
Strontium-89	50.563 days to yttrium-89	Strontium chloride in 0.1–0.5 N HCl	>99.8%
Strontium-90	28.79 years to yttrium-90	Nitrate solid	>99.99%
Technetium-99	2.111×10^5 years to ruthenium-99	Solid ammonium pertechnetate or technetium metal	>99%
Thorium-227	18.697 days to radium-223	Nitrate solid	≥99%
Thorium-228	1.9116 years to radium-224	Nitrate solid	≥99%
Thorium-229	7,880 years to radium-225	Nitrate in 0.1 N HNO_3 or dry nitrate salt	≥99%
Tin-117m	14.00 days to tin-117	Tin metal in quartz tube or tin(IV) in 0.1 N HCl	>99%
Titanium-44	60 years to scandium-44	Ti(IV) in 6 M HCl	
Tungsten-188	69.78 days to rhenium-188	Sodium tungstate solution	>99%

*Now available from domestic producers

ISOTOPE	HALF-LIFE/DAUGHTER	CHEMICAL FORM	RADIONUCLIDIC PURITY
Uranium-234	2.455 × 10^5 years to thorium-230	Oxide powder	>94%
Uranium-235	7.038 × 10^8 years to thorium-231	Oxide powder	>98%
Uranium-238	4.468 × 10^9 years to thorium-234	Oxide powder	>99.9%
Vanadium-48	15.9735 days to titanium-48	Vanadium(V) in 6 N HCl	>99%, excluding vanadium-49
Yttrium-86	14.74 hours to strontium-86	Yttrium(III) in 0.05–0.5 N HCl	>96%
Yttrium-88	106.626 days to strontium-88	Yttrium(III) in 0.1 N HCl	>99%
Zinc-65	243.93 days to copper-65	Zinc(II) in 0.05–0.5 N HCl	>99%
Zirconium-88	83.4 days to yttrium-88	Zirconium(IV) in 0.1 N HCl	>99% (excluding yttrium-88 daughter)

*Now available from domestic producers



Product Highlight
Actinium-225 (Thorium-229 Decay)

Actinium-225 (Ac-225) is of considerable interest for its uses in targeted alpha therapy because of its relatively short half-life and high-energy radiation capable of breaking bonds in DNA. Multiple clinical trials are underway in both the United States and Europe to study its effect on a variety of malignant cells including those found in acute myeloid leukemia, non-Hodgkin's lymphoma, brain tumors; gastric, prostate, bladder, ovarian, and pancreatic cancers; and melanoma.

To request a quote for actinium-225, **please visit isotopes.gov**

Half Life/Daughter:	9.920 days to francium-221
Chemical Form:	Solid actinium nitrate

Production

Production Route:	Decay of thorium-229
Radionuclidic Purity:	>99% Ac-225 by activity

Distribution

Primary Container:	Glass screw top V-vial in nonreturnable container
Availability:	Routinely available (weekly); order in advance due to limited supply
Unit of Sale:	Millicuries

Product Highlight
Astatine-211

Astatine-211 (At-211) is a radioisotope of interest for use in targeted alpha therapy. This short-lived alpha-emitting radionuclide ($t_{1/2}$ = 7.214 hours) has demonstrated significant potential in the treatment of blood, ovarian and certain types of brain cancers.

The success of At-211 as a cancer therapeutic relies on regional production and distribution of the isotope due to its relatively short half-life. Thus, the DOE IRP is working to establish a nationwide At-211 network, and two of its University Isotope Network partners – the University of Washington (UW) and Texas A&M University (TAMU) – now serve as its initial hubs.

To request a quote for astatine-211,
please visit isotopes.gov

Half Life/Daughter:	7.214 hours to polonium-211 and bismuth-207
Chemical Form:	Sodium astatide in NaCl solution (pH 6.5-7) - UW Sodium astatide in sodium acetate solution (pH 6.5 -7) - UW Absorbed onto 3-octanone impregnated column - TAMU
Radionuclidic Purity:	>99% At-211 (based on gamma spectroscopy, evaluated quarterly)
Radioisotopic Purity:	>99.5% (based on gamma spectroscopy, evaluated quarterly) - UW >99% At-211 (based on gamma spectroscopy) - TAMU
Radiochemical Purity:	≥85% (by radioTLC peak area) Na[At-211]At; other At-211 species may be present (e.g., [At-211]astatate) - UW >99% At-211 in 3-octanone - TAMU

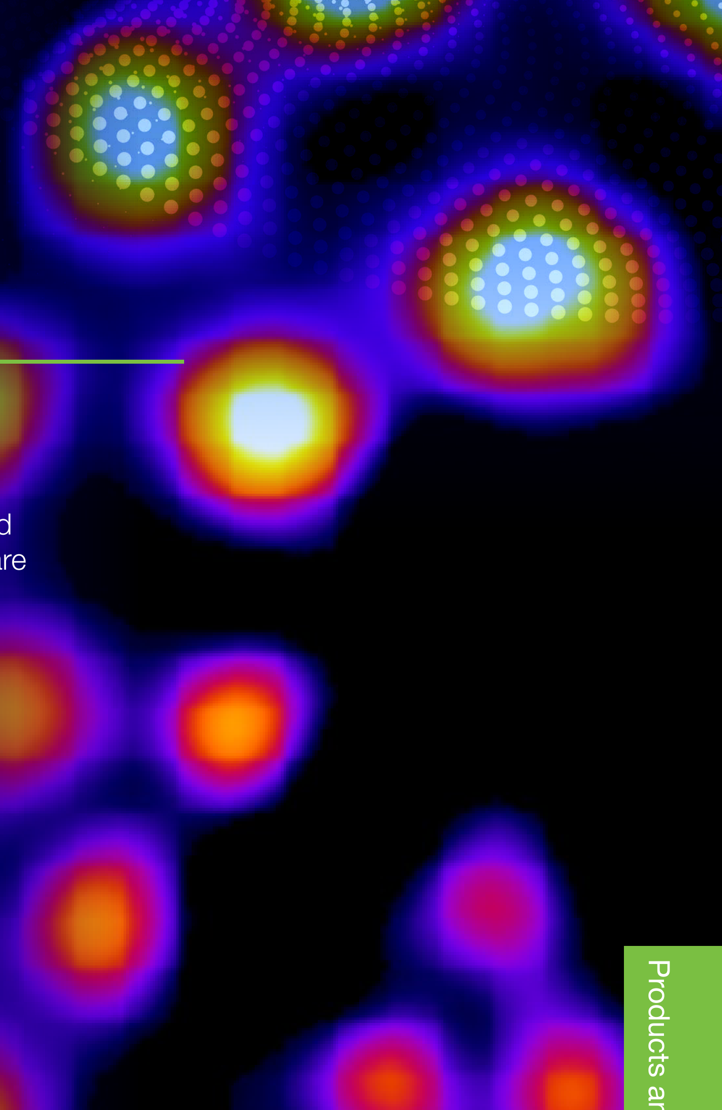
Production

Production Route:	Alpha irradiation of bismuth metal
Processing:	Wet chemistry isolation - UW Tellurium-packed column isolation - UW Dissolution in nitric acid and SPE with 3-octanone impregnated column - TAMU

Distribution

Primary Container:	Screw-cap vial in approved DOT package - UW SPE column in approved DOT package - TAMU
Availability:	Special order
Unit of Sale:	Millicuries

Product Highlight
Lead-203



Lead-203 (Pb-203) has drawn interest as a Single Photon Emission Computed Tomography (SPECT) imaging isotopic analogue to the therapeutic lead-212, an alpha-emitter. Its addition to the NIDC Catalog establishes a theranostic matched pair of isotopes. The IRP is filling a gap in the market as there are currently no other domestic producers.

Pb-203 is routinely available in millicurie quantities. The final product is distributed in a 1.5 mL microcentrifuge tube with a ≥98% radionuclidic purity.

To request a quote for lead-203,
please visit isotopes.gov

Half Life/Daughter:	51.7 hours to thallium-203
Chemical Form:	Pb-203 as $PbCl_2$ in <500 µL 1 N HCl
Radionuclidic Purity:	≥98%

Production

Production Route:	Proton irradiation of Tl target
Processing:	Ion chromatography

Distribution

Primary Container:	1.5 mL microcentrifuge tube, metal free
Availability:	Routinely available
Unit of Sale:	Millicuries

Product Highlight
Cerium-134

The DOE IRP is the first global supply chain for **cerium-134 (Ce-134)**, enabling emerging technologies and advancing new treatments to combat cancer. Ce-134 is an essential step in advancing the use of alpha emitters for cancer therapy due to its promise as a PET imaging analog for therapeutic actinium-225 and thorium-227 radioisotopes.

Cerium-134 is produced monthly using high-energy proton linear accelerators at both Los Alamos and Brookhaven National Laboratories. Together, these sites enable year-round production of this critical radionuclide.

Cerium-134 is supplied in a chloride solution of Cerium(III) in 0.1 M HCl. It is shipped in a glass crimp-top v-vial.

To request a quote for cerium-134,
please visit isotopes.gov

Half Life/Daughter:	3.16 days to lanthanum-134
Chemical Form:	Ce (III) in 0.1M HCl
Radionuclidic Purity:	>99.8% (excluding Ce-135, Ce-137m, Ce-139 and La daughters), Ce-135 <1%, Ce-137m <5%, Ce-139 <3%

Production

Production Route:	Proton irradiation of La target
Processing:	Dissolution and ion exchange

Distribution

Primary Container:	Glass crimp-top V-vial
Availability:	Special order
Unit of Sale:	Millicuries

Product Highlight
Radium-224, Lead-212, Bismuth-212

Product: Radium-224 generator for lead-212 and bismuth-212, derived from thorium-228 decay

Radium-224 has been used for many years as a generator of lead-212 and bismuth-212, both of which are used in targeted alpha therapies for breast and ovarian cancers and melanoma. Research has demonstrated the effectiveness of these isotopes in destroying cancer cells while limiting damage to healthy cells caused by specific biological targeting of the isotopes to the cancer cells and the short range of alpha particles in tissue.

Thorium-228 is extracted from the processing of actinium-227 and decays into Ra-224. The Ra-224 is loaded onto a generator from which either Pb-212 or Bi-212 can be eluted. The generator is routinely available through the NIDC, and a quote can be requested through the website.

To request a quote for radium-224, lead-212, bismuth-212
please visit isotopes.gov

Half Life/Daughter:	3.66 days to radon-220, 55.6 seconds to polonium-216, 0.145 seconds to lead-212, 10.64 hours to bismuth-212
Chemical Form:	Ra-224 absorbed on AG-MP50 resin
Radionuclidic Purity:	>99.9% Ra-224; <0.1% Th-228

Production

Production Route:	Decay of thorium-228
Processing:	Ion exchange separation

Distribution

Primary Container:	Generator is housed in a one inch lead pig with inlet/outlet holes
Availability:	Routinely available (monthly up to 16 mCi); order 8–10 weeks in advance
Unit of Sale:	Millicuries

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National **Isotope** Development Center

Managed by U.S. DOE Office of Isotope R&D and Production

Product Highlight
Nickel-63

Nickel-63 (Ni-63) is primarily used in explosive trace detectors to detect explosives, or hazardous chemicals and vapors. Ni-63 acts as an annihilation source in these detectors, stripping the molecules that are given off by a material for analysis. Ni-63 is also used in beta-voltaic nuclear batteries, since it is a long-lived (101-year half-life) pure beta emitter where the low energy beta particles can be converted into electrical energy.

Curie quantities of Ni-63 are now in inventory. Nickel-63 is produced through neutron capture on enriched nickel-62. The final product is distributed as a chloride solution (0.1 M HCl) or dried chloride solid.

To request a quote for nickel-63
please visit isotopes.gov

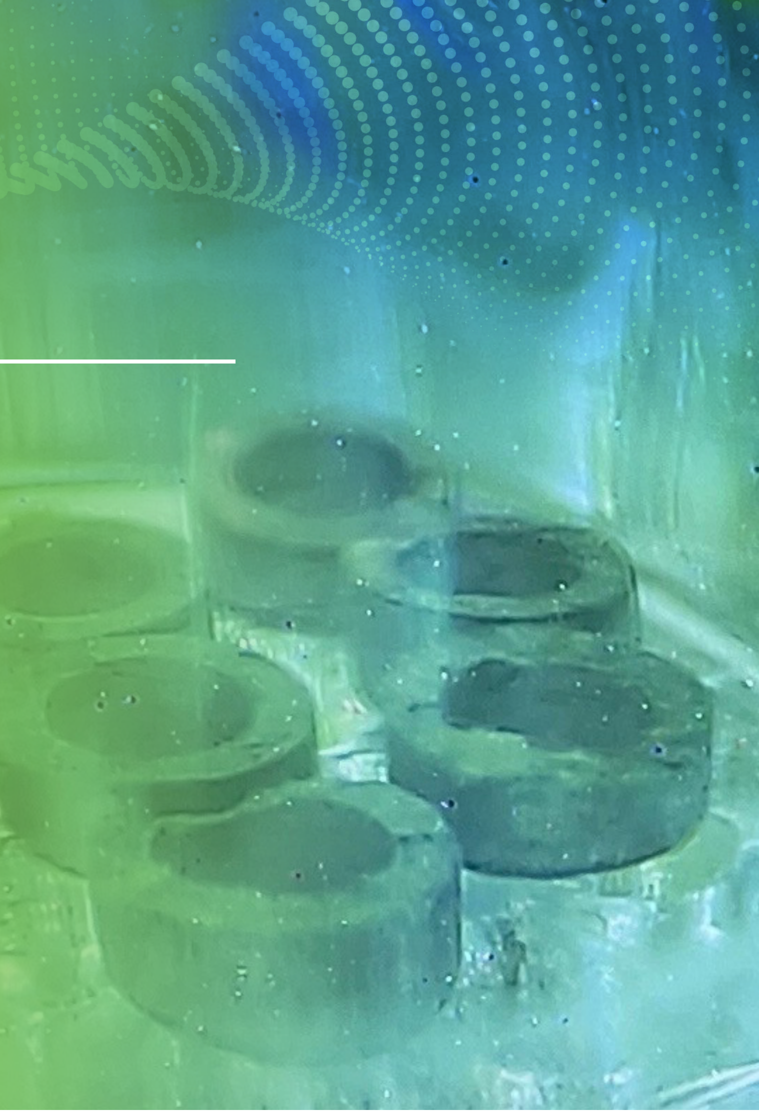
Half Life/Daughter:	101.2 years to copper-63
Chemical Form:	Chloride solution 0.1 M (HCl) or dried chloride solid
Radioisotope Purity:	>99.9%

Production

Production Route:	Neutron capture on enriched nickel-62
Processing:	Irradiated target dissolution followed by anion and cation exchange purification to a chloride solution in HCl

Distribution

Primary Container:	Glass vial in nonreturnable container
Availability:	Stock
Unit of Sale:	Millicuries



Product Highlight
Tungsten-188

In recent years **tungsten-188 (W-188)** and its daughter isotope rhenium-188 (Re-188) have gained attention in the nuclear medicine community for their gamma and beta emissions. They offer therapeutic and diagnostic value. For example, Re-188's beta emissions have demonstrated impressive results when penetrating malignant tumors, especially bone metastases.

Tungsten-188 ($t_{1/2}$ = 69.78 days) is produced at the High Flux Isotope Reactor at Oak Ridge National Laboratory through the neutron bombardment of the enriched stable isotope, tungsten-186. The W-188 product is offered as sodium tungstate in NaOH solution.

To request a quote for tungsten-188,
please visit isotopes.gov

Half Life/Daughter:	69.78 days to rhenium-188
Chemical Form:	Sodium tungstate solution
Radionuclidic Purity:	>99%

Production

Production Route:	Double neutron capture on enriched tungsten-186 metal targets
Processing:	Target dissolved in excess sodium hydroxide and hydrogen peroxide

Distribution

Primary Container:	Screw cap bottle in nonreturnable container
Availability:	Special order; 10–12 weeks advanced notice requested

Product Highlight
Barium-133

Barium-133 (Ba-133) is used for various purposes, including as an x-ray radiocontrast agent and as a gamma source in multiphase flow meters used in the oil and gas industry.

Millicurie quantities of Ba-133 are now available for purchase. Barium-133 is produced at Oak Ridge National Laboratory through neutron capture on enriched barium-132 at the High Flux Isotope Reactor.

To request a quote for barium-133,
please visit isotopes.gov

Half Life/Daughter:	10.551 years to cesium-133
Chemical Form:	Barium nitrate in dilute HNO_3
Radionuclidic Purity:	>99.9%

Production

Production Route:	Neutron capture on enriched barium-132
Processing:	Dissolution, inorganic processing, and ion exchange

Distribution

Primary Container:	Screw cap bottle
Availability:	Special order

Stable Isotopes

Element	Isotope	Enrichment (%)	Abundance (%)	Product Form
Antimony	Sb-121	>99.4	57.21	Metal, oxide, sulfide
	Sb-123	>99	42.79	
Argon	Ar-36	>99.8	0.3336	Gas*
	Ar-40	>99.95	99.6035	
Barium	Ba-130	8–37	0.106	Carbonate, chloride, metal, nitrate
	Ba-132	21–28	0.101	
	Ba-134	73	2.147	
	Ba-135	78–93	6.592	
	Ba-136	92–95	7.854	
	Ba-137	81–89	11.232	
	Ba-138	>97	71.698	
Bromine	Br-79	>98	50.69	Ammonium bromide*
	Br-79 non EM	90–91	50.69	Potassium bromide, silver bromide, sodium bromide
	Br-81	>97	49.31	Potassium bromide, silver bromide, sodium bromide
Cadmium	Cd-106	79–88	1.25	Bromide, chloride, iodide, metal, oxide, sulfide
	Cd-108	68–69	0.89	
	Cd-110	93–97	12.49	
	Cd-111	92–96	12.80	
	Cd-112	97–98	24.13	
	Cd-113	91–95	12.22	
	Cd-114	>98	28.73	
	Cd-116	93–98	7.49	
Calcium	Ca-40	>99.8	96.94	Carbonate, chloride, iodide, metal, nitrate, oxide
	Ca-42	92–94	0.647	
	Ca-43	61–83	0.135	
	Ca-44	79–98	2.09	
	Ca-46	4–30	0.004	
	Ca-48	66–97	0.187	
Cerium	Ce-136	21–50	0.185	Chloride, hydrated nitrate, metal, oxide
	Ce-138	17–26	0.251	
	Ce-140	>99	88.45	
	Ce-142	83–92	11.114	
Chlorine	Cl-35	>99.3	75.76	Barium chloride, lead chloride, potassium chloride, silver chloride, sodium chloride
	Cl-35 non EM	>99.6	75.76	
	Cl-37	95–98	24.24	
Chromium	Cr-50	75–97	4.345	Metal powder, oxide
	Cr-52	>99.7	83.789	
	Cr-53	95–98	9.501	
	Cr-54	90–96	2.365	
Copper	Cu-63	>99.6	69.15	Metal, oxide
	Cu-65	>99.4	30.85	

* Material sold as is

Element	Isotope	Enrichment (%)	Abundance (%)	Product Form
Dysprosium	Dy-156	20–22	0.056	Chloride, metal, nitrate, oxide
	Dy-158	20–32	0.095	
	Dy-160	69.6	2.329	
	Dy-161	90–95	18.889	
	Dy-162	92–96	25.475	
	Dy-163	89–96	24.896	
	Dy-164	92–98	28.26	
Erbium	Er-162	27–34	0.139	Chloride, metal, nitrate, oxide
	Er-164	62–73	1.601	
	Er-166	96	33.503	
	Er-167	91	22.869	
	Er-168	95–97	26.978	
	Er-170	95–96	14.91	
Europium	Eu-151	91–96	47.81	Chloride, metal, nitrate, oxide
	Eu-153	98	52.19	
Gadolinium	Gd-152	32–34	80.2	Chloride, metal, nitrate, oxide
	Gd-154	65–66	2.18	
	Gd-155	84–94	14.80	
	Gd-156	82–99	20.47	
	Gd-157	79–88	15.65	
	Gd-158	81–97	24.84	
	Gd-160	>97	21.86	
Gallium	Ga-69	>99.4	60.108	Metal, oxide
	Ga-71	>99.2	39.892	
Germanium	Ge-70	84–98	20.57	Metal, oxide, germane
	Ge-72	90–98	27.45	
	Ge-73	83–94	7.75	
	Ge-74	94–98	36.50	
	Ge-76	73–92	7.73	
Hafnium	Hf-174	6–19	0.16	Metal, oxide
	Hf-176	63–77	5.26	
	Hf-177	84–91	18.60	
	Hf-178	87–94	27.28	
	Hf-179	81–86	13.62	
	Hf-180	93–98	35.08	
Helium	He-3	>99.80		Gas
Indium	In-113	59–96	4.29	Metal, oxide
	In-115	>99.9	95.71	
Iridium	Ir-191	95–98	37.3	Metal powder
	Ir-193	>98	62.7	

* Material sold as is

ELEMENT	ISOTOPE	ENRICHMENT (%)	ABUNDANCE (%)	PRODUCT FORM
Iron	Fe-54	95–98	5.845	Chloride, metal, nitrate, oxide, sulfate
	Fe-56	>99.6	91.754	
	Fe-57	72–92	2.119	
	Fe-58	65–84	0.282	
Krypton	Kr-78	8–99	0.355	Gas*
	Kr-80	71–97	2.286	
	Kr-82	71–92	11.593	
	Kr-84	90–92	56.987	
	Kr-86	50–99	17.279	
Lanthanum	La-138	6	0.08881	Chloride, nitrate, oxide
	La-139	>99.9	99.9119	
Lead	Pb-204	63–99	1.4	Acetate, carbonate, chloride, metal, nitrate, oxide, sulfide
	Pb-206	>98	24.1	
	Pb-207	91–92	22.1	
	Pb-208	>97	52.4	
Lithium	Li-6	95–99	7.59	Hydroxidemonohydrate, carbonate, chloride, flouride, metal, sulfate oxide
	Li-7	>99.5	92.41	
Lutetium	Lu-175	>99.8	97.401	Metal, nitrate, oxide
	Lu-176	39–74	2.599	
Magnesium	Mg-24	>99.6	78.99	Carbonate, chloride, metal, oxide, sulfate
	Mg-25	97–98	10.00	
	Mg-26	>98	11.01	
Mercury	Hg-196	13–73	0.15	Chloride, metal, oxide, sulfide
	Hg-198	82–93	9.97	
	Hg-199	85–91	16.87	
	Hg-200	88–96	23.10	
	Hg-201	74–96	13.18	
	Hg-202	>95	29.86	
	Hg-204	83–98	6.87	
Molybdenum	Mo-92	90–98	4.53	Metal, oxide
	Mo-94	82–92	9.15	
	Mo-95	89–96	15.84	
	Mo-96	91–96	16.67	
	Mo-97	83–94	9.60	
	Mo-98	95–98	24.39	
	Mo-100	91–99	9.82	
Neodymium	Nd-142	84–98	27.152	Chloride, metal, nitrate, oxide
	Nd-143	90–91	12.174	
	Nd-144	97	23.798	
	Nd-145	73–91	8.293	
	Nd-146	63–97	17.189	
	Nd-148	87–95	5.756	
	Nd-150	68–97	5.638	
Neon	Ne-22	71	9.25	Gas*

* Material sold as is

ELEMENT	ISOTOPE	ENRICHMENT (%)	ABUNDANCE (%)	PRODUCT FORM
Nickel	Ni-58	>99.5	68.077	Chloride, metal, oxide
	Ni-60	>98	26.223	
	Ni-61	84–99	1.1399	
	Ni-62	86–99	3.6346	
	Ni-64	90–99	0.9255	
Nitrogen	N-15	67-69	0.37	Ammonium sulfate
Osmium	Os-184	5	0.02	Dioxide, metal powder
	Os-186	67–79	1.59	
	Os-187	34–73	1.96	
	Os-188	86–94	13.24	
	Os-189	81–95	16.15	
	Os-190	95–96	26.26	
	Os-192	>98	40.78	
Oxygen	O-16	>99.9	99.757	Water*
Palladium	Pd-102	73–78	1.02	Chloride, metal, oxide
	Pd-104	86–95	11.14	
	Pd-105	90–97	22.33	
	Pd-106	96–98	27.33	
	Pd-108	96–98	26.46	
	Pd-110	97–98	11.72	
Platinum	Pt-190	1–4	0.012	Metal
	Pt-192	41–56	0.782	
	Pt-194	91	32.86	
	Pt-195	93–97	33.78	
	Pt-196	94	25.21	
	Pt-198	91	7.36	
Potassium	K-39	>99.9	93.2581	Carbonate, chloride, nitrate
	K-40	2–3	0.0117	
	K-41	>98	6.7302	
Rhenium	Re-185	96	37.40	Metal
	Re-187	>96	62.60	
Rubidium	Rb-85	>99.4	72.17	Carbonate, chloride, iodide, nitrate
	Rb-87	>97	27.83	
Ruthenium	Ru-96	93-99	5.54	Metal powder, oxide
	Ru-98	82–89	1.87	
	Ru-99	96–97	12.76	
	Ru-100	95–97	12.60	
	Ru-101	96–97	17.06	
	Ru-102	>98	31.55	
	Ru-104	>98	18.62	

* Material sold as is

ELEMENT	ISOTOPE	ENRICHMENT (%)	ABUNDANCE (%)	PRODUCT FORM
Samarium	Sm-144	85	3.07	Chloride, metal, nitrate, oxide
	Sm-147	98	14.99	
	Sm-148	90–96	11.24	
	Sm-149	91–97	13.82	
	Sm-150	87–99	7.38	
	Sm-152	>97	26.75	
	Sm-154	98	22.75	
Selenium	Se-74	55–77	0.89	Metal, oxide
	Se-76	93–97	9.37	
	Se-77	91–94	7.63	
	Se-78	97–98	23.77	
	Se-80	>99.3	11.24	
	Se-82	87–97	8.73	
Silicon	Si-28	>97	92.223	Metal, oxide, silicic acid, silane
	Si-29	88–95	4.685	
	Si-30	83–96	3.092	
Silver	Ag-107	>98	51.839	Acetate, chloride, metal, nitrate
	Ag-109	>97	48.161	
Strontium	Sr-84	80–99	0.56	Carbonate, chloride, fluoride, metal, nitrate, oxide
	Sr-86	95–97	9.86	
	Sr-87	84–94	7.00	
	Sr-88	>99.8	82.58	
Sulfur	S-32	>98	31.55	Cadmium sulfide, calcium sulfate, calcium sulfide, elemental, iron sulfide, lead sulfide, magnesium sulfate, potassium sulfate, sodium sulfate, zinc sulfide
	S-33	17–88	0.75	
	S-34	85–94	4.25	Cadmium sulfide, calcium sulfate, calcium sulfide, elemental, iron sulfide, lead sulfide, magnesium sulfate, potassium sulfate, sodium sulfate, zinc sulfide
	S-34 non EM	9–97	4.25	Carbon disulfide*
	S-36	1–3	0.01	Cadmium sulfide, calcium sulfate, calcium sulfide, elemental, iron sulfide, lead sulfide, magnesium sulfate, potassium sulfate, sodium sulfate, zinc sulfide
	S-36 non EM	5–30	0.01	Carbon disulfide*
Tantalum	Ta-180	5	0.01201	Oxide
Tellurium	Te-120	41–56	0.09	Metal, oxide
	Te-122	94–97	2.55	
	Te-123	77–90	0.89	
	Te-124	93–98	4.74	
	Te-125	93–95	7.07	
	Te-126	98	18.84	
	Te-128	>98	31.74	
	Te-130	>98	34.08	
Thallium	Tl-203	92–97	29.524	Nitrate, oxide
	Tl-205	>99	70.48	

* Material sold as is

ELEMENT	ISOTOPE	ENRICHMENT (%)	ABUNDANCE (%)	PRODUCT FORM
Tin	Sn-112	67–68	0.97	Chloride, metal, oxide
	Sn-114	51–69	0.66	
	Sn-115	17–40	0.34	
	Sn-116	95–96	11.24	
	Sn-117	84–92	7.68	
	Sn-118	96–97	24.22	
	Sn-119	84–89	8.59	
	Sn-120	97–98	32.58	
	Sn-122	90–92	4.63	
	Sn-124	92–96	5.79	
Titanium	Ti-46	73–96	8.25	Metal powder or solid, crystal bar, oxide
	Ti-47	80–94	7.44	
	Ti-48	>99	73.72	
	Ti-49	66–96	5.41	
	Ti-50	67–83	5.18	
Tungsten	W-180	6–11	0.12	Ammonium tungstate, metal powder, oxide
	W-182	92–94	26.50	
	W-183	73–87	14.31	
	W-184	92–95	30.64	
	W-186	>96	28.43	
Vanadium	V-50	36–44	0.25	Oxide
Xenon	Xe-124	5–99	0.0952	Gas*
	Xe-126	99	0.089	
	Xe-129	80–88	26.4006	
	Xe-131	81–87	14.09	
	Xe-134	51	10.4357	
	Xe-136	89–94	8.8573	
Ytterbium	Yb-168	13–33	0.123	Chloride, metal, nitrate, oxide
	Yb-170	64–78	2.982	
	Yb-171	87–95	14.09	
	Yb-172	92–97	21.68	
	Yb-173	89–94	16.103	
	Yb-174	96–98	32.026	
	Yb-176	96-99.7	12.996	
Zinc	Zn-64	>97	49.17	Acetate, chloride, metal, oxide, sulfate, beads
	Zn-66	>98	27.73	
	Zn-67	88–94	4.04	
	Zn-68	>99	18.45	
	Zn-70	65–99	0.61	
Zirconium	Zr-90	>96	51.45	Metal, oxide
	Zr-91	88–94	11.22	
	Zr-92	94–98	17.15	
	Zr-94	96–98	17.38	
	Zr-96	58–95	2.80	

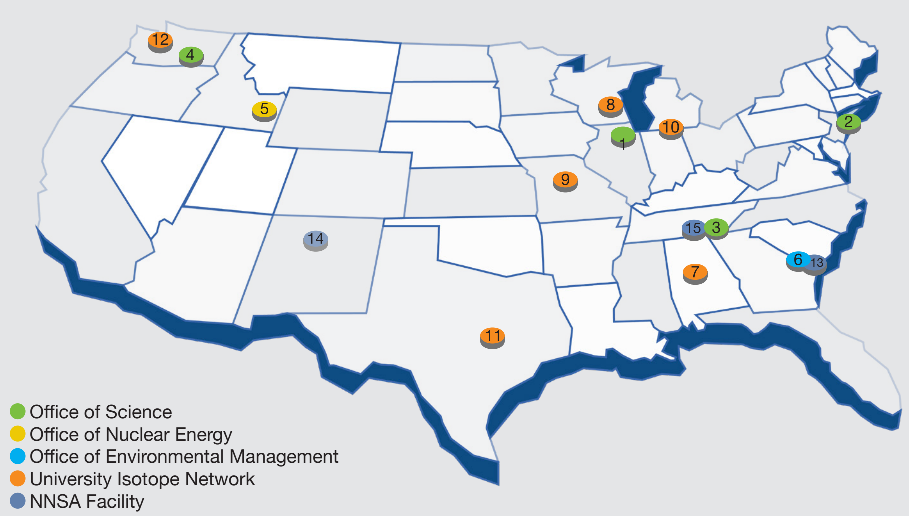
* Material sold as is

Aligning the Nation's Key Isotope Producers

The DOE IRP has stewardship over the Brookhaven Linear Isotope Producer (BLIP) Facility at Brookhaven National Laboratory (BNL); the Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL); and hot cell facilities for processing isotopes at Oak Ridge National Laboratory (ORNL), BNL, and LANL. Additionally, it supports the production of isotopes at several of other facilities, including the High Flux Isotope Reactor (HFIR) at ORNL; the Enriched Stable Isotope Prototype Plant (ESIPP) at ORNL; and the Advanced Test Reactor (ATR) at Idaho National Laboratory (INL); the Plutonium Facility at LANL; the Facility for Rare Isotope Beams at Michigan State University; the Tritium Facility at Savannah River National Laboratory (SRNL); the Low-Energy Accelerator Facility at Argonne National Laboratory (Argonne); and Pacific Northwest National Laboratory (PNNL).

In addition, the DOE IRP's University Isotope Network (UIN) comprises six schools: the University of Washington, the University of Missouri Research Reactor Center, the University of Wisconsin, University of Alabama-Birmingham, Texas A&M University and Michigan State University.

1. Argonne National Laboratory
2. Brookhaven National Laboratory
3. Oak Ridge National Laboratory
4. Pacific Northwest National Laboratory
5. Idaho National Laboratory
6. Savannah River National Laboratory
7. University of Alabama at Birmingham
8. University of Wisconsin
9. University of Missouri (MURR)
10. Michigan State University
11. Texas A&M University
12. University of Washington
13. Savannah River Site
14. Los Alamos National Laboratory
15. Y-12



Argonne National Laboratory
Low-Energy Accelerator Facility (LEAF)

The **Low-Energy Accelerator Facility** (LEAF) combines an electron linear accelerator (Linac) with a Van de Graaff (VDG) electron accelerator. The LEAF has undergone significant improvements since its construction in 1969, including an increase in beam energy to 50 MeV and power up to 25 kW (average exceeding 20 kW in energies relevant to radioisotope production).

The LEAF's Linac provides continuous or pulsed beams, and multiple target station locations facilitate remote operations and post-run target transfers. The low energy (3 MeV) VDG electron accelerator complements the Linac by delivering high levels of electron/photon dose rates (in pulsed or continuous mode) to critical components, testing for radiation hardness and stability while avoiding activation and handling hazards of the irradiated targets.

General Applications

Radioisotope separation and purification method development, radioisotope production, targetry, radiation testing and material response to received dose, and material activation.

Supporting Facilities

Hot cells, radiochemical laboratories, and an analytical chemistry laboratory are housed at the LEAF to support separations, processing, and purity analysis activities.

Routinely Produced Radioisotopes

- Scandium-47 (under development)

Brookhaven Linac Isotope Producer (BLIP)

Built in 1972, the **Brookhaven Linac Isotope Producer (BLIP)** uses high-energy protons for radioisotope production by diverting excess beam off of the 200 MeV BNL proton linear accelerator (Linac).

Proton Energies: Energies of 118, 140, 162, 184, or 202 MeV are diverted down a 30 m long beamline.

Target Channels: Six mechanically independent target channels are available. Most recently, target channels have been grouped into two boxes which hold up to four targets each.

Operating Cycles

The production of isotopes in the BLIP is dependent upon the operating cycle of the Linac. The schedule and duration of Linac operation is determined by the plans and funding of the nuclear physics experiments.

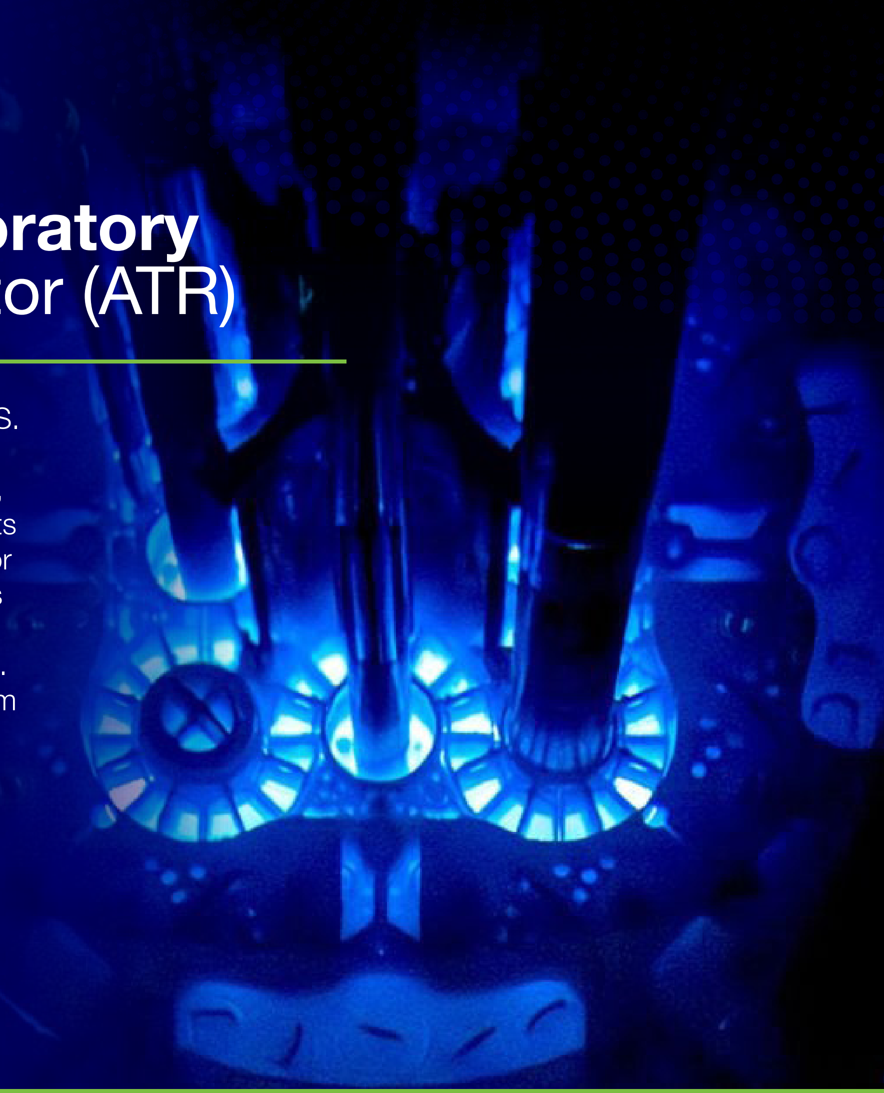
Supporting Facilities

Eight radiochemistry development labs and nine lead and steel hot cells are housed at the BLIP. In addition, BNL is equipped with an instrumentation lab for radionuclide assay by high-purity germanium detection, gamma ray spectroscopy, NaI spectroscopy, liquid scintillation, and elemental assay by inductively coupled plasma optical emission spectroscopy, inductively coupled plasma mass spectrometry, and labeling determinations with high-performance liquid chromatography (HPLC). Isotopes may be produced under Current Good Manufacturing Practice (cGMP) conditions when a customer quality agreement is in place.

Routinely Produced Radioisotopes

- Beryllium-7
- Cerium-134
- Selenium-72
- Titanium-44
- Zinc-65
- Yttrium-86

Idaho National Laboratory Advanced Test Reactor (ATR)



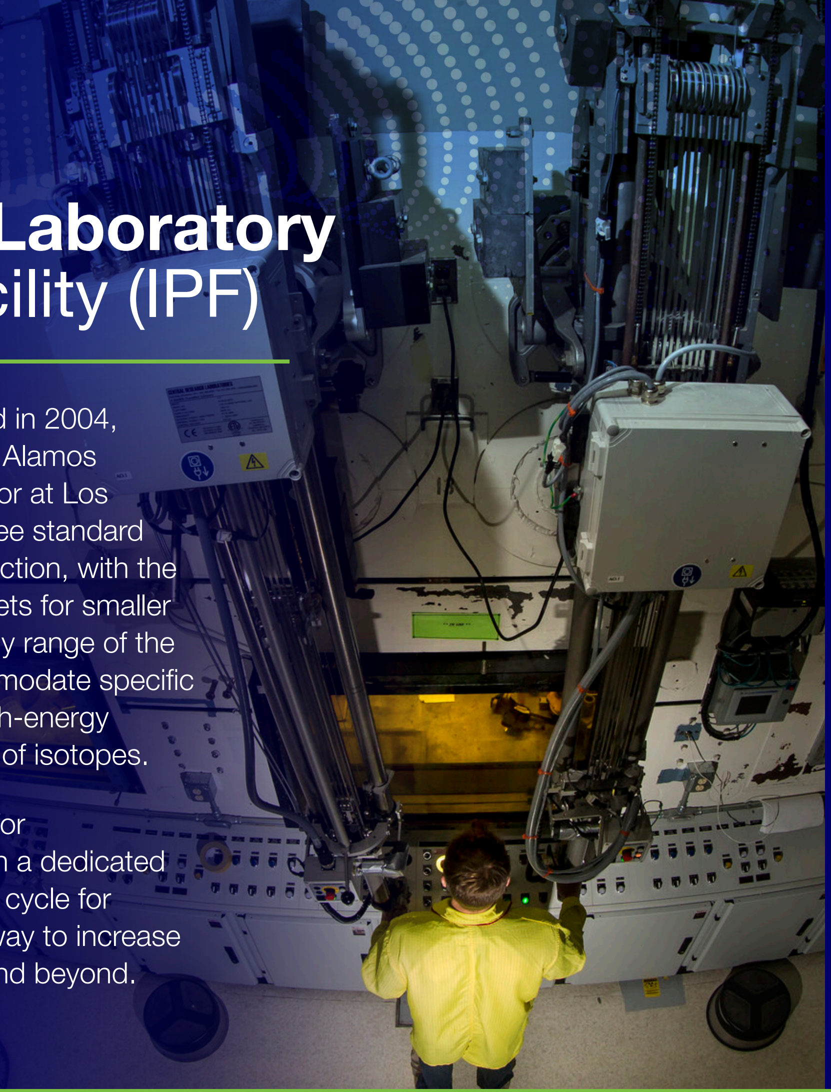
The **Advanced Test Reactor (ATR)** is the only U.S. research reactor that offers large-volume, high-flux neutron irradiation in a prototype environment, making it a prime candidate for studying the effects of intense neutron and gamma radiation on reactor materials and fuels. The 250 MW reactor operates at low pressure and low temperature with a high neutron flux up to ~10^{15} neutrons/cm^2 per second. The reactor is cooled by light water with a beryllium reflector for high neutron efficiency.

Irradiation Positions

The ATR can accommodate an extensive range of irradiation testing. It is equipped with a unique serpentine core that allows the reactor's corner lobes to be operated at different power levels, making it possible to conduct multiple simultaneous experiments under different testing conditions. Other key characteristics include large test volumes, up to 48 in. long and 5 in. in diameter; 77 testing positions; fast/thermal flux ratios ranging from 0.1 to 1.0; constant axial power profile; power tilt capability for experiments in the same operating cycle; frequent experiment changes; and a seismic shutdown system that can automatically shut down the plant if certain levels of seismic activity are detected.

Routinely Produced Radioisotopes

- Cobalt-60



Los Alamos National Laboratory
Isotope Production Facility (IPF)

The Isotope Production Facility (IPF), commissioned in 2004, is a 100 MeV proton beam line extracted from the Los Alamos Neutron Science Center (LANSCE) 800 MeV accelerator at Los Alamos National Laboratory. The target station has three standard irradiation positions used for large-scale isotope production, with the option to operate at lower currents and/or thinner targets for smaller productions or nuclear data measurements. The energy range of the irradiation positions can also be customized to accommodate specific experiments. Small targets may be activated in the high-energy secondary neutron flux to produce research quantities of isotopes.

IPF operates routinely at beam currents up to 275 μA for approximately 3,500 hours year but can be operated in a dedicated mode for additional operation hours. The standard run cycle for LANSCE is from June to December. Efforts are underway to increase the maximum current for target irradiation to 450 μA and beyond.

Irradiation Positions

High-enery slot:
90–70 MeV (p,xn) and (p,xnyp) reactions

Medium-energy slot:
65–45 MeV (p,xn) and (p,αxn) reactions

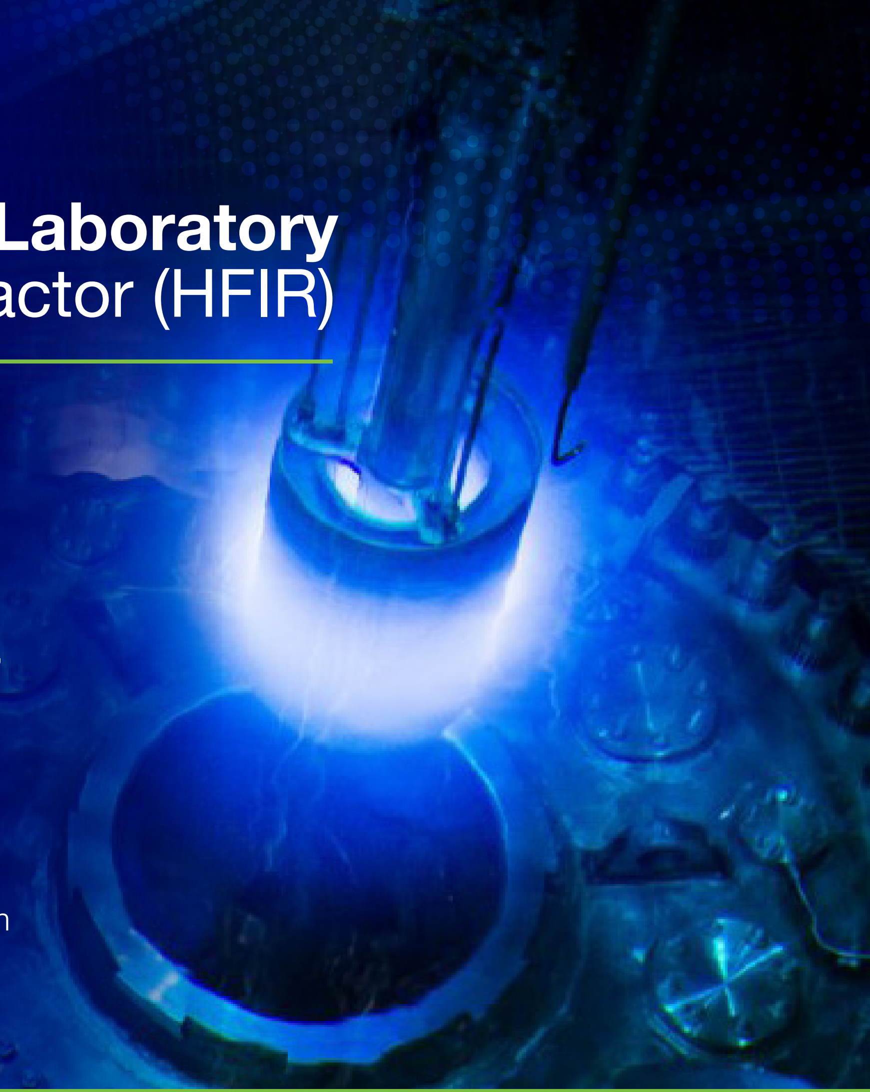
Low-energy slot:
30–0 MeV (p,xn) and (p,αxn) reactions

Hot Cell and Processing Facilities

The LANL Hot Cell Facility at TA-48 contains 13 hot cells with shielding sufficient for handling 1 kCi of cobalt-60, is equipped for performing routine separations via standard techniques including chromatography and liquid-liquid extraction. Laboratories are equipped with robust counting capabilities and analytical equipment for qualifying final products. Isotopes may be produced under cGMP conditions when a customer quality agreement is in place.

Routinely Produced Radioisotopes

- Aluminum-26
- Arsenic-73
- Bismuth-207
- Cadmium-109
- Cerium-134
- Cerium-139
- Gadolinium-148
- Germanium-68
- Silicon-32
- Sodium-22
- Titanium-44
- Yttrium-88
- Zirconium-88



Oak Ridge National Laboratory
High Flux Isotope Reactor (HFIR)

The High Flux Isotope Reactor (HFIR) offers the highest flux (up to 2.6 × 10^{15} neutrons/cm^2 per second at 85 MW) and is one of the most versatile irradiation facilities in the world. It was constructed to meet production needs of heavy element isotopes, but its mission has since expanded to include materials irradiation, neutron activation, and neutron scattering. More than 500 researchers conduct neutron scattering experiments each year at HFIR.

The reactor is beryllium-reflected, light-water-cooled, and moderated, and uses highly enriched uranium-235 as fuel. With its beryllium reflector last replaced in 2002, operation is expected through at least 2030.

Irradiation Positions

Hydraulic Tube (HT) Facility
Nine HT high-flux irradiation positions in the core region permit insertion/removal of targets at any time during reactor operation. This facility is ideally suited for short-term irradiations.

High-Volume/High-Flux Large Target Positions
The core region also has unparalleled space for very large targets.

Peripheral Target Positions
Located on edge of flux trap and permit thermal flux values of 1–1.7 × 10^{15} neutrons/cm^2 per second at 85 MW and 6 positions available for full-cycle irradiations. Accessible only during refueling and used for long-term and multicycle irradiations.

High-Volume Irradiation Positions
These positions are located in the beryllium reflector region, control rod access plugs holes, vertical experiment facility positions, and others.

Routinely Produced Radioisotopes

- Actinium-225
- Actinium-227
- Barium-133
- Californium-252
- Nickel-63
- Radium-223
- Radium-224/Lead-212
- Radium-226
- Selenium-75
- Strontium-89
- Thorium-227
- Thorium-228
- Tungsten-188

National Isotope Development Center
Managed by U.S. DOE Office of Isotope R&D and Production

U.S. DEPARTMENT of ENERGY | Office of Science
Office of Isotope R&D and Production

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