U.S. Department of Energy

The Nation's Needs for Isotopes

Present and Future

John Pantaleo
Program Director
Isotope Program
Office of Nuclear Energy

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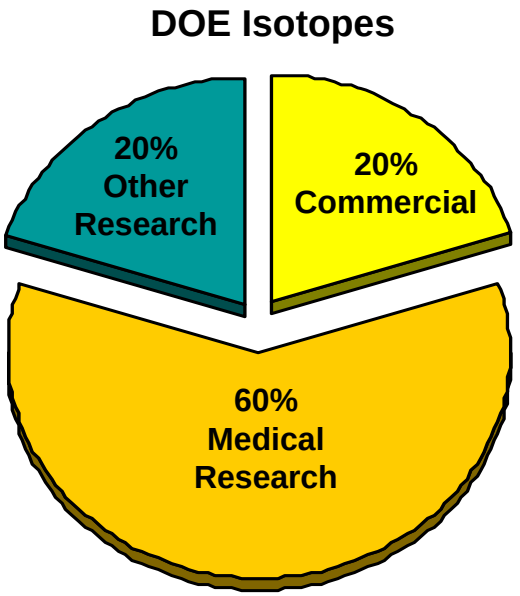
Mission of DOE's Isotope Program

- Produce and sell radioactive and stable isotopes, associated byproducts, surplus materials, and related isotope services.
- Maintain the infrastructure required to supply isotope products and related services.
- Served over 160 customers in FY 2007 and made 484 shipments, most to universities and hospitals



Production Locations

Idaho
Iridium/Ir-192 - Industrial nondestructive examination
Cobalt-60/Co-60 - Sterilization of surgical equipment and blood

Pacific Northwest
Stronium/Sr-90 - cancer therapy

Brookhaven - BLIP:
Copper/Cu-67 - Antibody labeling for cancer therapy and imaging
Germanium/Ge-68 - Calibration sources for PET equipment; Antibody labeling
Strontium/Sr-82 - Cardiac imaging

Oak Ridge - Stable Isotopes Inventory:
Calcium/Ca-42 - Calcium retention studies
-43 - Nutrition
-44 - Bone growth
-45 - Nucleosynthesis
-48 - Nuclear physics
Strontium/Sr-88 - Reactor targets for Sr-89 (used in bone cancer therapy and labeling of monoclonal antibodies)
Thallium/Tl-203 - Targets for Tl-201 production in accelerators (Ti-201 used in cardiac imaging)

High Flux Isotope Reactor/Inventory:
Selenium-75 - Industrial nondestructive examination
Nickel-63 - Explosives detection
Californium-252 - Industrial source
Tungsten/Tn-188 - Cancer therapy
Actinium/Ac-225 - Cancer therapy

UC Davis/McClellan:
Iodine/I-125 - Prostate cancer therapy

Trace Life Sciences:
Copper/Cu-67 - Cancer therapy

Los Alamos - LANSCE:
Aluminum/Al-26 - Research: Alzheimers disease Acid rain
Copper/Cu-67 - Antibody labeling for cancer therapy and imaging
Germanium/Ge-68 - Calibration sources for PET equipment; Antibody labeling
Strontium/Sr-82 - Cardiac imaging

Missouri University Research Center:
Lutetium-177 - Treatment of ovarian and colon cancer
Holmium-166 - Treatment of multiple myeloma and rheumatoid arthritis
Phosphorus-32 - SPECT imaging

Savannah River:
Helium-3 - Helium-Lithium and Helium-Neon lasers
- Fuel source for fusion reactors
- Research: Properties of super fluids studies

Brookhaven Linac Isotope Producer (BLIP)

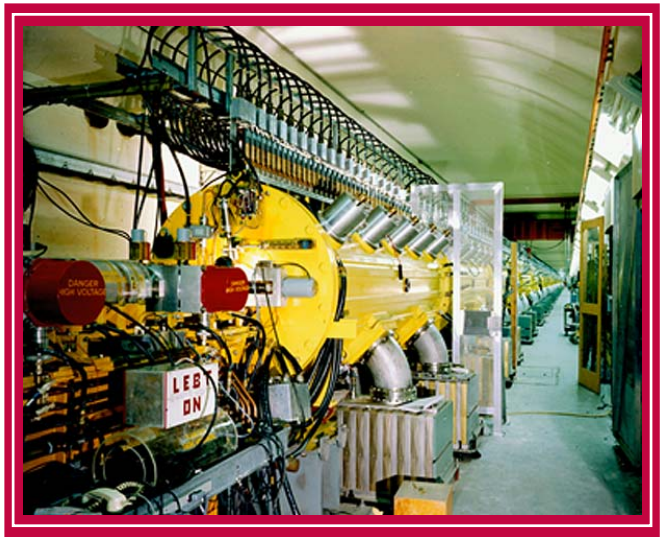
Brookhaven National Laboratory

Major Medical Isotopes and Their Applications

Copper-67	**Antibody labeling for cancer therapy**
Germanium-68	**Calibration sources for Positron Emission Tomography equipment, antibody labeling**
Strontium-82/ Rubidium-82	**Cardiac imaging**

Advantages of BLIP for isotope production

High energy beam with flexible access
(200 MeV proton beam)
Well-equipped hot cell facility
Target insertion and retrieval



Isotope Production Facility (IPF)

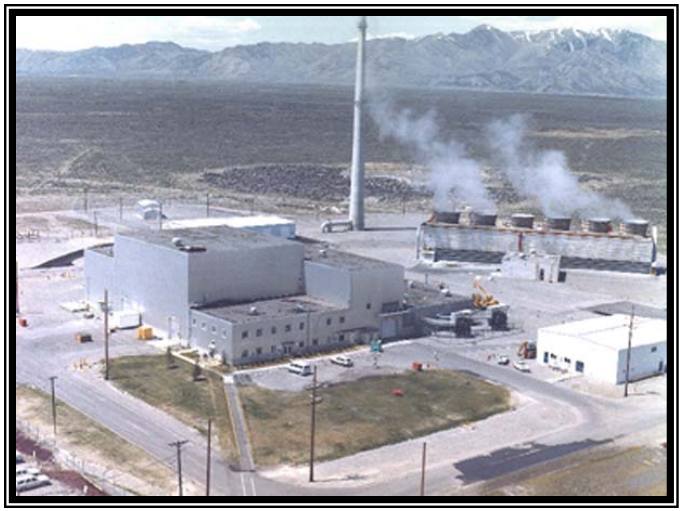
Los Alamos National Laboratory

Medical Isotopes and Their Applications

Germanium-68	**Calibration sources for Positron Emission Tomography equipment, antibody labeling**
Arsenic-73	**Biomedical Tracer for Arsenic Uptake**
Strontium-82/ Rubidium-82	**Cardiac imaging**

Advantages of IPF for isotope production

- High energy beam with flexible access (100 MeV proton beam)
- State-of-the-art facility – target insertion and retrieval
- Well-equipped and staffed Hot Cell Facility
- Available 30-40 weeks per year
- Will enhance short-lived isotope supply

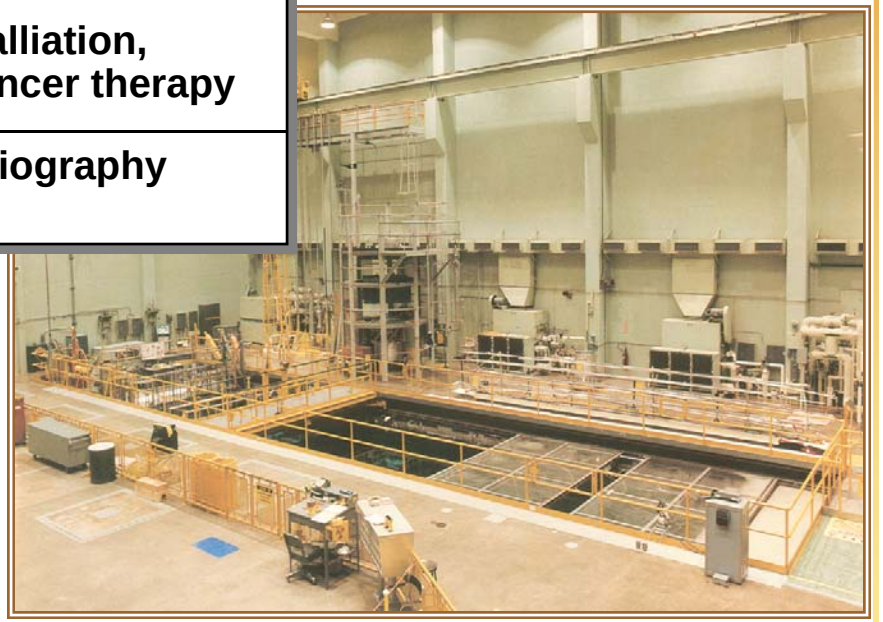


High Flux Isotope Reactor (HFIR)

Oak Ridge National Laboratory

Medical Isotopes and Their Applications

Californium-252	**Cancer therapy**
Nickel-63	**Gas sensing devices**
Tungsten-188/Rhenium-188	**Bone pain palliation, from liver cancer therapy**
Selenium-75	**GAMMA Radiography sources**



Advantages of HFIR for isotope production

- Neutron flux (~2.6 x 10^{15})
- 3 Easy-access hydraulic tubes
- Several hot cell facilities

Future

- Capacity exists to produce many more isotopes

Advanced Test Reactor (ATR)

Idaho National Laboratory

Isotopes Produced and Their Applications

Co-60	**Irradiators for sterilization of medical equipment, etc.**

ATR Advantages

- Moderately high flux neutron flux (~3 x 10^{14})
- Many irradiation positions available
- Hot cell facilities

Future

- In 2008, install hydraulic tube for short-lived isotopes

Lutetium-177 and Cesium-131

Chemical and Materials Laboratories

Oak Ridge National Laboratory

Stable Isotope Services

Chemical physical forms	Metal and ceramic powder
Pyrochemical conversion – oxides to high purity metal	Wire rolling/swaging (hot or cold)
Drop casting	Target fabrication

These laboratories are available to provide unique stable services and dispense over 200 different isotopes in a wide variety of chemical and physical forms.

Materials Laboratory

Separated Isotopes

- In addition to extensive capabilities for the reactor and accelerator production of radioisotopes, a number of isotopes are also available from the decay of long-lived stock materials or as fission products resulting from the processing of nuclear materials.
- Such isotopes include:

Ac-225	Am-241 (currently unavailable)
Cm-248	He-3
Sr-90	U-234

Quality Products and Services

- cGMP Radioisotopes
  - Current Good Manufacturing Practice (cGMP) capabilities have been developed at the national laboratories and are now available for Strontium-82 and Germanium-68 (BNL and LANL) and for Tungsten-188/Rhenium-188 generators (ORNL). These products are provided non-sterile as Bulk Pharmaceutical Products under the cGMP programs.
- ISO 9001
  - Over 200 Stable Isotopes are provided from ORNL as off-the-shelf products in various chemical forms. Custom chemical conversions and physical form preparations are available using metallurgical, ceramic, or vacuum process to provide most stable isotopes in the desired forms for customer applications. Enriched stable isotopes are also often used as the precursor for the production of various radioisotopes. The preparation and distribution of enriched stable isotope products has been ISO 9001 registered through Underwriters Laboratories, Inc., since 1996.

Isotope Development

- Lutetium-177 high specific activity used in peptide radio-labeling emits a low beta energy, which reduces radiation side effects and produces a tissue-penetration range appropriate for smaller tumors, colon, bone, liver, lung cancer.
- Barium-131 is the parent isotope in a Ba-131/Cs-131 generator, an alternative used for the manufacture of seed implants used for prostate cancer therapy.
- Yttrium-86 is a positron emitter which can be used for PET imaging prior to cancer immunotherapy with yttrium-90. Yttrium-86 labeled tumor-seeking monoclonal antibodies (Mab) can be used for evaluating effective tumor uptake and radiation dose.

National Isotope Data Center

- The Department of Energy National Isotope Data Center (formerly the Isotope Business Office) is located at Oak Ridge National Laboratory and coordinates the distribution of all DOE isotope products and services available from DOE facilities.
- Information and quotations for products and services can be obtained by contacting: National Isotope Data Center, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6158, Phone: (865) 574-6984, Fax: (865) 574-6986, Email: isotopes@ornl.gov

Radioactive Isotopes for Research and Applications

Isotope	Half-Life	Examples of Important Applications	Production	
Actinium-225/Ac-225	10 days	Radioisotope used as the starting material for the Ac-225/bismuth-213 generator. Bismuth-213 is used for targeted alpha therapy for treatment of a variety of cancers, including acute myelogenous leukemia	ORNL - extract Th-229 from U-233, and recover Ac-225 daughter. Production also possible from reactors or accelerators.	1
Actinium-227/Ac-227	21.8 years	Parent of Ra-223, which is used for treating skeletal metastases from breast and prostate cancer	ORNL/PNNL - purify Ac-227 from Ac/Be sources	2
Silver-110m/Ag-110m	250 days	Use in combination with other radioisotopes for measuring blast furnace performance.	ORNL - Neutron capture on Ag-109 target	2
Aluminum-26/Al-26	7.2 E+5 years	Medical research on Alzheimer's and environmental research on acid rain	LANL(TRIUMF) - proton spallation on potassium chloride target	2
Americium-241/Am-241	432.7 years	As gamma source, Am-241 is used for well-logging in oil exploration, for analyzing sulfur content in oil, and in home smoke detectors	LANL/PNNL - recovery from operations associated with plutonium production or excess materials dispositioning	2
Barium-133/Ba-133	1.6 days	Calibration source for radiation measurement instrumentation	ORNL - neutron capture on Ba-132 target	2
Beryllium-7/Be-7	53.3 days	Berylliosis studies	BNL - proton irradiation of water	1
Berkelium-249/Bk-249	320 days	Heavy element radiochemistry	ORNL - multiple neutron capture on Cm-244	2

Notes: 1. Limited Quantities Available 2. Currently Not Available 3. Customer Inquiries; Not in Production 4. Being Developed

Radioactive Isotopes for Research and Applications (cont'd)

Isotope	Half-Life	Examples of Important Applications	Production	
Californium-252/Cf-252	2.6 years	Primarily used as a neutron source for reactor start-up, for detection of presence of nitrogen based chemical explosives, and for analysis of sulfur content of petroleum. Technology also being developed for use in brachytherapeutic treatment of cervical cancer	ORNL - multiple neutron capture on Cm-244	1
Cesium-131/Cs-131	9.7 days	Treatment for prostate cancer	INL - daughter product of Ba-131 decay. Ba-131 made by neutron capture on Ba-130	2
Cesium-137/Cs-137	30 years	As a gamma source for cargo imaging systems, as a brachytherapy source for intracavitary cancer treatment, as a calibration source in medical imaging systems and radiation protection instrumentation, as the gamma source for blood irradiators, sterilizers, and in research irradiators	Fission product of U-235, recovered from spent nuclear fuels	2
Cobalt-60/Co-60	5.3 years	As the gamma source for industrial and agricultural irradiators and sterilizers, external beam teletherapy machines, and gamma knife systems for brain cancer treatment	INL - neutron capture on Co-59 target	1
Copper-67/Cu-67	2.6 days	As a therapeutic agent for cell-targeted radioimmunotherapy of cancer	LANL/BNL - proton irradiation of zinc oxide targets. Material currently available from Trace Life Sciences	3
Gallium-67/Ga-67	3.3 days	Medical imaging	LANL - proton irradiation of Zn-68	3
Gadolinium-153/Gd-153	241.6 days	Line sources for PET imaging quality assurance, bone density measurements for osteoporosis detection	INL - Neutron capture on Eu-151 and Gd-152	3

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Radioactive Isotopes for Research and Applications (cont'd)

Isotope	Half-Life	Examples of Important Applications	Production	
Holmium-166/Ho-166	1.12 days	Beta emitting radioisotope studied as a therapeutic agent for rheumatoid arthritis, metastatic liver cancer (microspheres), and hepatoma.	ORNL - Neutron capture on Ho-165 (natural holmium)	2
Iridium-192/Ir-192	73.8 days	Gamma radiography inspection of welds and localized brachytherapy for treating cancer	ORNL - neutron capture on iridium-191 metal	3
Iron-52/Fe-52	8.3 hours	Blood metabolism and blood disease studies	LANL/BNL - proton irradiation of Ni metal	3
Krypton-85/Kr-85	10.7 years	Low pressure beta sources for thickness gauges	Fission product	2
Lutetium-177/Lu-177 High Specfic Activity	6.7 days	As a therapeutic agent for cell-targeted radioimmunotherapy of cancer	ORNL - neutron capture on enriched Lu-176 target	4
Magnesium-28/Mg-28	20.9 hours	Research in biometabolic studies and plant nutrient uptake	BNL - proton irradiation on potassium chloride	3
Mercury-197/Hg-197	2.7 days	Medical research and diagnosis in lung and kidney	LANL - proton irradiation of Au-197	3
Mercury-203/Hg-203	46.6 days	As a brain imaging agent, kidney imaging agent, and as an assay for metallothioneins	ORNL - neutron capture on Hg-202	3
Molybdenum-99/Mo-99	2.7 days	Starting generator material for the Tc-99m generator used in medical imaging	Fission product. Possible reactor production by neutron capture on Mo-98 target	2
Neptunium-237/Np-237	2.1 E+6 years	Neutron dosimetry and criticality safety and nuclear nonproliferation experiments	Fission product	2

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Radioactive Isotopes for Research and Applications (cont'd)

Isotope	Half-Life	Examples of Important Applications	Production	
Nickel-63/Ni-63	100 years	Beta emitter used for as an ionization source in scientific instruments and as a miniature power source for remote instrumentation	ORNL - neutron capture on enriched Ni-62. Less than a five year supply of Ni-62 exists	1
Promethium-147/Pm-147	2.6 years	Beta emitter used as a miniature power source for military electronics	Fission product. Reactor production by neutron capture on Nd-146 target	2
Selenium-75/Se-75	119.8 days	Gamma radiography	ORNL - neutron capture of Se-74	3
Silicon-32/Si-32	104 years	Research on oceanic circulation, atmospheric circulation, groundwater flow, and dating of marine siliceous biota	LANL (TRIUMF) - proton spallation on potassium chloride target	4
Strontium-85/Sr-85	64.8 days	Evaluation of bone metastases and for brain scans	LANL - proton irradiation on natural molybdenum targets	3
Strontium-89/Sr-89	50.5 days	Treatment for pain relief from skeletal metastases of breast and prostate cancer	ORNL - neutron capture of Sr-88	3
Technetium-95m/Tc-95m	61 days	Radioactive tracer in medical research	BNL - proton irradiation on molybdenum or rhodium targets	3
Thorium-228/Th-228	1.9 years	Parent of Bi-212 for monoclonal antibody labeling used in cancer research and therapy	PNNL - extracted from U-232	3
Tin-117m/Sn-117m	13.6 days	Treatment for pain relief in bone cancer	ORNL - neutron capture on enriched Sn-117 target. Production by accelerator being developed	4
Titanium-44/Ti-44	47.3 years	Parent for Sc-44 used in positron emission tomography	LANL - proton irradiation on manganese chloride target	3

Notes: 1. Limited Quantities Available 2. Currently Not Available 3. Customer Inquiries; Not in Production 4. Being Developed

Radioactive Isotopes for Research and Applications (cont'd)

Isotope	Half-Life	Examples of Important Applications	Production	
Uranium-234/U-234	2.5 years	Neutron detection instrumentation	ORNL - recovered as a daughter product from Pu-238	1
Vanadium-48/V-48	15.9 days	Nutritional and environmental research	LANL - proton irradiation on zinc oxide target	3
Yttrium-86/Y-86	14.7 hours	As a photon-emitting surrogate for yttrium-90 in various cancer treatment applications	BNL - proton irradiation on Sr-88 target	4

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DOE Isotopes in Short Supply

Enriched, Stable Non-Radioactive Isotopes used for various applications including as target materials for production of radioisotopes. Although a large inventory of various stable isotopes is available, this List summarizes key examples which have been provided to the academic, research and industrial communities.

Isotope	Examples of Important Applications	Production
Boron/B-10	Biomedical labeling and shielding and neutron detection	LANL - ICON
Boron/B-11	Biomedical labeling and production of borosilicate glasses in rad-hard elctronic applications	LANL - ICON
Gadolinium/Gd-157 (2nd pass)/Gd-154	Nuclear fuel studies	ORNL - calutron enrichment
Helium-3/He-3	Commercially used in Helium-Lithium (HeLi) and Helium-Neon (HeNe) neutron detectors and lasers. Possible fuel source for fusion reactors. Used as a research isotope to study properties of super fluids. Some medical applications	SRO - He-3 processing facility
Lead/Pb-204/Pb-207	Lead poisoning studies	ORNL - calutron enrichment
Mercury-202/Hg-202	Analysis for mercury pollution	ORNL - calutron enrichment
Ruthenium-96/Ru-96	Precursor to Ru-97 which is used as a spinal fluid imaging agent and diagnosis of liver disease	ORNL - calutron enrichment
Samarium-150/Sm-50	Nuclear science studies	ORNL - calutron enrichment
Tantalum-181/Ta-181	Electronic industry research	ORNL - calutron enrichment
Tungsten-180/W-180	Precursor to W-181 used in medical research	ORNL - calutron enrichment
Vanadium-51/V-51	Metal alloying research	ORNL - calutron enrichment