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ISOTOPE MATERIALS AVAILABILITY AND SERVICES FOR TARGET PRODUCTION AT THE OAK RIDGE NATIONAL LABORATORY*
J. E. Ratledge, Oak Ridge National Laboratory.¹ (30 min.)

Materials available through the Isotope Distribution Program include separated stable isotopes, byproduct radioisotopes, and research quantities of source and special nuclear materials. Isotope products are routinely available in the forms listed in the product description section of the Isotopes Products and Services Catalog distributed by the Oak Ridge National Laboratory (ORNL). Different forms can be provided in some cases, usually at additional cost. Routinely available services include cyclotron target irradiations, fabrication of special physical forms, source encapsulation, ion implantation, and special purifications. Materials and services that are not offered as part of the routine distribution program may be made available from commercial sources in the United States.

Specific forms of isotopic research materials include thin films and foils for use as accelerator targets, metal or other compounds in the form of bars or wires, and metal sheets. Methods of fabrication include evaporation, sputtering, rolling, electrolytic deposition, pressing, sintering, and casting. High-purity metal forms of plutonium, americium, and curium are prepared by vacuum reduction/distillation. Both fissionable and nonfissionable neutron dosimeters are prepared for determining the neutron energy spectra, flux, and fluence at various locations within a reactor.

Details on what materials are available and how the materials and related services can be obtained from ORNL are described.

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¹T. L. Dahl, C. L. Ottinger, W. S. Aaron, and H. L. Adair, Co-authors, Operations Division, Oak Ridge National Laboratory.

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J. E. Ratledge, T. L. Dahl, C. L. Ottinger, W. S. Aaron, and H. L. Adair

INTRODUCTION

The Isotope Distribution Program (IDP) at the Oak Ridge National Laboratory (ORNL) is a group of individual activities with separate and diverse DOE sponsors that share the common functions of the production and distribution of isotope products and the performance of isotope-related services. Although no formal charter for the IDP exists, its basic mission is to provide isotope products and associated services to the user community by utilizing government-owned facilities. The basic policies under which the IDP is conducted are as follows:

- o The program will operate at no cost to the government.
- o The materials and services provided through the program will be limited to those that are not produced and reasonably available from domestic private sources.
- o The operation will not adversely influence any of DOE's research and development programs.

The IDP is in its 40th year of operation. Initially, the program provided research quantities of radioactive materials, and through the 1950's, it was the major supplier of radioisotopes for both research and commercial application. Distribution of enriched stable isotopes began in 1954. As private production of radioisotopes increased, the government withdrew from production, except for those products which private producers did not supply.

The IDP currently provides over 300 individual isotope products and associated services to a wide and varied international market. Ultimate applications of the products include health care, research in virtually every scientific discipline, education, industrial use, and national defense. Prices for the products and services are established to recover actual costs, a representative fraction of the government's investment in capital facilities, and an appropriate share of DOE administrative expense. The initial funding is provided through the budgets of various DOE programs, which are credited when the costs of sales transactions are recorded. The revenues realized from sales are returned as an appropriation reimbursement.

Except for some selected stable isotopes distributed through DOE's Mound Laboratory, production and distribution of the isotope products and services are administered by the Oak Ridge Operations Office through the Oak Ridge National Laboratory. Several field offices and DOE sites participate in the program by providing finished products and/or raw materials.

PRODUCTS AND SERVICES

The IDP consists of the production and distribution of four major categories of isotope products and the performance of related services. In all, there are over 300 distinct products and services routinely offered, each with its individual characteristics, uses, markets, etc. Other products and/or services are provided under special circumstances. The major categories of isotopes defined for accounting and management purposes are Radioisotopes, Electromagnetically (EM) Enriched Stable Isotopes, Non-EM Stable Isotopes, and Heavy Elements (also called Other Special Materials).

Radioisotopes include specifically produced radioactive materials and byproduct materials with atomic numbers between 1 and 83. The radioisotopes offered vary widely in half-life, physical/chemical form, and production batch size. The present radioisotope product line includes 35 isotopes which represent the remainder of a line which at one time included approximately 150 different isotopes; the others were withdrawn in favor of private producers. However, 20 new isotopes have been added in recent years. Services associated with radioisotopes include encapsulation, packaging, special chemical processing, fabrication of special physical forms, and irradiation services.

Electromagnetic stable isotopes are separated in the Electromagnetic Isotope Enrichment Facility at ORNL, and each isotope is inventoried in a standard chemical form. The quantities produced, enrichments, and prices vary widely among the 235 different EM stable isotopes sold. In general, buyers prefer the highest enrichment of the respective isotopes. In some cases, however, the requirement is to reduce the concentration of a specific isotope of the element to the lowest possible value. Separation campaigns are usually directed toward the production of one primary isotope of an

element, with other isotopes of that element also being recovered if needed for the stable isotopes inventory. Services related to EM stable isotopes include conversion to noninventory forms, special purifications, and fabrication of specialized physical forms.

Non-EM stable isotopes are no longer produced by the DOE. Sales of the four isotopes in this category (Li-6, Li-7, B-10, and B-11) are made from existing inventories located at ORNL and at other sites. Services related to non-EM stable isotopes are similar to those for EM materials.

The category of isotopes referred to as Heavy Elements (HE) includes radioactive isotopes with atomic numbers greater than 83. Most of the 22 HE isotopes offered are used for research; however, some have industrial uses. Services include special chemical separations, fabrication of targets and other physical forms, and packaging.

Production of radioisotopes and HE products is conducted at various DOE sites. Radioactive products include byproducts of other operations as well as materials produced specifically for the IDP using reactors and accelerators. In some cases, the finished products are shipped directly to the buyer from the production site, and in other cases, the products are shipped to ORNL for distribution.

Other than the fact that they are referred to as "isotopes," the only common characteristic shared by all products offered under this program is that they are not produced and reasonably available from domestic private sources. The stable isotopes, most of the HE products, and a few of the radioisotopes are amenable to production, storage, and distribution on an inventory basis, but many radioactive

isotopes must be produced frequently or on demand because of rapid decay. There are no prepackaged quantities, so each order must be handled individually. Stable isotopes are usually sold in solid form, but radioactive isotope products may be solid, liquid, or gas. Stable isotopes and most HE products are sold by weight (milligrams or grams), while radioisotopes are sold by the quantity of radioactivity (microcuries, millicuries, or curies). The services performed in the IDP are customer-specific. Each service represents an individual transaction with its own specifications, schedules, etc.

The DOE maintains a separate inventory of highly enriched EM stable isotope products, referred to as the Research Materials Collection (RMC). These products, and some radioactive materials in special circumstances, are loaned for various periods of time to the scientific community for nondestructive experiments. The loanee pays for the work necessary to prepare samples and may also pay for the use of the material; the latter depending on the government's interest in the specific experiment. The RMC and other loaned materials are not produced under the IDP, but the transactions are handled by the IDP staff.

SPECIAL RESEARCH MATERIALS

ORNL operates the Isotope Research Materials Laboratory (IRML) to provide special research forms of various separated stable isotopes and radioisotopes that are not available from U.S. private suppliers. These special forms include, but are not limited to, compounds in the form of bars or wires, and metal sheets. Methods of fabrication include evaporation, rolling, electrolytic deposition, pressing, sintering, casting, and others. Special purifications can be done by chemical means or by such techniques as crystal-bar preparation (van Arkel-de Boer Process), zone refining and levitation melting. In some cases, single-crystal preparation is possible either in thin-film or bulk form. High-purity metal forms of plutonium, americium, and curium can be prepared by vacuum reduction/distillation using thorium as the reductant; yields of approximately 75% for Pu and Am and 50 to 60% for Cm are typical.

In addition to research samples, IRML provides neutron dosimetry materials for determining neutron energy spectra, flux, and fluence at various locations within a reactor. Both fissionable and non-fissionable materials are available for monitoring the neutron energy range of interest. Most of the materials are available as ceramic oxide "wires" and are encapsulated in either 1.27-mm or 0.89-mm diam by 3.05-mm- to 8.64-mm-long vanadium capsules. Each capsule is individually identified, and the encapsulated material is accurately characterized.

As a guide to users, lists of targets and neutron dosimeters made by IRML are shown in Table 1. Many preparations are not listed, and the ranges noted can be expanded depending on sample size and shape.

Table 1. Special research material prepared by IRML at ORNL¹.

Legend: a - evaporation
b - rolling
c - electrolytic deposition
d - casting or pressing
e - miscellaneous
f - methyl methacrylate binder²

1. self-supporting
2. metal
3. thin carbon

Element	Thickness Range g/cm ²	Method of Preparation	Backing	Form of Deposit
Aluminum	5 to 12,000	a	2	Element
	>150	a	1	Element
	>1000	d	1	Element
Americium	>1	a	2	Element or oxide
	Variable	d	1	Element or oxide
Antimony	>10	a	2	Element
	500 to 1000	a	1	Element
Arsenic	10 to 200	a	2	Element
Barium	10 to 1000	a	2	Element or salt
	>2000	b	1	Element
	Variable	d	1	Salt
Beryllium	Variable	a	1,2,3	Element
Bismuth	>10	a	2	Element
	500 to 15,000	a	1	Element
Boron	10 to 1000	a	1	Element
	20 to 100	a	2	Element
	1,000 to 25,000	f	1	Element in plastic
	Variable	d	1	Element
Bromine	10 to 1000	a	2	Salt
	>5000	d	1	Salt

¹Target size, price, and delivery schedule are available upon request. Rolled foils are usually 2 x 2 cm².

²Hot pressing or rolling.

Table 1. Continued.

Element	Thickness Range g/cm ²	Method of Preparation	Backing	Form of Deposit
Cadmium	10 to 200	a	2	Element
	>1500	b	1	Element
	Variable	d	1	Element
Calcium	10 to 1000	a	2	Element
	>700	b	1	Element
	Variable	d	1	Element or carbonate
Californium	10 ⁻⁶ to 1.0	e	2,3	Oxychloride
Carbon (normal)	5 to 200	a	1	Element
	>50,000	d	1	Element
Cerium	>10	a	2	Element or oxide
	>1000	b	1	Element
	Variable	d	1	Element or oxide
Cesium	10 to 1000	a	2	Salt
Chlorine	10 to 1000	a	2	Salt
	>5000	d	1	Salt
Chromium	>10	a,c	2	Element
	>300	c	1	Element
Cobalt	>10	a	2	Element
	100 to 1000	a	1	Element
	>1000	b	1	Element
	Variable	d	1	Element
Copper	10 to 1000	c	2	Element
	>200	a	1	Element
	>700	b	1	Element
	Variable	d	1	Element
Curium	>10 ⁻³	a	2,3	Oxide
	Variable	d	1	Oxide
Dysprosium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element or oxide
Erbium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element or oxide

Table 1. Continued.

Element	Thickness Range g/cm ²	Method of Preparation	Backing	Form of Deposit
Europium	>10	a	2	Element
	>2000	b	1	Element
	Variable	d	1	Element or oxide
Fluorine	25 to 500	a	2	Salt
Gadolinium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element or oxide
Gallium	10 to 200	a	3	Oxide
	>10	a	2	Element
	Variable	d	1	Oxide
Germanium	>10	a	2	Element
	>20	a	1	Element
	Variable	d	1	Element or oxide
Gold	>10	a	2	Element
	Variable	a	1	Element
	Variable	d	1	Element
	Variable	b	1	Element
Hafnium	Variable	b	1	Element
	Variable	d	1	Element
¹ H, ² H or ³ H absorbed on Zr, Y, Ti, or Er	≥100	e	2	Hydride, deuteride, or tritide
Indium	>10	a	2	Element
	>5000	b	1	Element
	Variable	d	1	Element
Iridium	10 to 100	a	2	Element
	≥10	e	2	Element
Iron	>10	a	2	Element
	>700	b	1	Element
	Variable	d	1	Element
Lanthanum	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element

Table 1. Continued.

Element	Thickness Range g/cm ²	Method of Preparation	Backing	Form of Deposit
Lead	10 to 1000	a	2	Element
	500 to 8000	a	1	Element
	>6000	b	1	Element
	Variable	d	1	Element
Lithium	10 to 500	a	3	Hydride
	10 to 500	a	2	Element
	1000 to any cast size	b,d	1	Element
Lutetium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element or oxide
Magnesium	>150	b	1	Element
	>20,000	a	1	Element
	Variable	d	1	Element
Manganese	>10	a	2	Element
	300 to 1600	a	1	Element
Mercury	1000 to 4000	c	on Au	Element
	Variable	a	2	Salt
Molybdenum	10 to 1000	a	2	Element
	>500	b	1	Element
	Variable	d	1	Element or oxide
Neodymium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element or oxide
Neptunium	>10	a	2,3	Oxide
	Variable	d	1	Oxide
Nickel	>10	a	2	Element
	>500	b	1	Element
	Variable	d	1	Element
Niobium	>10	a	2	Element
	>700	b	1	Element
Osmium	>10	a	2,3	Element
	Variable	d	1	Element

Table 1. Continued.

Element	Thickness Range μ/cm ²	Method of Preparation	Backing	Form of Deposit
Palladium	>10	a	2	Element
	≥1500	b	1	Element
	Variable	d	1	Element
Platinum	>10	a	2	Element
	≥1500	b	1	Element
	Variable	d	1	Element
Plutonium	>1	a	2	Oxide
	≥5000	b	1	Element (1% Al)
	Variable	d	1	Oxide
Potassium	7500 to any cast size	b,d	1	Element
Praseodymium	10 to 500	a	2	Element
	1000 to any cast size	b,d	1	Element
	Variable	d	1	Element or oxide
Promethium	>10	a	2	Oxide
	≥10	a	2	Element
	Variable	b	1	Element
	Variable	d	1	Element or oxide
Rhenium	≥10	a	2,3	Element
Rubidium	≥10	a	2,3	Element or salt
Ruthenium	≥1000	f	1	Element in plastic
Samarium	>10	a	2	Element
	≥1000	b	1	Element
	Variable	d	1	Element or oxide
Scandium	>10	a	2	Element
	≥1000	b	1	Element
	Variable	d	1	Oxide
Selenium	10 to 5000	a	2	Element
	300 to 5000	a	1	Element
	Variable	d	1	Element

Table 1. Continued.

Element	Thickness Range g/cm ²	Method of Preparation	Backing	Form of Deposit
Silicon	10 to 150	a	2,3	Oxide
	10 to 1,000	a	2	Element
	25 to 150	a	1	Oxide
	50 to 400	a	1	Element
Silver	10 to 1000	a	2	Element
	100 to 5000	a	1	Element
	>1000	b	1	Element
	Variable	d	1	Element
Sodium	7500 to any cast size	b,d	1	Element
Strontium	>2000	b	1	Element
Sulfur	10 to 100	a	2	Element
	>5000	d	1	Element
Tantalum	10 to 1000	a	2	Element
	>1000	b	1	Element
Technetium	>10	c	2	Element
	10 to 1000	a	2	Element
Tellurium	10 to 1000	a	2,3	Element
	Variable	d	1	Element
Terbium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element or oxide
Thallium	>10	a	2	Element
	>8000	b	1	Element
Thorium	>10	a	2,3	Element or oxide
	>4000	b	1	Element
Thulium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Oxide
Tin	10 to 1000	a	2	Element
	100 to 4000	a	1	Element
	>4000	b	1	Element
	Variable	d	1	Element

Table 1. Continued.

Element	Thickness Range g/cm ²	Method of Preparation	Backing	Form of Deposit
Titanium	>10	a	2	Element
	>500	b	1	Element
	Variable	d	1	Element
Tungsten	>2,000	d	1	Element
	Variable	b	2	Element (in Cu matrix)
Uranium	>10	a	2	Oxide
	>5000	b	1	Element
	Variable	d	1	Element or oxide
Vanadium	>10	a	2	Element
	>1000	b	1	Element
	Variable	d	1	Element
Ytterbium	>10	a	2	Element
	>2000	b	1	Element
	Variable	d	1	Oxide
Yttrium	>10	a	2	Element
	>700	b	1	Element
	Variable	d	1	Element or oxide
Zinc	>10	a	2	Element
	>800	b	1	Element
	Variable	d	1	Oxide
Zirconium	10 to 5000	a	2	Element
	>500	b	1	Element
	Variable	d	1	Element

Table 1. Continued.

NEUTRON DOSIMETERS

Pure Materials

<u>Element</u>	<u>Form</u>
^{238}U	UO_2 ceramic oxide wire
^{235}U	UO_2 ceramic oxide wire
^{237}Np	NpO_2 ceramic oxide wire
^{239}Pu	PuO_2 ceramic oxide wire
Sc	Sc_2O_3 ceramic oxide wire
Mn	Mn_3O_4 ceramic oxide wire
^{232}Th	ThO_2 ceramic oxide wire

Dilute Materials

^{238}U	0.5-1.0 wt % ^{238}U -V alloy
^{235}U	0.5-1.0 wt % ^{235}U -V alloy
^{239}Pu	0.5-1.0 wt % Pu as PuO_2 -MgO ceramic oxide wire
^{237}Np	0.5-1.0 wt % Np as NpO_2 -MgO ceramic oxide wire
^{233}U	0.5-1.0 wt % ^{233}U -V alloy
Sc	0.1 wt % Sc as Sc_2O_3 -MgO ceramic oxide wire
Co	0.1 wt % Co as CoO -MgO ceramic oxide wire

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