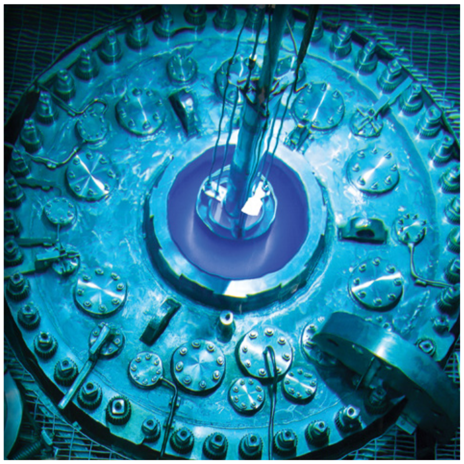


PRODUCT CATALOG

Isotope Program

U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY | Office of Science

Providing the Nation with Critical Isotopes

The U.S. Department of Energy Isotope Program (DOE IP), managed by the Office of Nuclear Physics, 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 or development purposes, medical diagnoses and therapy, industrial, homeland security, agricultural, and other useful applications in the national interest.

The program is centrally managed from DOE Headquarters in Germantown, Maryland. Currently, the DOE IP is maintaining 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 program 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 IP has established the National Isotope Development Center (NIDC) as an organization that interfaces with the user community and provides corporate services to the DOE IP.

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

Oak Ridge National Laboratory
P.O. Box 2008, MS6158
Oak Ridge, Tennessee 37831-6158

Phone: 865.574.6984
Fax: 865.574.6986
Email: contact@isotopes.gov
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 non-consumptive use.

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

To order, contact the 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 DOE 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 prices stated therein will apply for the term of the order. Price estimates can be obtained from the NIDC. Firm quotations are developed during the ordering process.

PRODUCT HIGHLIGHT

Thorium-228, Radium-224, Lead-212, Bismuth-212

Product: Radium-224 Generator for Lead-212 and Bismuth-212, derived from Thorium-228 Decay

Intended Use: Radium-224 (Ra-224) has been used for years as a generator of lead-212 (Pb-212) and bismuth-212 (Bi-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, due to 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.

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: Separated by ion exchange

DISTRIBUTION

Shipment: Generator is housed in a 1-inch lead pig with inlet/outlet holes

Availability: Monthly up to 16 mCi; 10–12 week advance order depending on schedule

Unit of Sale: Millicuries

To request a quote for
Ra-224/Pb-212/Bi-212 Generator,

please visit www.isotopes.gov

RADIUM

Radioactive Isotopes

Isotope	Half-life/Daughter	Chemical Form	Radionuclidic Purity
Actinium-225 (Th-229 Decay Product)	9.920 days to francium-221	Nitrate solid or solution	>98% Ac-225; <2% Ra-225
Actinium-225 (Accelerator-Produced)	9.920 days to francium-221	Nitrate solid or solution	>98% Ac-225; ~0.12% Ac-227 at EOB
Actinium-227	21.772 years to thorium-227	Nitrate solid	>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 NaOH	Greater than 99.9% At-211 (no impurities detectable)
Barium-133	10.551 years to cerium-133	Nitrate solid	>99.9%
Berkelium-249	330 days to californium-249	Nitrate or chlorine 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 N HNO_3	>99%
Cadmium-109	461.9 days to silver-109	Cadmium (II) in 0.1 N HCl	>99.9% (excluding Cd-113m)
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 %
Cobalt-60	1,925.28 days to nickel-60	Nickel-plated pellets (1 mm × 1 mm)	>99%
Copper-67	61.83 hours to zinc-67	Copper (II) in 0.05–2.5 N HCl	>99%
Curium-244	18.11 years to plutonium-240	Nitrate solid	Variable; analysis provided
Curium-248	3.48×10^5 years to plutonium-244	Nitrate or chloride solid	>97%

Isotope	Half-life/Daughter	Chemical Form	Radionuclidic Purity
Dysprosium-166	81.6 hours to holmium-166	Dysprosium chloride in 0.1 N HCl	>99%
Gadolinium-148	74.6 years to samarium-144	Gadolinium (III) in 0.1 N HCl	>95%
Germanium-68	270.95 days to gallium-68	Germanium (IV) in <1 N HCl	>99%
Holmium-166m	1.20×10^3 years to erbium-166	Oxide powder	>98%
Iridium-192	73.829 days to platinum-192	Solid metal	>99%
Iron-52	8.275 hours to manganese-52m	Iron (III) in 0.05–0.5 N HCl	Fe-55 1% and Fe-59 ~0.33%
Iron-55	2.744 years to manganese-55	Chloride solution (0.5 N HCl)	Determined on each lot
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%)
Mercury-194	444 years to gold-194	2M HN03	>99%
Neptunium-237	2.144×10^6 years to protactinium-233	Oxide powder	>99.99%
Neptunium-237 Fission Monitors	2.144×10^6 years to protactinium-233	Ceramic oxide wire encapsulated in high purity vanadium	<40 ppm fissionable atoms
Nickel-63	101.2 years to copper-63	Chloride solution (HCl) or dried chloride solid	>99%
Plutonium-238	87.7 years to uranium-234	Oxide powder	80–97%
Plutonium-239	2.411×10^4 years to uranium-235	Oxide powder or nitrate solid	>99%
Plutonium-240	6,561 years to uranium-236	Oxide powder or nitrate solid	>99%
Plutonium-241	14.329 years to americium-241	Nitrate solid	80–93%
Plutonium-242	3.73×10^5 years to uranium-238	Oxide powder or nitrate solid	>99%
Polonium-209	102 years to lead-205	5 N nitric acid solution	>99%

ISOTOPE	HALF-LIFE/DAUGHTER	CHEMICAL FORM	RADIONUCLIDIC PURITY
Radium-223	11.43 days to radon-219	Nitrate solid	>99.9%, not including decay products
Radium-224	3.66 days to radon-220, 55.6 seconds to polonium-216, 0.145 seconds to lead-212, 10.64 hours to bismuth-212	Radium in 1M HCl	>99.9% Ra-224; <0.1% Th-228
Radium-224/ Lead-212 Generator	3.66 days to radon-220, 55.6 seconds to polonium-216, 0.145 seconds to lead-212, 10.64 hours to bismuth-212	Ra-224 absorbed on AG-MP50 resin	>99.9% Ra-224; <0.1% Th-228
Radium-225	14.9 days to actinium-225	Nitrate solid	>99%
Rhenium-186	3.7183 days to osmium-186	Sodium perrhenate solution or solid	>99%
Rubidium-83	86.2 days to krypton-83	Rubidium (I) in 0.05-0.5 N HCl	Rb-86/Rb-83: <0.1% Rb-84/Rb-83: <0.5%
Samarium-153	46.50 hours to europium-153	Nitrate or chloride solid	>99%
Selenium-72	8.40 days to arsenic-72	Selenium (IV) in 0.5-5.0 N HCl	>95%
Selenium-75	119.78 days to arsenic-75	Selenium (IV) in 6 N HNO_3	High purity. TBD after inital processing
Silicon-32	153 years to phosphorus-32	Si(IV) in 0.1 N NaOH	>99.9%
Sodium-22	2.6018 years to neon-22	Sodium chloride in H_2O	>99%
Strontium-82	25.34 days to rubidium-82	Strontium (Sr^{2}+) chloride in 0.05–0.5 N HCl	Contact NIDC for additional information
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%
Tellurium-123m	119.2 days to tellurium-123	Elemental	Major impurity is I-131 at ~150 µCi/mg Te
Thorium-227	18.68 days to radium-223	Nitrate solid	>99%
Thorium-228	1.9125 years to radium-224	Nitrate solid	>99%
Thorium-229	7,340 years to radium-225	Nitrate in 0.1 N HNO_3	>99%

ISOTOPE	HALF-LIFE/DAUGHTER	CHEMICAL FORM	RADIONUCLIDIC PURITY
Tin-117m	14.00 days to tin-117	Tin metal in quartz tube or tin (IV) in 0.1 N HCl	>99%
Tungsten-188	69.78 days to rhenium-188	Sodium tungstate solution	>99%
Tungsten-188 Generator	69.78 days to rhenium-188	W-188 as tungstic acid absorbed in alumina in glass column; Re-188 eluted as sodium perrhenate with saline solution	75–85% Re-188/bolus, based on W-188 parent
Uranium-234	2.455×10^5 years to thorium-230	Oxide powder	>95%
Uranium-235	7.038×10^8 years to thorium-231	Oxide powder	93% or >98%
Uranium-238	4.468×10^9 years to thorium-234	Oxide powder	>99.9%
Uranium-238 Fission Monitors	4.468×10^9 years to thorium-234	Ceramic oxide wire encapsulated in high purity vanadium	<40 ppm fissionable atoms
Vanadium-48	15.9735 days to titanium-48	Vanadium (V) in 6 N HCl	>99%, excluding vanadium-49
Vanadium-49	330 days to titanium-49	Vanadium (V) in 6 N HCl	>99%
Xenon-127	36.4 days to iodine-127	Elemental gas	≥99% radioxenons; ≥ 80% xenon-127
Yttrium-86	14.74 hours to strontium-86	Yttrium (III) in 0.05–0.5 N HCl	>98%
Yttrium-88	106.627 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)

Ac-225 Products

Intended Use: Actinium-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 U.S. 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. Bismuth-213, a daughter isotope of actinium-225 and fellow alpha emitter, is also available through the DOE IP via an Ac-225/Bi-213 generator.

To help mitigate anticipated shortages as Ac-225 progresses from clinical trials to developed radiopharmaceutical drugs, the DOE IP now routinely produces Ac-225 via high energy proton accelerators located at Brookhaven and Los Alamos National Laboratories, in addition to regular "milking" of a Th-229 cow housed at Oak Ridge National Laboratory. Furthermore, the program continues to actively pursue and invest in additional production routes to further augment global supply.

Ac-225 (Thorium-229 Decay)

Half Life/Daughter: 9.920 days to francium-221

Chemical Form: solid actinium nitrate

Radionuclidic Purity: >98% Ac-225; <2% Ra-225

PRODUCTION

Production Route: Decay of thorium-229

Processing: Separated by ion exchange

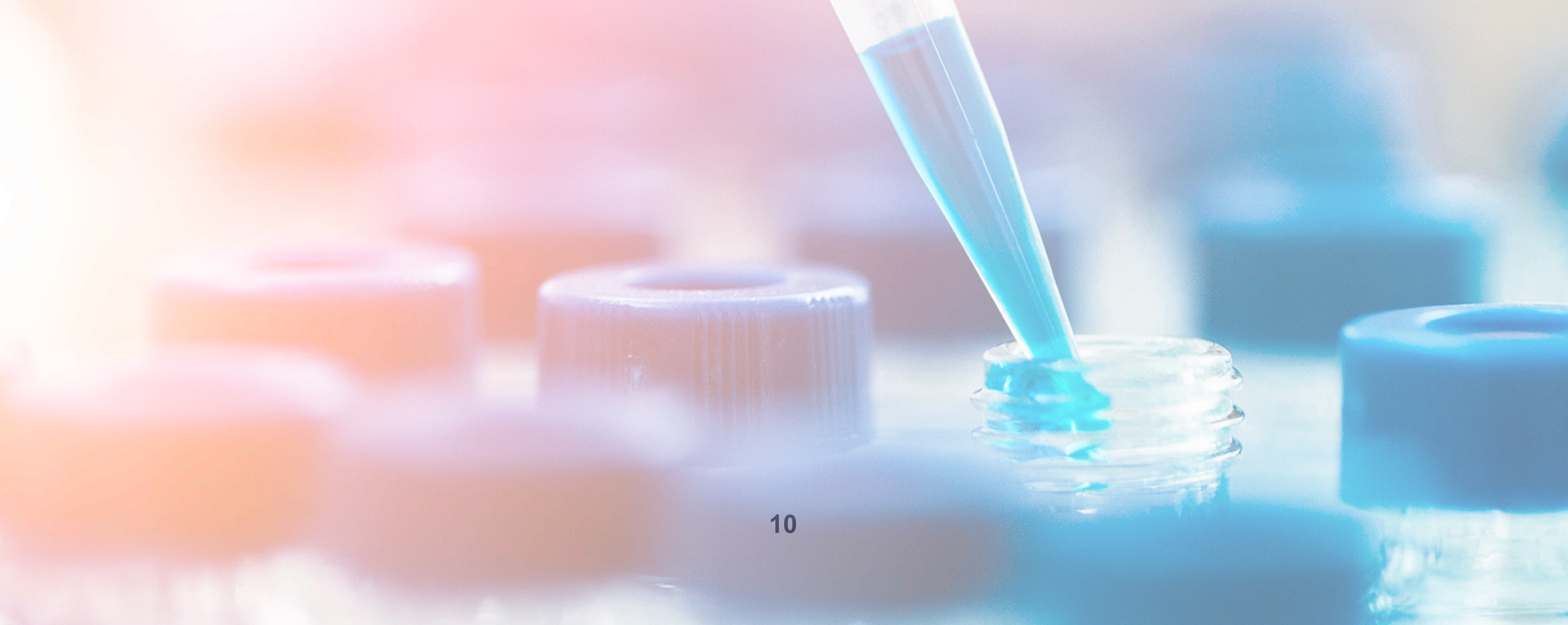
DISTRIBUTION

Shipment: Glass screw cap bottle in nonreturnable container

Availability: Weekly; 4–6 weeks advance order

Special Ordering Information: Can also be supplied as a low-activity Bi-213 generator

Unit of Sale: Millicuries



Ac-225 (Accelerator-Produced)

Half Life/Daughter: 9.920 days to francium-221

Chemical Form: Solid actinium nitrate

Radionuclidic Purity: ≥99% by activity (gamma spectroscopy), not including daughter isotopes or Ac-227; ≤2% Ac-227 at shipment (value extrapolated from earlier runs)

PRODUCTION

Source: Proton irradiation of a natural thorium target at Brookhaven or Los Alamos National Laboratory, chemically processed at Oak Ridge National Laboratory

Processing: Separated by ion exchange and extraction chromatography

DISTRIBUTION

Shipment: Glass screw top V-vial in nonreturnable container

Availability: Every other month

Special Ordering Information: Can also be supplied as a Bi-213 generator

Unit of Sale: Millicuries

To request a quote for Ac-225
(Thorium Decay or Accelerator Produced),

please visit www.isotopes.gov

ACTINIUM

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, nitrate, chloride, metal
	Ba-132	21–28	0.101	
	Ba-134	73	2.417	
	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	Sodium bromide, potassium bromide, silver bromide
		90–91	50.69	Ammonium bromide*
	Br-81	>97	49.31	Sodium bromide, potassium bromide, silver bromide
Cadmium	Cd-106	79–88	1.25	Oxide, chloride, bromide, iodide, sulfide, metal
	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, oxide, nitrate, metal, iodide
	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	Oxide, hydrated nitrate, metal, chloride
	Ce-138	17–26	0.251	
	Ce-140	>99	88.45	
	Ce-142	83–92	11.114	
Chlorine	Cl-35	>99.3	75.76	Sodium chloride, potassium chloride, silver chloride, barium chloride, lead chloride
	Cl-37	95–98	24.24	
Chromium	Cr-50	75–97	4.345	Oxide, metal powder
	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	Oxide, metal powder
	Cu-65	>99.4	30.85	

Element	Isotope	Enrichment (%)	Abundance (%)	Product Form
Dysprosium	Dy-156	20–22	0.056	Oxide, nitrate, metal, chloride
	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	Oxide, nitrate, metal, chloride
	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	Oxide, nitrate, metal, chloride
	Eu-153	98	52.19	
Gadolinium	Gd-152	32–42	80.20	Oxide, nitrate, metal, chloride
	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	Oxide, metal
	Ga-71	>99.2	39.892	
Germanium	Ge-70	84–98	20.57	Oxide, metal
	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	Oxide, metal powder
	Hf-176	63–77	5.26	
	Hf-177	84–91	18.60	
	Hf-178	87–94	27.28	Oxide, metal powder, crystal bar
	Hf-179	81–86	13.62	
	Hf-180	93–98	35.08	
Indium	In-113	59–96	4.29	Oxide, metal
	In-115	>99.9	95.71	
Iridium	Ir-191	95–98	37.3	Metal powder
	Ir-193	>98	62.7	
Iron	Fe-54	95–98	5.845	Oxide, metal, chloride, nitrate, sulfate
	Fe-56	>99.6	91.754	
	Fe-57	72–92	2.119	
	Fe-58	65–84	0.282	

Element	Isotope	Enrichment (%)	Abundance (%)	Product Form
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	Oxide, nitrate, chloride
	La-139	>99.9	99.9119	
Lead	Pb-204	63–99	1.4	Carbonate, chloride, oxide, nitrate, metal pellets, single metal piece, acetate, sulfide
	Pb-206	>98	24.1	
	Pb-207	91–92	22.1	
	Pb-208	>97	52.4	
Lithium	Li-6	95–99	7.59	Metal, hydroxide monohydrate, fluoride, chloride, sulfate, carbonate
	Li-7	>99.5	92.41	
Lutetium	Lu-175	>99.8	97.401	Oxide, nitrate, metal
	Lu-176	39–74	2.599	
Magnesium	Mg-24	>99.6	78.99	Oxide, metal, carbonate, chloride, sulfate
	Mg-25	97–98	10.00	
	Mg-26	>98	11.01	
Mercury	Hg-196	13–73	0.15	Oxide, sulfide, metal, chloride
	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 powder, 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	Oxide, nitrate, metal, chloride
	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*
Nickel	Ni-58	>99.5	68.077	Metal powder, oxide, chloride
	Ni-60	>98	26.223	
	Ni-61	84–99	1.1399	
	Ni-62	86–99	3.6346	
	Ni-64	90–99	0.9255	

ELEMENT	ISOTOPE	ENRICHMENT (%)	ABUNDANCE (%)	PRODUCT FORM
Osmium	Os-184	5	0.02	Metal, dioxide
	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*
				Gas*
Palladium	Pd-102	73–78	1.02	Metal, chloride, 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 powder
	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	Chloride, carbonate, nitrate
	K-40	2–3	0.0117	
	K-41	>98	0.0117	
Rhenium	Re-185	96	37.40	Metal
	Re-187	>96	62.60	
Rubidium	Rb-85	>99.4	72.17	Chloride, carbonate, nitrate, iodide
	Rb-87	>97	27.83	
Ruthenium	Ru-96	~96%	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	
Samarium	Sm-144	85	3.07	Oxide, nitrate, metal, chloride
	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	49.61	
	Se-82	87–97	8.73	

ELEMENT	ISOTOPE	ENRICHMENT (%)	ABUNDANCE (%)	PRODUCT FORM
Silicon	Si-28	>97	92.223	Oxide, metal powder, silicic acid, crystal bar
	Si-29	88–95	4.685	Oxide, metal powder, silicic acid
	Si-30	83–96	3.092	
Silver	Ag-107	>98	51.839	Metal, chloride, nitrate, acetate
	Ag-109	>97	48.161	
Sulfur	S-32	>98	94.99	Elemental, cadmium sulfide, lead sulfide, zinc sulfide, calcium sulfide, iron sulfide, calcium sulfate, magnesium sulfate, potassium sulfate, sodium sulfate
	S-33	17–88	0.75	
	S-34	9	4.25	Sulfur hexafluoride*
		50–92	4.25	Elemental*
		50–97	4.25	Carbon disulfide*
		85–94	4.25	Elemental, cadmium sulfide, lead sulfide, zinc sulfide, calcium sulfide, iron sulfide, calcium sulfate, magnesium sulfate, potassium sulfate, sodium sulfate
	S-36	1–3	0.01	Elemental, cadmium sulfide, lead sulfide, zinc sulfide, calcium sulfide, iron sulfide, calcium sulfate, magnesium sulfate, potassium sulfate, sodium sulfate
		5–30	0.01	Carbon disulfide*
Strontium	Sr-84	80–99	0.56	Carbonate, nitrate, chloride, metal, fluoride, oxide
	Sr-86	95–97	9.86	
	Sr-87	84–91	7.00	
	Sr-88	>99.8	82.58	
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	Oxide, metal, nitrate
	Tl-205	>99	70.48	
Tin	Sn-112	67–68	0.97	Oxide, metal, chloride
	Sn-114	51–69	0.66	
	Sn-115	17–40	0.34	
	Sn-116	95–96	14.54	
	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	Oxide
	Ti-47	80–94	7.44	
	Ti-48	>99	73.72	
	Ti-49	66–96	5.41	
	Ti-50	67–83	5.18	

Element	Isotope	Enrichment (%)	Abundance (%)	Product Form
Tungsten	W-180	6–11	0.12	Oxide, metal powder, ammonium tungstate
	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	21.232	
	Xe-134	51	10.4357	
	Xe-136	62–94	8.8573	
Ytterbium	Yb-168	13–33	0.123	Oxide, nitrate, metal, chloride
	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	96–97	12.996	
Zinc	Zn-64	>97	49.17	Oxide, metal flakes, acetate, chloride, sulfate, beads (depending on quality)
	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	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”

PRODUCT HIGHLIGHT

Astatine-211

Product: Astatine-211 (At-211)

Intended Use: Astatine-211 is of interest for use in targeted alpha therapy. This short-lived alpha-emitting radionuclide ($t_{1/2}$ = 7.214 hours) is well-suited for this purpose, as it offers the potential for extremely localized irradiation of malignant cells when attached to cancer-targeting agents while leaving neighboring cells intact. Currently, clinical trials are underway to study the effectiveness of an At-211-labeled radiopharmaceutical in treating patients with leukemia and lymphoma.

The DOE IP has worked with a team at the University of Washington, a DOE IP university partner, to routinely produce At-211 via the $^{209}Bi(\alpha,2n)^{211}At$ reaction by bombarding a natural bismuth metal target with α-particles at its Medical Cyclotron Facility. As the DOE IP's University Isotope Network continues to expand, At-211 and other short-lived alpha-emitting isotopes will benefit from a more robust and reliable regional production network.

Half Life/Daughter: 7.214 hours to polonium-211 and bismuth-207

Chemical Form: Sodium astatide in 0.05 N sodium hydroxide

Activity: 370–1,850 MBq (10–50 mCi) at shipment

Radionuclidic Purity: >99% At-211 (based on gamma spectroscopy, evaluated quarterly)

Radioisotopic Purity: >99.5% (based on gamma spectroscopy, evaluated quarterly)

Radiochemical Purity: ≥85% (area%) Na[^{211}At] At; other ^{211}At species may be present (e.g. [^{211}At]astatate)

PRODUCTION

Production Route: Alpha irradiation of bismuth metal

Processing: Special order

DISTRIBUTION

Shipment: Screw-cap vial in approved DOT package

Availability: Special order

Unit of Sale: Millicuries

Grade: Non-cGMP grade

To request a quote for At-211,

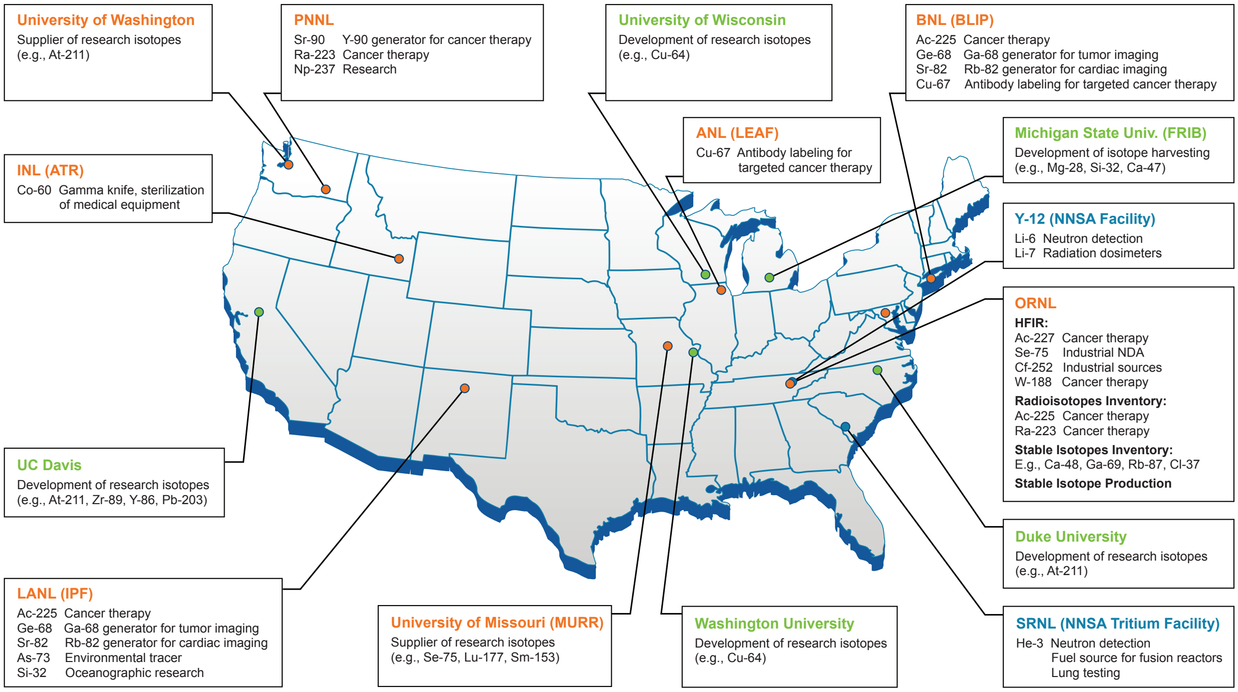
please visit www.isotopes.gov

ASTATINE

Aligning the Nation's Key Isotope Producers

The DOE IP 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, they support the production of isotopes at a number of other facilities, including the High Flux Isotope Reactor (HFIR) at ORNL, the Advanced Test Reactor (ATR) at Idaho National Laboratory (INL), the Tritium Facility at Savannah River National Laboratory (SRNL), the Low-Energy Accelerator Facility (LEAF), at Argonne National Laboratory (ANL), and Pacific Northwest National Laboratory (PNNL).

In addition, the University of Washington and the University of Missouri Research Reactor Center (MURR) recently became the first members of the DOE IP's University Isotope Network.



Argonne's Low-Energy Accelerator Facility (LEAF)

LEAF Description

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

Copper-67, Scandium-47 (under development)

Technical Contact

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The Brookhaven Linac Isotope Producer (BLIP)

BLIP Description

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 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 holding up to four targets each.

Operating Cycles

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 has an instrumentation lab for radionuclide assay by HPGe, gamma ray spectroscopy, NaI spectroscopy, liquid scintillation, and elemental assay by ICP-OES, ICP-MS, and labeling determinations with HPLC.

Examples of Routinely Produced Radioisotopes

Actinium-225
Beryllium-7
Cadmium-109
Copper-67
Magnesium-28
Rubidium-83
Strontium-82
Technetium-95m
Technetium-96
Zinc-65

Currently in Development: Iron-52

Technical Contact

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The INL Advanced Test Reactor (ATR)

Reactor Description

The INL 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} n/cm^2/sec. 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 inches long and 5 inches 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.

Examples of Routinely Produced Radioisotopes

High specific activity Cobalt-60

Technical Contact

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The LANL Isotope Production Facility (IPF)

Accelerator Description

The Isotope Production Facility (IPF) is a 100 MeV proton beam line spurred off of the Los Alamos Neutron Science Center (LANSCE) 800 MeV accelerator at Los Alamos National Laboratory. The target station has three irradiation positions. The facility was commissioned in 2004.

Currently IPF operates for ~3,000 μA/h per year at a maximum current of 450 μA but is available to run in dedicated mode for additional operation hours. Current run cycle for LANSCE is from June to December. The capability is expected to be expanded in the next few years to maximize the current with which targets can be irradiated, and to allow for the irradiation of alpha-emitting targets.

Target sizes are nominally tens of grams.

Anticipated lifetime is 2024.

Irradiation Positions

High energy 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

Cross Section Measurements

Facilities at the LANSCE accelerator also allow for the measurement of proton-induced cross sections at 800 MeV and 200 to 100 MeV using a proton beam with an ~100 nA current to optimize irradiation parameters and improve purity.

Hot Cell and Processing Facilities

The LANL hot cell facility at TA-48 contains 13 hot cells.

Examples of Current Routinely Produced Radioisotopes

Actinium-225, Arsenic-73, Germanium-68, Sodium-22, Strontium-82, Yttrium-88

Technical Contact

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The ORNL High Flux Isotope Reactor (HFIR)

Reactor Description

Oak Ridge National Laboratory's High Flux Isotope Reactor, or HFIR, offers the highest flux (up to 2.6×10^{15} neutrons/cm^2/sec 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

An HT facility with nine HT high-flux irradiation positions in the core region permit insertion/removal of targets any time during reactor operation. Ideally suited for short-term irradiations.

High-Volume/High-Flux Large Target Positions

Core region also has unparalleled space for very large targets.

Peripheral Target Positions

Located on edge of flux trap. Permit thermal flux values of $1–1.7 \times 10^{15}$ neutrons/cm^2/sec at 85 MW–42 positions available for full-cycle irradiations. Accessible only during refueling and used for long-term and multi-cycle irradiations.

High-Volume Irradiation Positions also Available in Beryllium Reflector Region

RB units, control rod access plugs holes, VXF positions, etc.

Examples of Current Routinely Produced Radioisotopes

HT/Core

Actinium-225	Californium-252	Selenium-75
Actinium-227	Lutetium-177	Strontium-89
Barium-133	Nickel-63	Tungsten-188

Technical Contact

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Front Cover: From top: Reactor defueling operations in the High Flux Isotope Reactor pool, with a blue glow showing the Cherenkov radiation (image courtesy of Oak Ridge National Laboratory); Advanced Test Reactor at sunrise (image courtesy of Idaho National Laboratory); Researcher loading targets at the Brookhaven Linac Isotope Producer (image courtesy of Brookhaven National Laboratory)

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