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AMERICIUM-241: THE MOST USEFUL ISOTOPE OF THE ACTINIDE ELEMENTS

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ABSTRACT

Used extensively in nuclear gauges and in many other areas, this man-made element (Atomic Number 95) was first isolated in weighable amounts during World War II. Americium is now a very useful by-product of the nuclear industry and is produced in kilogram amounts by appropriate recovery, separation and purification processes. A review will be presented of its discovery, nuclear and chemical properties, and uses, with emphasis on its production process and separations chemistry.

Americium Chemical Society Colorado Section Award Address, University of Denver, Denver, Colorado, April 19, 1984.

Picture of
Rocky Flats Plant

What do Rocky Flats (RF) and this smoke detector have in common? I will answer that question by first telling you briefly about RF. As you know, RF is located between Golden and Boulder next to the foothills of the Rocky Mountains. The plant property covers about 10 square miles. It is presently operated by Rockwell International for the U.S. Department of Energy and has ~ 6000 employees.

Front Page of
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Denver Post

RF was built in 1951 by the U.S. Atomic Energy Commission. Dow Chemical first operated the plant for the government until 1975, at which time Rockwell took over. Primarily RF is a metal fabrication, assembly and chemical processing plant, with heavy emphasis on production-related research. The final products are component parts for various nuclear weapons, manufactured from uranium,plutonium, beryllium, stainless steel and other metals.

Schematic of
Smoke Detector

You may be wondering now what smoke detectors have to to with the nuclear industry. Most smoke detectors contain a very small amount of radioactive material to ionize the air in the sensing chamber so it can conduct electricity. This flow of electricity is interrupted and the alarm circuit triggered when tiny smoke particles enter the detector's chamber. Since more than half of all households have at least one such detector, the majority of us unwittingly harbour in our homes a miniscule but completely harmless amount of radioactive material. (However, you might be interested to know that according to a recent article in Family Safety magazine, if you install a smoke detector in your home, you have doubled your chances of surviving a fire.)

Picture of
AmO_2

- Discovery
- Production
- Nuclear Properties
- Uses
- Chemistry
- Separation Methods

Americium Production

$$^{239}Pu\ (n,\gamma)^{240}Pu\ (n,\gamma)^{241}Pu \xrightarrow[14\ yr]{\beta-} {}^{241}Am$$

$$10g\ {}^{239}Pu \xrightarrow{10\ yr} 4g\ {}^{241}Am$$

The radiation source in ionization type smoke detectors is americium-241 - the most useful isotope of the actinide elements. Am-241 was first offered for sale in March 1962 (3 months after I started working at RF) at $1500/g by the USAEC. The first allotment of 200 g, offered through the USAEC Isotope Pool at Oak Ridge National Laboratory, came from Rocky Flats as a by-product of plutonium processing. So if you have an ionization type of smoke detector in your home, a piece of it probably came from RF. RF as a sole source of Am-241 has been supplemented in recent years from nuclear fuel reprocessing facilities at Hanford, Washington, and Savannah River, S.C. and now from the small Los Alamos, N.M. plutonium scrap recovery facility.

Tonight I will briefly review the discovery, nuclear and chemical properties, and uses of americium with emphasis on its process and separations chemistry. The latter is highlighted because RF has played an important role in developing new separation and purification processes, developing a better understanding of americium process chemistry, and of course in supplying purified americium to the DOE Isotope Pool at ORNL.

Americium, atomic number 95, was the fourth transuranium, manmade element to be discovered. Am-241 was identified by Seaborg, James, Morgan and Ghiorso late in 1944 at the Wartime Metallurgical Laboratory, (now Argonne National Laboratory) of the University of Chicago, as a result of successive neutron capture reactions by plutonium isotopes in a nuclear reactor. Glenn Seaborg announced the discovery of the two as yet unnamed new elements 95 & 96 on November 11, 1945 on the national radio program "Quiz Kids".

Picture of
periodic table
of elements

By analogy with the naming of its rare earth homolog europium after Europe, in 1946 element 95 was named americium after the Americas. Actinium and the group of elements at the bottom of the periodic table are referred to as the actinides. Actinium, thorium, protactinium and uranium are naturally occurring actinide elements whereas the remaining elements are man-made. Neptunium was the first synthetic transuranium element to be discovered, followed by plutonium in 1940.

$$^{241}Am_{95} \xrightarrow{\alpha,\gamma} {}^{237}Np_{93}$$

432 yr. half-life

Americium has isotopes with mass numbers between 232 and 247. Only three isotopes have half-lives greater than a few hours: Am-243 (7400 yr), Am-241 (432 yr) and Am-242 (152 yr). Am-241 decays to Np-237, emitting alpha and gamma radiation. Because of its essentially monoenergetic alpha (5.4 and 5.5 MeV) and gamma (0.06 MeV) radiations, ^{241}Am is particularly suited for use as an X-ray excitation source and in a multitude of industrial and scientific gauging, thickness, density and radiographic measurements. The list of applications is largest of any actinide isotope.

Uses of ^{241}Am Alpha Ionizing Radiation

- Gas density
- Ionization detector in gas chromatography
- Smoke detector
- Luminous paint preparation
- Thin film uniformity determination
- Relative humidity of air determination

Some of the fields and industries using the ionizing radiation of Am-241 include atmospheric science, analytical chemistry, building trades, watchmaking, gauging, etc.

Field/Industry Utilizing Gamma Transmission Property of ^{241}Am

- Medicine
- Industrial Gauging
- Soil Science
- Hydrology
- Mineralogy

The gamma emission of ^{241}Am is used in medicine to determine the mineral content of bones, lipid content of soft tissue and body composition. In industrial gauging, it is used to determine thickness of plate glass, metals, wire, etc. In soil science it is used to determine the moisture and density of soil. In hydrology it is used for logging of groundwater and sediment concentration, and to determine ore concentrations in minerology.

Field/Industry Using Alpha Neutron Source

- Petroleum
- Soil Science
- Coke and Concrete
- Analytical Chemistry

Neutron sources of various sizes contain Am-241 to furnish alpha particles for the reaction $^{9}Be\ (\alpha,n)\ ^{12}C$. The neutron sources find uses in oil well logging, determining soil density and moisture content, measuring moisture content of coke and concrete and in activation analysis of many materials as well as in neutron counters.

Some Compounds of Americium

Oxides: AmO_2, Am_2O_3, $AmO_{1.6-1.9}$

Halides: AmF_3, AmF_4, AmO_2F_2, $AmCl_2$, $AmCl_3$, $AmOCl$, $AmBr_3$, $AmBr_2$, AmI_2, AmI_3, $AmOI$

Carbonates: $Am_2(CO_3)_3$, $MAmO_2CO_3$

Sulfates: $Am_2(SO_4)_3$, $MAm(SO_4)_2$

$Am(OH)_3$ was the first americium compound to be isolated. As with other actinide elements, Am forms a variety of oxides with varying Am to O ratios, of which AmO_2 is the most common. Various halides, carbonates and sulfates also have been prepared. In the processing of Am, the oxide (AmO_2), and fluoride (AmF_3) are the most common compounds encountered, in addition to Am(III)oxalate.

Preparation of Am Metal

$$2AmF_3 + 3Ba_{(g)} \xrightarrow{1200^\circ C} 3BaF_2 + 2Am$$

melting point = 1170°C

density = 11.7 g/ml

Am F_3 is used to prepare Am metal, which has a whiter luster and is more silvery than Pu or Np. It is more malleable than U or Np and it tarnishes slowly in dry air at room temperature.

Oxidation States of Americium

Am^{2+}	
Am^{3+}	(light salmon)
Am^{4+}	(pink red)
AmO_2^{+}	(yellow)
AmO_2^{2+}	(light tan)
AmO_2^{3+}	(green)

In aqueous solution, Am^{3+} is the most stable of oxidation states and difficult to oxidize. AmO_2^{+} is unstable with respect to disproportionation to Am^{3+} and AmO_2^{2+}. Am^{4+} does not exist in solution, but only in solid compounds and concentrated fluoride or phosphate solutions. AmO_2^{2+} exists only in basic solutions, and compounds of Am^{2+} have been prepared on a tracer level and appear analagous to lanthanum and europium.

Flow Sheet of

Rocky Flats Molten-Salt

Extraction Process

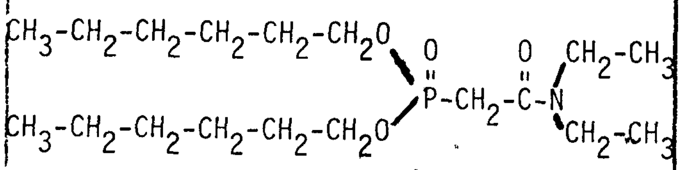
This is a flow-sheet for the process used to separate Pu from ^{241}Am-which grows into plutonium by the beta decay of ^{241}Pu. Molten Pu is contacted with a KCl-NaCl-$MgCl_2$ salt mixture for one hour in a restistance type furnance under an argon atmosphere at 750°C. Am is oxidized by the $MgCl_2$ to form $AmCl_3$ which reports to the salt phase. The salt is than processed by aqueous methods to recover and purify the americium. The purified plutonium is returned to the Foundry at RF.

Flow Sheet of
Cation Exchange - Anion
Exchange - Precipitation Processes

Various processes, using ion exchange and precipitation techniques, have been employed to separate Am from Pu and other elemental impurities in MSE waste salts. The present process includes (1) dissolution of the residues in dilute hydrochloric acid, (2) cation exchange or carbonate precipitation to convert from the chloride to the nitrate system and to remove gross amounts of monovalent impurities. (3) anion exchange to remove Pu, (4) oxalate precipitation, and (5) calcination at 600^{o}C to yield AmO_2.

dihexyl-N,N-diethylcarbamoylmethylphonate

(DHDECMP)



A new extraction chromatography process has been developed at RF for americium purification. The key to the process is the selective extraction of americium by the bifunctional organophosphorus extractant DHDECMP. The CMP extractant is sorbed on a solid support, Amberlite XAD-4, so that ion exchange columns can be used.

Flow Sheet of
Bidentate Process

Anion exchange is first used to remove plutonium from a nitric acid feed solution containing actinide and impurity elements. The ion column effluent and wash solutions are next passed through the extractant-support to selectively sorb americium. The extractant-support is then washed with nitric acid to remove residual impurities and the americium is eluted with water. The americium is finally precipitated from solution as the oxalate and calcined to AmO_2.

Picture of Hot Cell

This is the hot cell used to handle gram quantities of americium. The window has a foot-thick water wall to shield the operator from the gamma radiation of americium. The CMP process has been successfully demonstrated on a pilot plant scale in this box and is now undergoing production testing at RF.

Picture of Glovebox

This type of glovebox is used to handle plutonium and milligram quantitites af americium.

INTERNATIONAL SYMPOSIUM ON
AMERICIUM AND CURIUM CHEMISTRY AND TECHNOLOGY

COMMEMORATING G. T. SEABORG AND THE 40TH ANNIVERSARY OF THE DISCOVERY OF THESE ELEMENTS

as part of the

International Congress of Pacific Basin Societies

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If you would like to learn more about americium as well as curium - an actinide element similar to americium - plan to attend this ACS symposium in Honolulu this December.