Seaborg’s Plutonium?

A Case Study in Nuclear Forensics

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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"
Seaborg participated in the development of the Nuclear Science Wallchart
Production of Plutonium Isotopes
(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.
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Low background counting research specialist

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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 $^{239}\text{Pu}$. $^{38.7}$, $^{51.6}$, $^{94.7}$, $^{98.4}$, $^{129.3}$.
To determine the mass of $^{239}\text{Pu}$ contained in S338, we:

1. Measured the efficiency of our detector using calibrated sources of $^{57}\text{Co}$, $^{137}\text{Cs}$, and $^{241}\text{Am}$. 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 $^{239}\text{Pu}$ 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 $\text{PuO}_2$ with no uncertainty given. This would imply a $^{239}\text{Pu}$ 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.

- Americium-241
- 59 keV
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!

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

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

Thus, our failure to observe \(^{241}\text{Am}\) 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 $L_\alpha$ 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 $^{239}\text{Pu}$ 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.
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 $2.0 \pm 0.3$ $\mu$g. These observations are consistent with the identification of this object being the 2.77-$\mu$g 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 Exline

“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
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."
How the First Lump of Plutonium Made on Earth Was Forgotten and Found Again
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.
First visible sample of plutonium rediscovered in storage

By Chris Ziegler on January 18, 2015 12:47 am   Email   @zpower
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.

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