

Seaborg's Plutonium?

A Case Study in Nuclear Forensics

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UC Berkeley

February 24, 2015

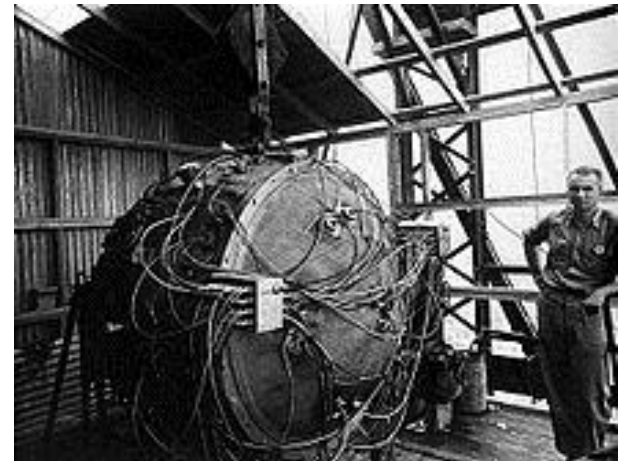
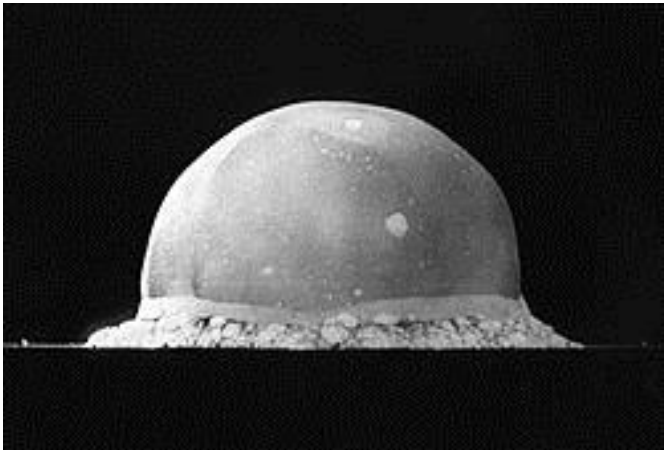


Berkeley Nuclear Engineering
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What do the objects shown in the next three slides share in common?

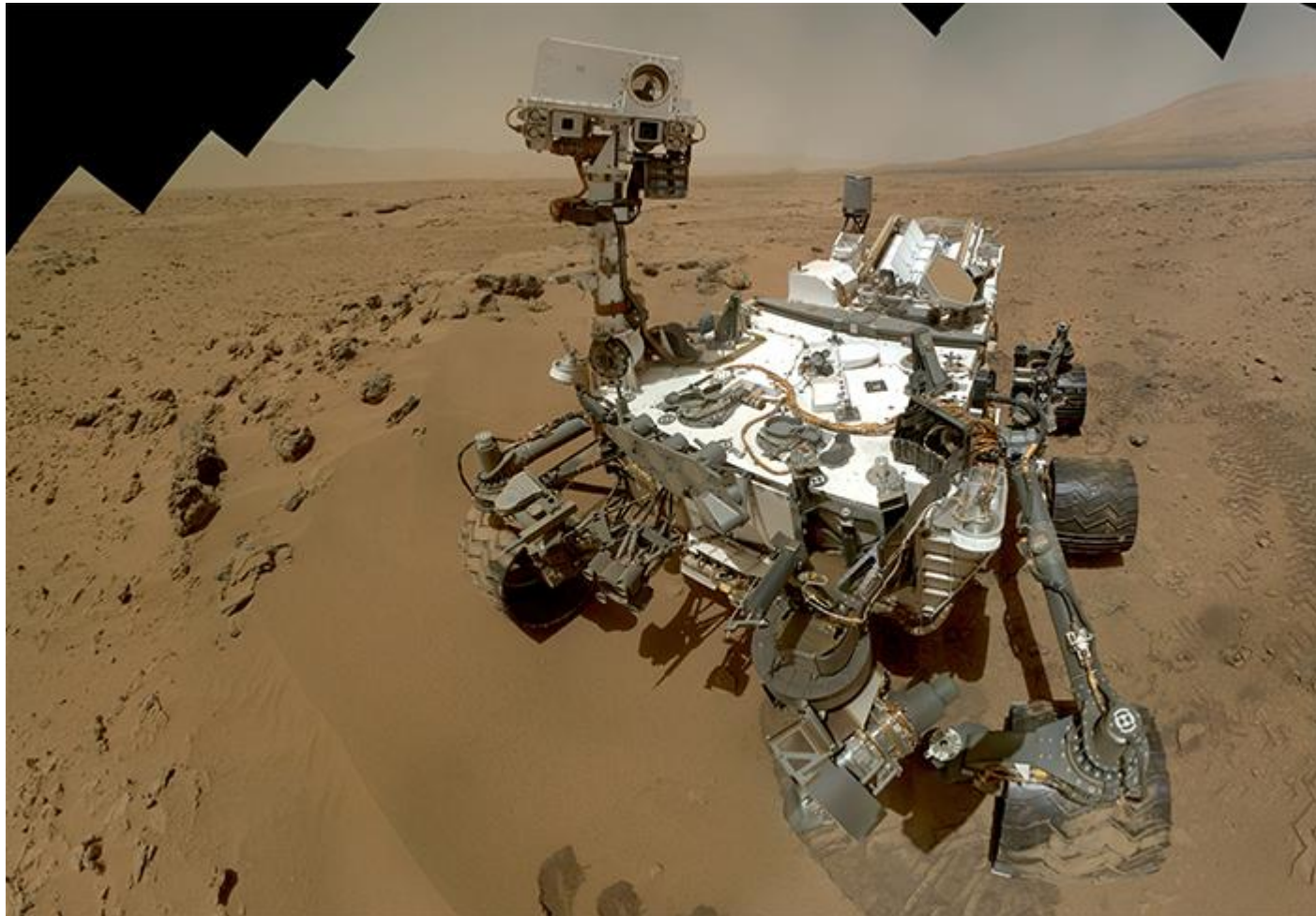
Trinity: First Nuclear Weapon Explosion

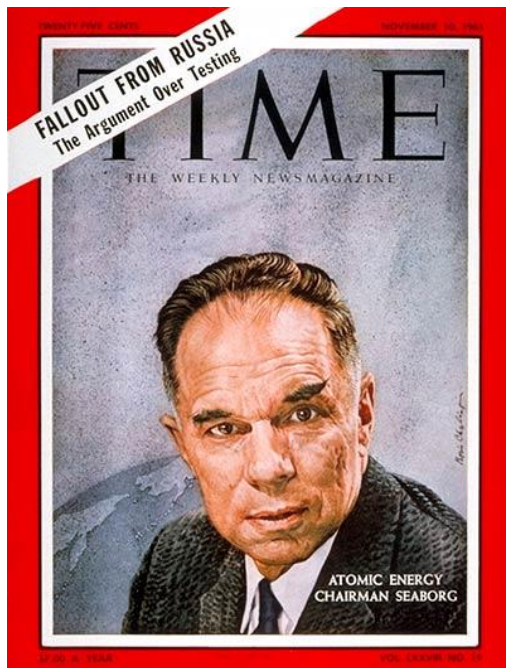


Ionization-Type Smoke Detector

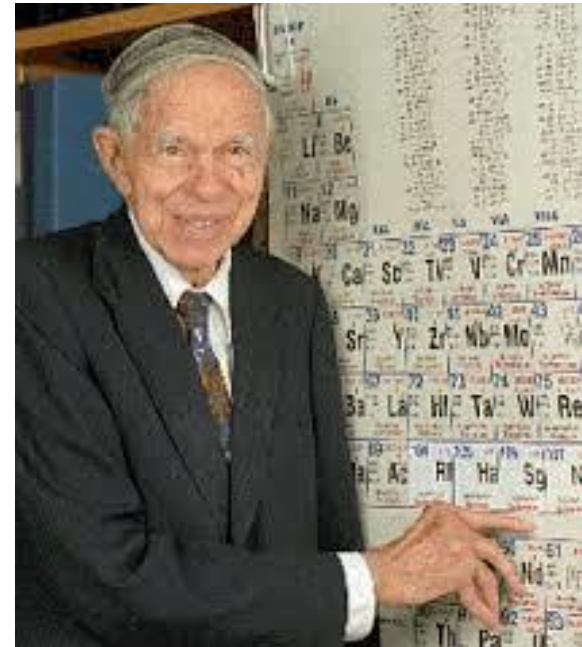


Curiosity Rover on Mars





The Nobel Prize in Chemistry 1951 was awarded jointly to Edwin Mattison McMillan and Glenn Theodore Seaborg "for their discoveries in the chemistry of the transuranium elements"



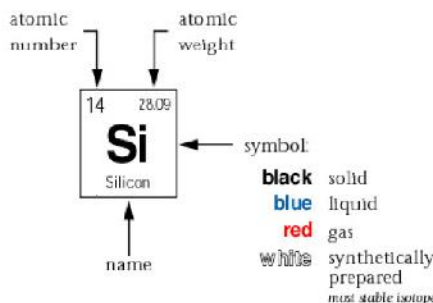
All my life I've been surrounded by people who are smarter than I am, but I found I could always keep up by working hard.

Glenn Seaborg

meetville.com

Periodic Table of the Elements

1 1.01 H Hydrogen																	2 4.003 He Helium	
3 6.94 Li Lithium	4 9.01 Be Beryllium																	10 20.18 Ne Neon
11 22.99 Na Sodium	12 24.31 Mg Magnesium																	18 39.96 Ar Argon
19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti Titanium	23 50.94 V Vanadium	24 51.996 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Iron	27 58.93 Co Cobalt	28 58.70 Ni Nickel	29 63.55 Cu Copper	30 65.37 Zn Zinc	31 69.72 Ga Gallium	32 72.59 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton	
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc Technetium	44 101.07 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.40 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.69 Sn Tin	51 121.75 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.30 Xe Xenon	
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.91 La ▶ Lanthanum	72 178.49 Hf Hafnium	73 180.95 Ta Tantalum	74 183.85 W Tungsten	75 186.21 Re Rhenium	76 190.20 Os Osmium	77 192.22 Ir Iridium	78 195.09 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.37 Tl Thallium	82 207.19 Pb Lead	83 208.98 Bi Bismuth	84 (209) Po Polonium	85 (210) At Astatine	86 (222) Rn Radon	
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.03 Ac ▶ Actinium	104 (261) Rf Rutherfordium	105 (262) Ha Hahnium	106 (266) Sg Seaborgium	107 (262) Bh Bohrium	108 (265) Hs Hassium	109 (266) Mt Meitnerium	110 (271) 	111 (272) 	112 (277) 	(113) 	114 (285) 	(115) 	116 (289) 	(117) 	118 (293) 	



- alkali metals
- alkaline earth metals
- transitional metals
- other metals
- nonmetals
- noble gases

- black solid
- blue liquid
- red gas
- white synthetically prepared most stable isotope

Lanthanide series ▶

58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.40 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium
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Actinide series ▶

90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 237.05 Np Neptunium	94 (244) Pu Plutonium	95 (243) Am Americium	96 (247) Cm Curium	97 (247) Bk Berkelium	98 (251) Cf Californium	99 (252) Es Einsteinium	100 (257) Fm Fermium	101 (260) Md Mendelevium	102 (269) No Nobelium	103 (262) Lr Lawrencium
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Seaborg participated in the development of the Nuclear Science Wallchart

The nuclear science wall chart, conceived at Berkeley Lab and developed with the help of an international organization of physicists and educators, is pictured here along with some of the many Berkeley Lab contributors who helped to see the project through.

The Nucleus
(1-10) × 10⁻¹⁵ m

At the center of the atom is a nucleus, formed from nucleons—protons and neutrons. Each nucleon is made from three quarks held together by their strong interactions, which are mediated by gluons. In turn, the nucleus is held together by the strong interaction between the protons and quark constituents of nucleons. Nuclear physicists often use the word of meson—particles which consist of a quark and antiquark, such as the pion—to describe the interactions among the nucleons.

In an atom, electrons range from the nucleus at distances typically up to 10⁵ times the nuclear diameter. If the electrons were shown to scale, this chart would cover a small town.

Radioactivity

Nuclear Energy

Key

Smoke Detectors

Radioactive Dating

Ex

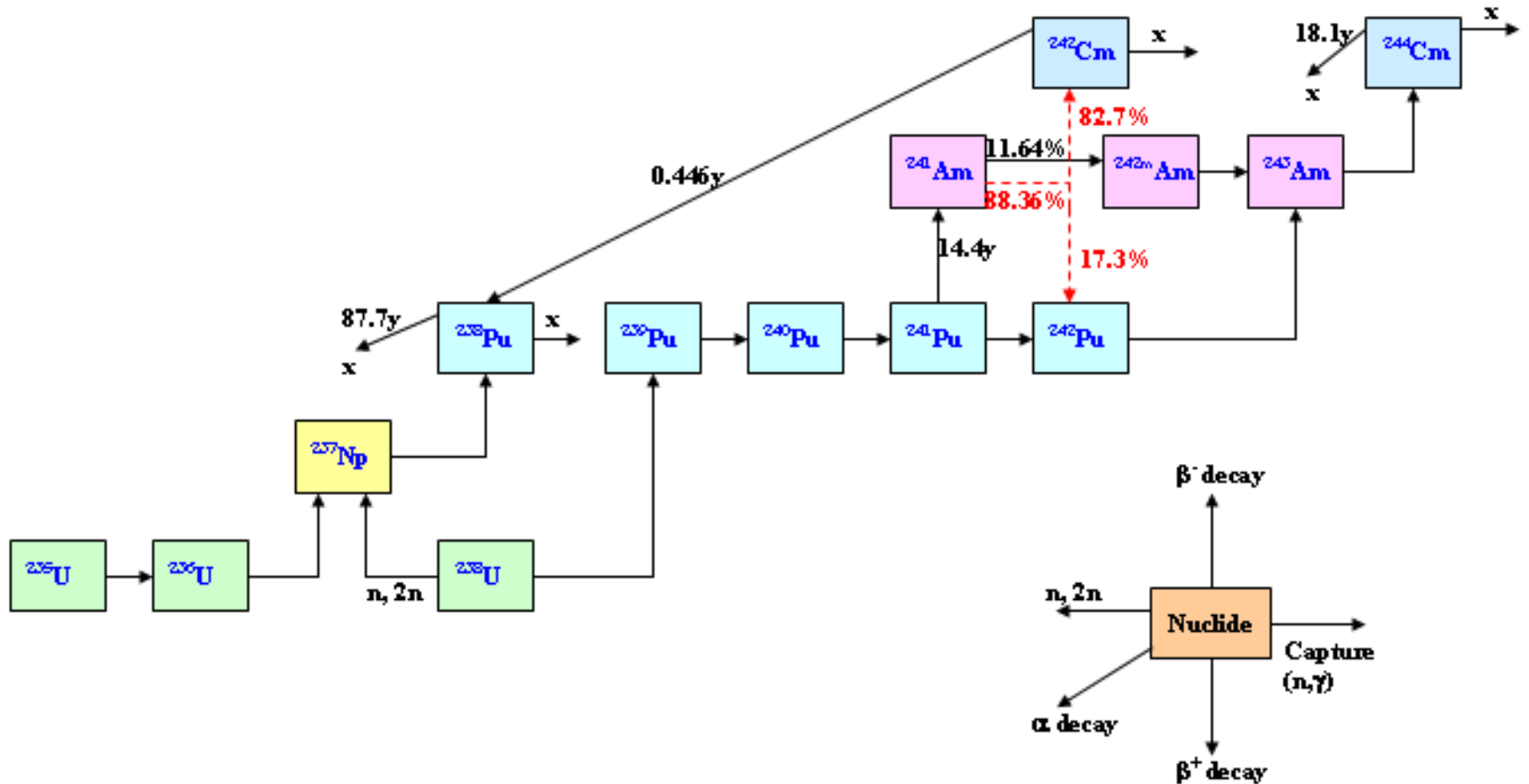
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http://pdg.lbl.gov

18 FALL 1998

Production of Plutonium Isotopes



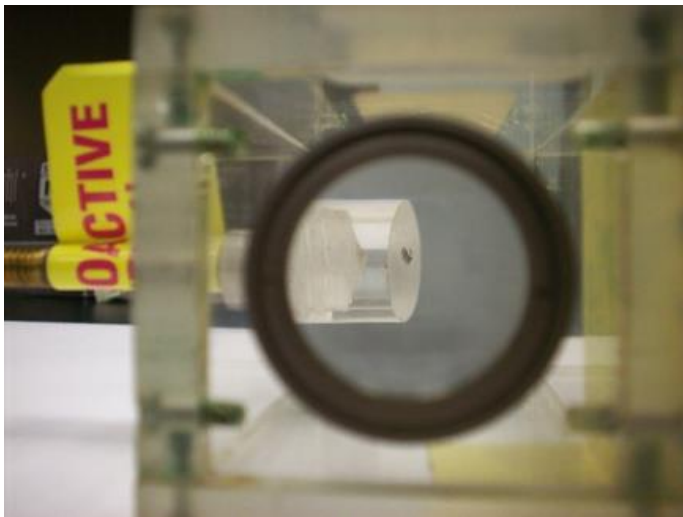
(a)



(b)



(c)



(a) outside of sample box with labels

(b) head-on view showing plastic rod with sample attached

(c) side view showing sample attached to plastic rod.

Keenan Thomas

**Low background counting
research specialist**



Kristina Telhami

**Undergraduate student from
San Diego State University**

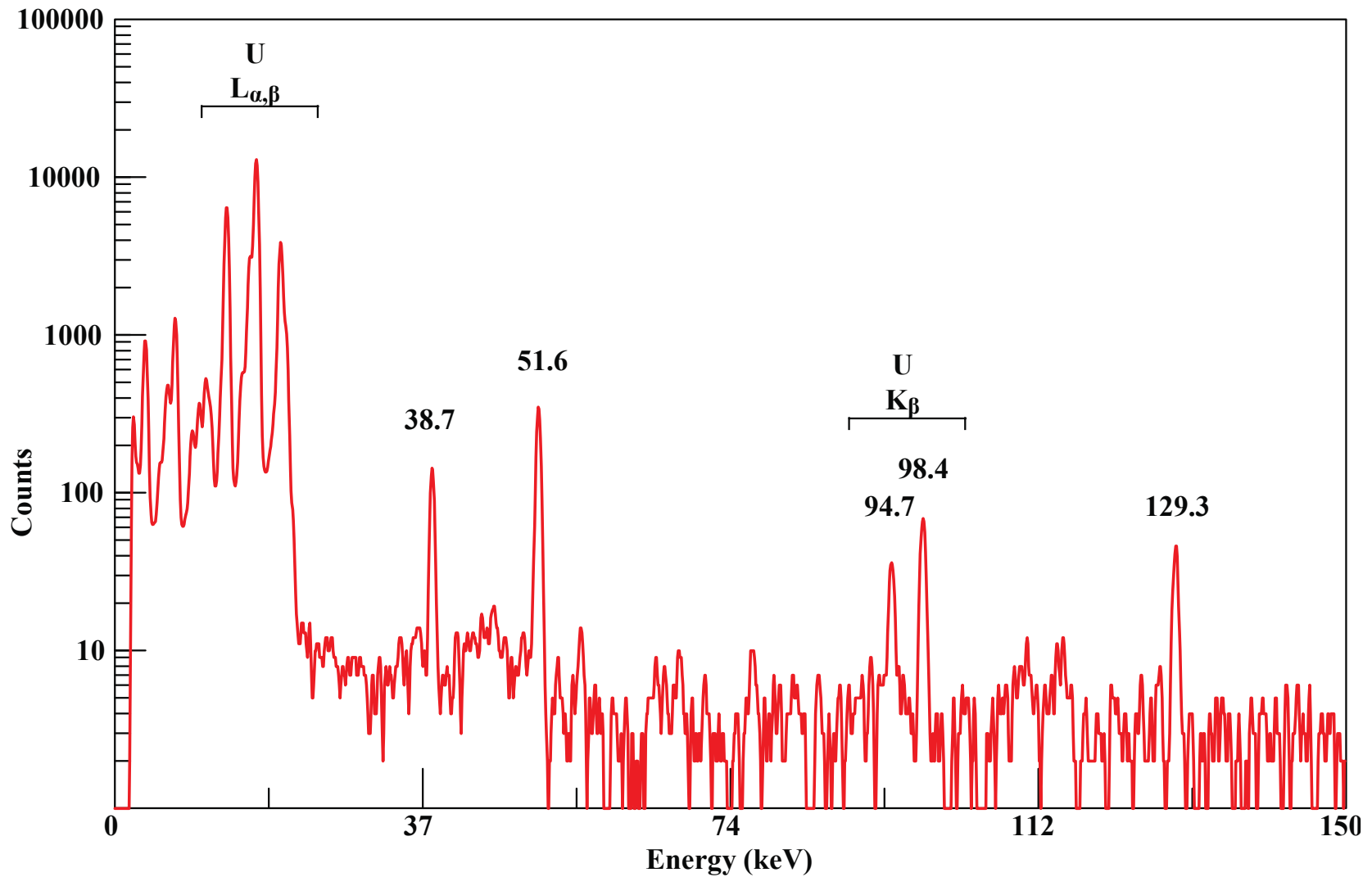


Funded by Nuclear Science and Security Consortium



Planar Ge detector used for measurements of sample S338

36-mm diameter by 13-mm thick planar germanium detector equipped with a thin Be window allowing detection of low-energy gamma rays and x rays. Shielded with 1.27 cm of copper and 5 to 10 cm of lead.

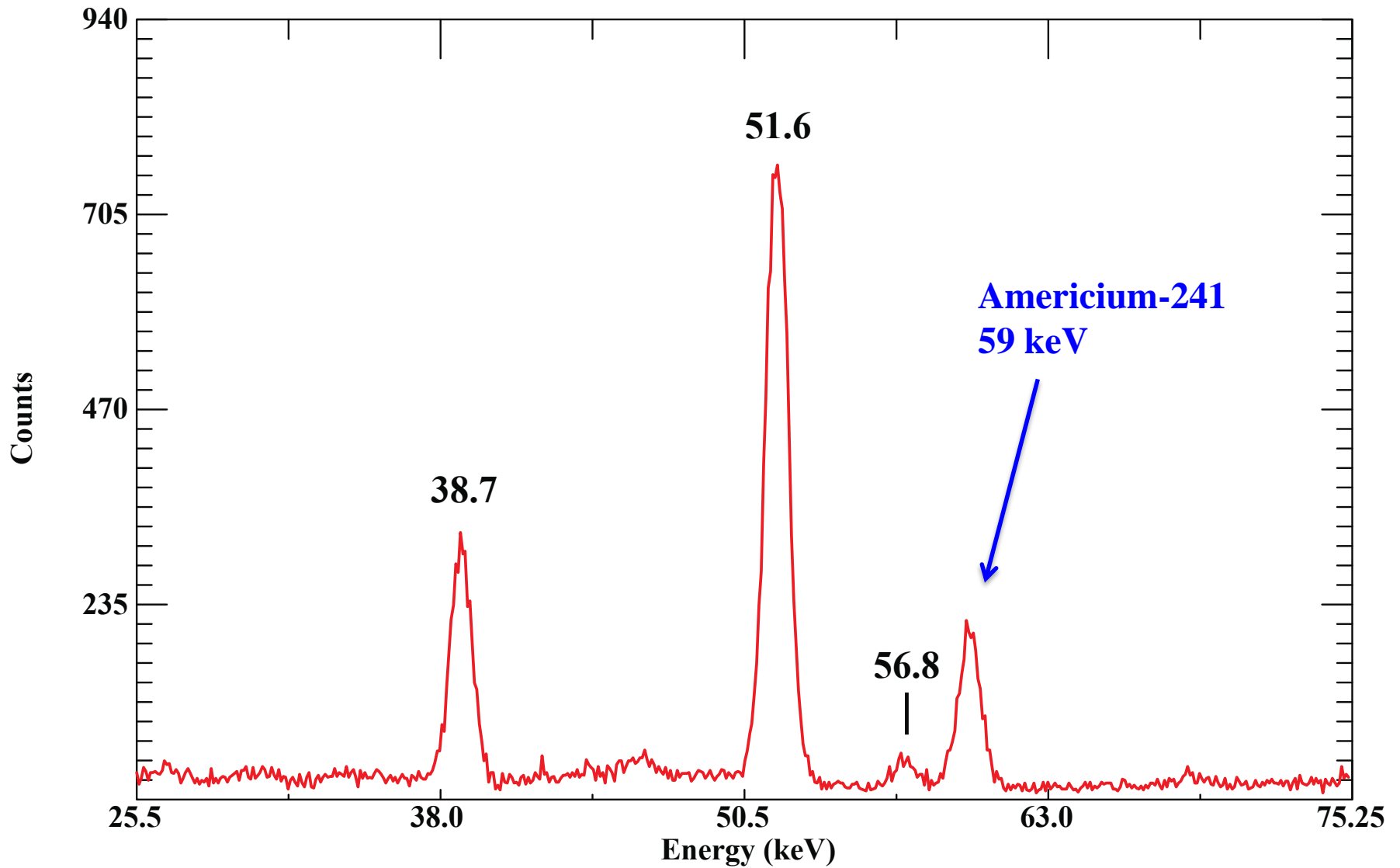


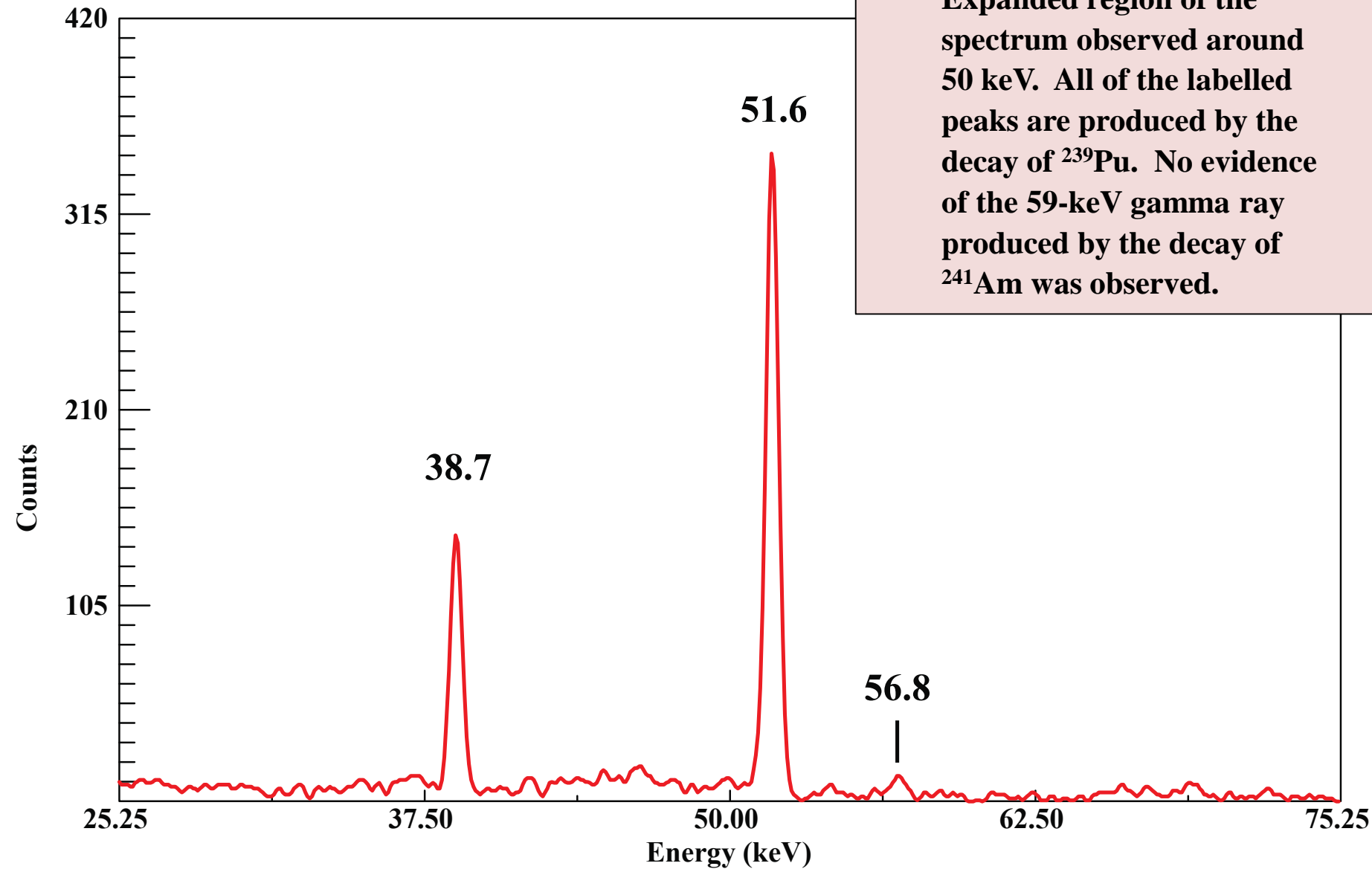
Background subtracted spectrum observed from Sample S338. All of the labelled peaks are x-rays and gamma rays produced by the decay of ^{239}Pu .

To determine the mass of ^{239}Pu contained in S338, we:

1. Measured the efficiency of our detector using calibrated sources of ^{57}Co , ^{137}Cs , and ^{241}Am . These sources provide x-ray and gamma-ray lines at 26, 32, 36, 59, 122, and 136 keV.
2. Gamma-rays emitted from the S338 sample had to pass through the 0.63-cm thick wall of the plastic box in which it is contained. In order to account for the attenuation this produced, we placed a 0.63-cm thick block of polyethylene between our sources and the detector.
3. We extracted the peak areas of the 38.7, 51.6, and 129.3-keV lines from the spectrum obtained from S338 and then determined the sample mass from each line. Results were averaged to establish the mass of ^{239}Pu contained in sample S338 to be $2.0 \pm 0.3 \mu\text{g}$.
4. Seaborg stated that the first weighed sample contained $2.77 \mu\text{g}$ of PuO_2 with no uncertainty given. This would imply a ^{239}Pu mass of $2.44 \mu\text{g}$.
5. Thus, the mass we determined is in reasonably good agreement with what Seaborg stated.

Gamma Spectrum from the same detector of “modern” Pu.





Expanded region of the spectrum observed around 50 keV. All of the labelled peaks are produced by the decay of ^{239}Pu . No evidence of the 59-keV gamma ray produced by the decay of ^{241}Am was observed.

In his reports, Seaborg states that **45 kg** of uranium irradiated for 2 months with neutrons (produced by deuteron breakup) produced **200 μg** of Pu.

From this one can infer a total neutron fluence

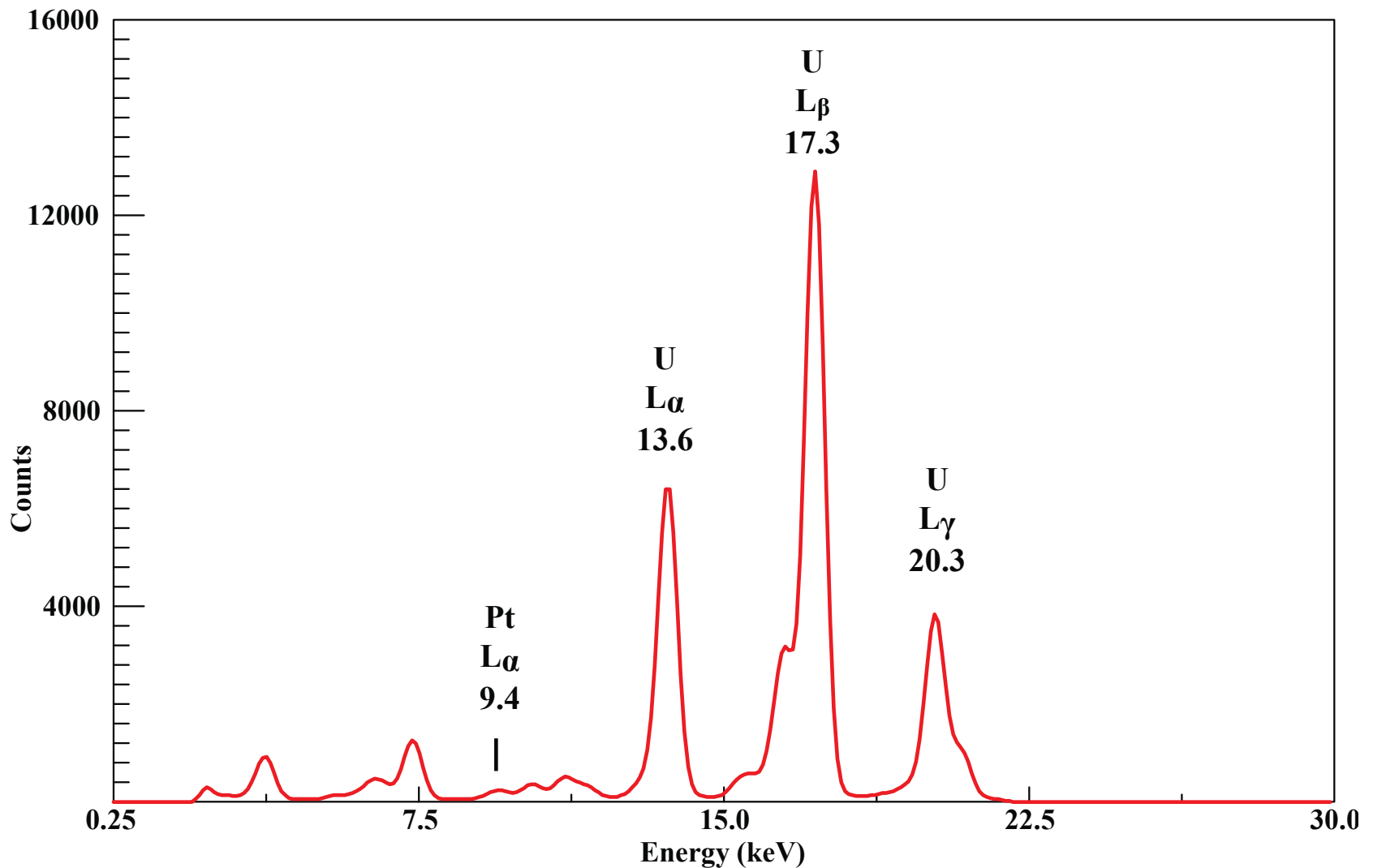
$$\Phi_n = 2 \times 10^{15} \text{ neutrons/cm}^2$$

Note: This is about the same as fluence a uranium nucleus in a modern commercial power plant sees in a few seconds !

→ expect $N(^{239}\text{Pu}) : N(^{240}\text{Pu}) : N(^{241}\text{Pu}) = 1.00 : 3 \times 10^{-7} : 6 \times 10^{-14}$

After 72 years, almost all of the ^{241}Pu would have decayed to ^{241}Am , producing less than $2 \mu\text{Bq}$ of activity (far too small for us to see)

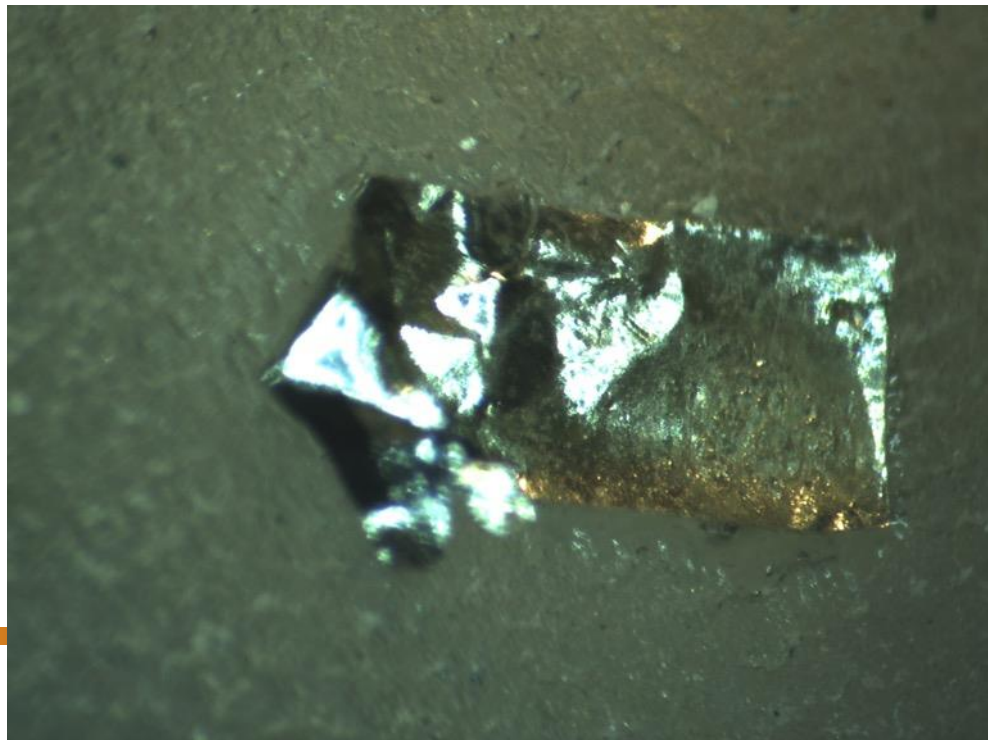
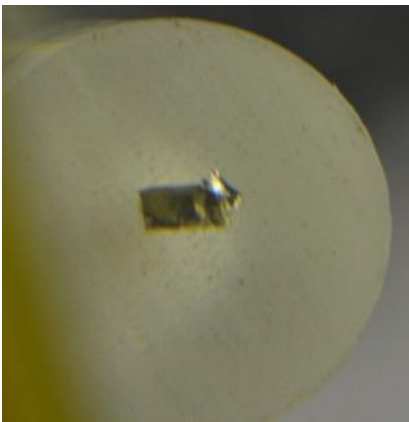
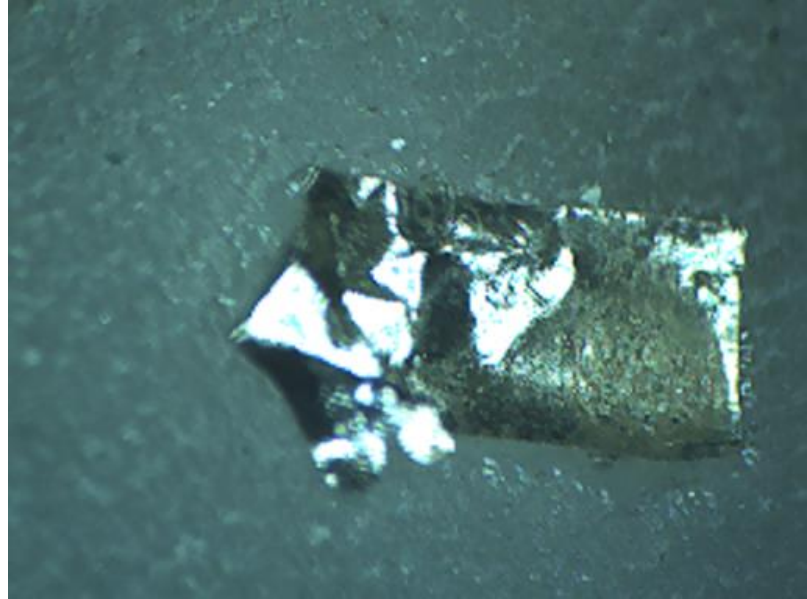
Thus, our failure to observe ^{241}Am is consistent with S338 being Seaborg's plutonium.



Low-energy portion of the spectrum showing uranium L x-rays produced by the decay of ^{239}Pu . The small peak at 9.4 keV is consistent with being an L α x-ray of platinum. The peaks at lower energies are likely to be Ge escape peaks produced by the higher energy x-rays



The first sample of ^{239}Pu containing 2.7-micrograms of oxide was weighed on September 10, 1942, at the University of Chicago's Metallurgical Laboratory. It is shown here as a deposit on a platinum foil held by forceps.



**If it looks like a duck, swims like a duck,
and quacks like a duck, then it probably is
a duck.**



**A mallard correctly identified as a
duck using the duck test**

Reference:

History of MET Lab Section C-I, April 1942 to April 1943, Glenn T. Seaborg (1977), p. 228-235.



<http://arxiv.org/abs/1412.7590>

Seaborg's Plutonium ?

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Abstract

Passive x-ray and gamma-ray analysis was performed on UC Berkeley's EH&S Sample S338. The object was found to contain ^{239}Pu . No other radioactive isotopes were observed. The mass of ^{239}Pu contained in this object was determined to be $2.0 \pm 0.3 \mu\text{g}$. These observations are consistent with the identification of this object being the 2.77- μg PuO_2 sample described by Glenn Seaborg and his collaborators as the first sample of ^{239}Pu that was large enough to be weighed.

Submitted to the American Journal of Physics

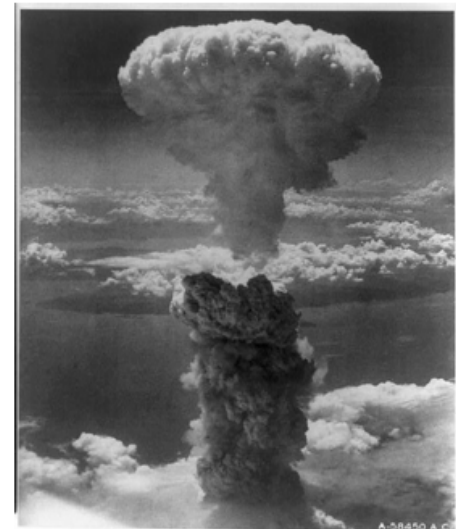
Manhattan Project Plutonium, Lost to Obscurity, Recovered by Scientists

Radioactive signatures identify one of the first pieces of plutonium seen by human eyes

January 15, 2015 | By [Andy Extance](#) |

“Fat Man,” the atomic bomb dropped by the U.S. on Nagasaki, Japan, in 1945, carried about 6.2 kilograms of enriched plutonium, roughly the size of a softball. The origin of that deadly hunk of metal can be traced back via a tiny sliver weighing less than three millionths of a gram, created in the labs of Manhattan Project researchers. It is a historic fragment, embodying both stunning scientific achievement and deep tragedy—that one bomb killed and wounded [at least 64,000 people](#) (estimates vary) as well as hastened Japan’s surrender. And in 2007 this historic sample, the first plutonium ever seen by researchers, vanished from the public eye.

Now it has resurfaced in a plastic box in a windowless, secure six-foot by six-foot room in the University of California, Berkeley’s Hazardous Material Facility. The tiny lump, derived from Nobel Prize–winning chemist Glenn Seaborg’s original discovery of the element, was accompanied by only limited documentation about its origins. But a Berkeley team has found radioactive fingerprints indicating the sliver indeed



Historic plutonium sample traced to Seaborg, Manhattan Project

By [Sarah Yang](#), Media Relations | January 15, 2015

BERKELEY — A tiny speck of plutonium on the UC Berkeley campus is making news for its connection to a momentous point in history.

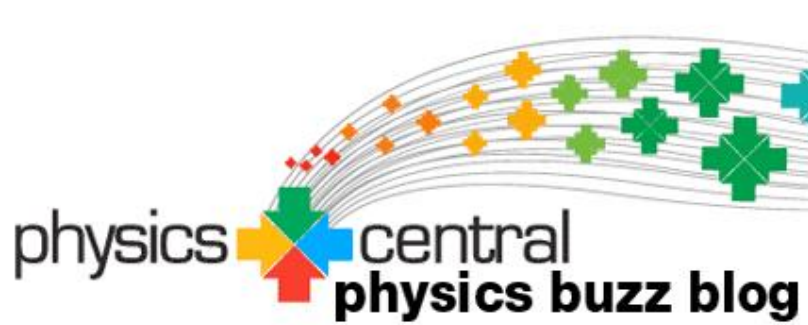
The plutonium, safely secured in the campus Hazardous Material Facility, has been identified with near certainty by nuclear scientists as a sample created through the Manhattan Project, led by the late Berkeley physics professor J. Robert Oppenheimer.

The plutonium sample was created by a team of scientists led by the late Berkeley chemist Glenn Seaborg. The synthesis of plutonium helped Seaborg earn a Nobel Prize in Chemistry in 1951. As part of the Manhattan Project, it was also an achievement that helped give birth to the atomic bomb used in World War II.

"This is the first sample of plutonium that was large enough to be weighed and its mass determined," said Eric Norman, the Berkeley professor of



Side view of a speck of plutonium created by the Manhattan Project. Created by a team led by Nobel-winning chemist Glenn Seaborg, it was the first sample big enough to be measured and weighed. (Photo courtesy of Eric Norman)



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Thursday, January 08, 2015

Identifying Seaborg's Lost Plutonium

This is the first sample of [plutonium](#) big enough to be seen by the naked eye. Probably. There's a sticker on the side that claiming it's the first plutonium sample large enough to be weighed, but the papers documenting the origins of this atomic artifact have long since disappeared. Scientists at Berkeley have had to rely on [nuclear forensics to substantiate](#) whether this radioactive fleck was really produced in 1942 by the physicist who first discovered the element, [Glenn Seaborg](#).

"I am 99 percent sure that's what this is," said [Eric Norman](#), a nuclear engineering professor at the University of California, Berkeley. "[But] we can't prove it unless you find Seaborg's DNA or his fingerprints on it."



5/9/2015

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2:15 PM, Inside

Science By : Sara Rennekamp,
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Originally published:
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10:15am EST

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How the First Lump of Plutonium Made on Earth Was Forgotten and Found Again



Sarah Zhang

Filed to: NUCLEAR HISTORY 1/08/15 4:00pm

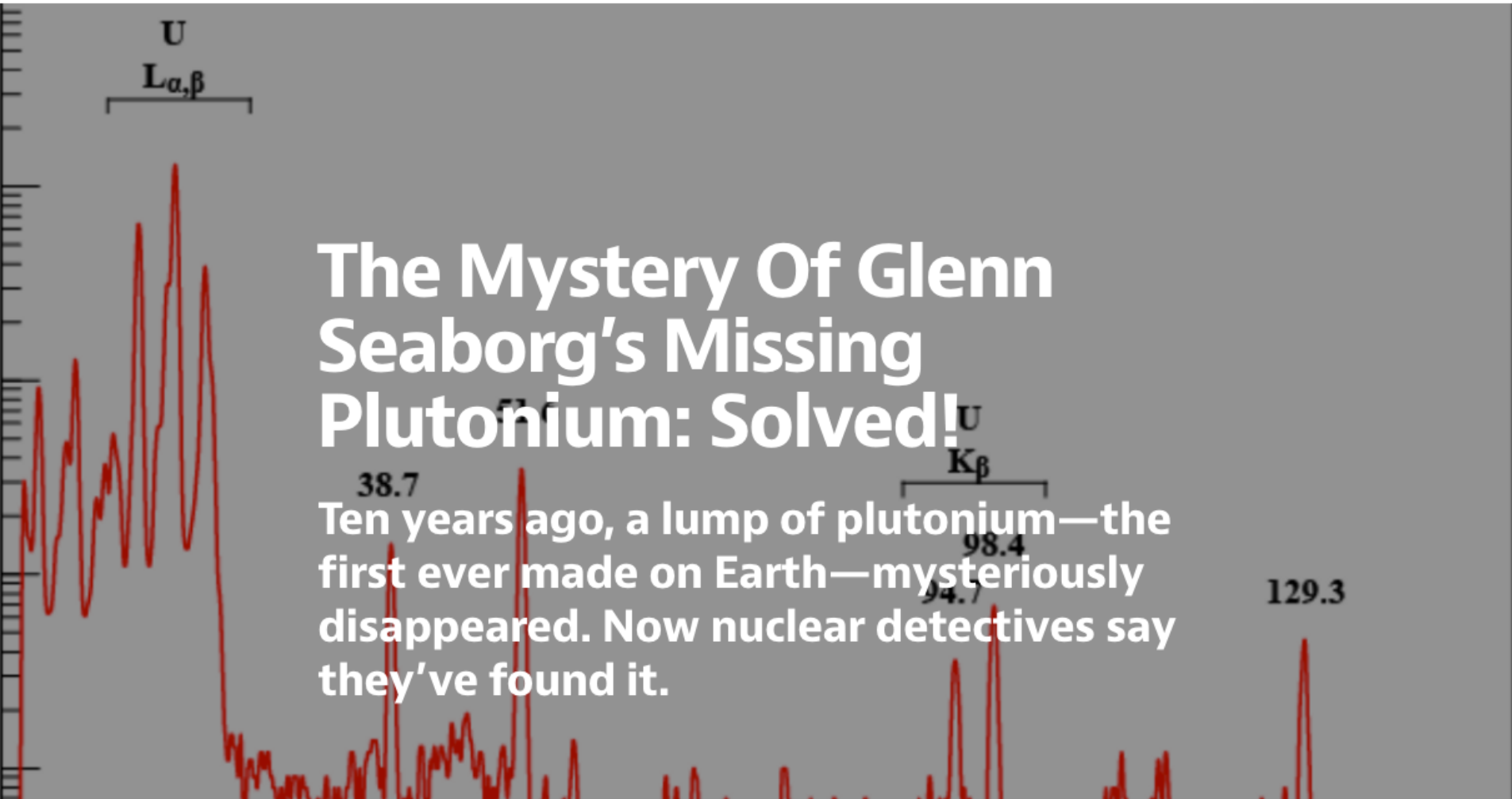
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The Physics arXiv Blog

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The Mystery Of Glenn Seaborg's Missing Plutonium: Solved!

Ten years ago, a lump of plutonium—the first ever made on Earth—mysteriously disappeared. Now nuclear detectives say they've found it.

  The Physics arXiv Blog on Jan 7 · 4 min

Andrew (Moby) and 8 others recommended    [Read next](#)

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First visible sample of plutonium rediscovered in storage

By **Chris Ziegler** on January 18, 2015 11:47 am [Email](#) [@zpower](#)

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Popular Mechanics

Earliest Plutonium Created By Humans For The Manhattan Project Has Been Rediscovered

A piece of the plutonium used in the first atomic bombs has indeed been sitting around UC-Berkeley for decades.



By John Wenz

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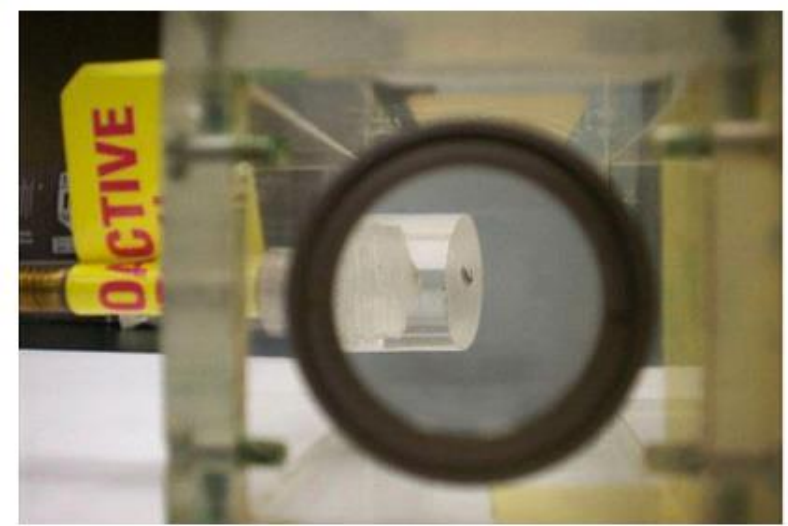
 **PIN**



3/9/2015

Historic plutonium sample traced to Seaborg, Manhattan Project

Jan 16, 2015 by Sarah Yang



Side view of a speck of plutonium created by the Manhattan Project. Created by a team led by Nobel-winning chemist Glenn Seaborg, it was the first sample big enough to be measured and weighed. Credit: Eric Norman

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