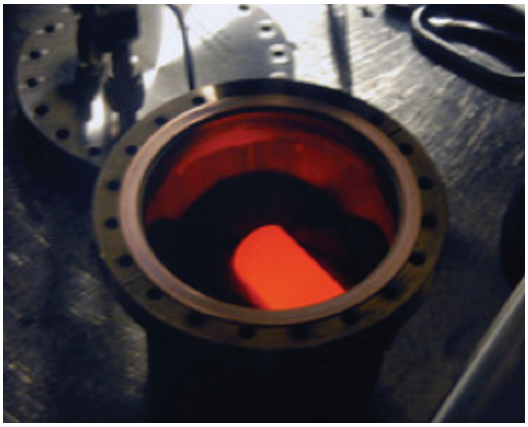
NASAfacts

What is Plutonium-238?

Plutonium-238 is a special material that emits steady heat due to its natural radioactive decay. Several unique features of plutonium-238 have made it the material of choice to help produce electrical power for more than two-dozen U.S. space missions that have been enabled by radioisotope power systems (RPS).

Plutonium-238 (abbreviated as Pu-238) was selected as the heat source to power these missions by the Department of Energy (DOE), which develops and provides RPS to NASA for use in space exploration. This unique material has been used to create electricity for a wide variety of spacecraft and hardware, from the science experiments deployed on the Moon by the Apollo astronauts to durable robotic explorers, such as the Curiosity Mars rover and the Voyager 1 and 2 spacecraft, which are at the edge of the solar system.

In many cases, the heat from this radioisotope has also been used to keep spacecraft electronics and other components warm enough to be able to operate effectively in the frigid environments often found in deep space and on planetary surfaces like Mars.



Credit: DOE/INL

Plutonium-238 fuel (in the form of a ceramic) glows with the heat of its natural decay inside a protective cylindrical shell of graphite, during the assembly of the heat sources for the electrical power system on NASA's Curiosity Mars rover at the Department of Energy's Idaho National Laboratory.

What is plutonium?

- Plutonium is a metallic chemical element with a silvery-white color. The plutonium used on NASA spacecraft is transformed in a laboratory into a silvery-black ceramic material called plutonium dioxide.
- Chemical elements are distinguished by the nature of their atom—every atom consists of a nucleus, composed of protons and neutrons, surrounded by a cloud of electrons. The number of protons in the nucleus (called the atomic number) is unique for each element and largely determines the chemical behavior of the element. Plutonium has 94 protons in its nucleus, so it is given the atomic number 94. (There are currently 118 known elements, from hydrogen to ununoctium.)
- Plutonium can be found naturally in extremely small traces, but it was discovered in 1940 by researchers at the University of California-Berkeley. They made the new element by using a particle accelerator (called a cyclotron) to transform a sample of the known element uranium into plutonium.
- The mass number of a chemical element is defined by the number of protons plus neutrons in the nucleus. Variants of a given element with differing numbers of neutrons are called isotopes. Pu-238 is a variant (or isotope) of plutonium with an atomic weight of 238 (94 protons plus 144 neutrons); it was the first isotope of plutonium that was discovered.
- Some isotopes of a given element, known as radioisotopes, are unstable and decay by emission of energy and particles. These particles could include alpha particles (two protons and two neutrons, the same composition as the nucleus of a helium atom), beta particles (an electron), and gamma rays (similar to X-rays, but more energetic). Pu-238 decays by alpha emission, generating heat as the alpha particles interact with surrounding material. Alpha particles emitted by Pu-238 decay can be blocked by simple barriers such as a thin sheet of paper.
- The half-life of Pu-238 is about 88 years, which means half of it decays into other radioisotopes during this period.
- Plutonium is a heavy metal with a mass density of 19.8 grams per cubic centimeter; for comparison, this makes it nearly 20 times denser than water. The ceramic form of Pu-238 used as a fuel in an RPS has a mass density of about 9.6 grams per cubic centimeter (almost 10 times more dense than water).
- Pu-238 would not work well as the fuel in a nuclear reactor and it is not the type of plutonium used for nuclear weapons.

Why is Pu-238 used as radioisotope fuel in an RPS?

- Performance: Pu-238 is an ideal radioisotope fuel for RPS applications because it generates heat that declines in output by only one half after 88 years. As a result, the ability of an RPS to produce electricity decreases slowly in a highly predictable manner; today the typical RPS is designed for at least 14 years of operation. This allows deep space missions to function for extremely long durations in places where alternatives such as solar panels would be impractical or ineffective.

  Pu-238 also has a high heat density, which means that heat sources can be made compact and that the fuel transfers its heat effectively to power conversion devices and heater units.

- Less Shielding: Pu-238 decays by the alpha emission process, and these alpha particles can be stopped by material as thin as a sheet of paper. This greatly enhances radiation protection safety. Other radioisotopes would require much greater (and heavier) shielding to protect both the humans working on the power source and its spacecraft on the ground before launch, as well as the many radiation-sensitive electronic parts onboard a spacecraft.

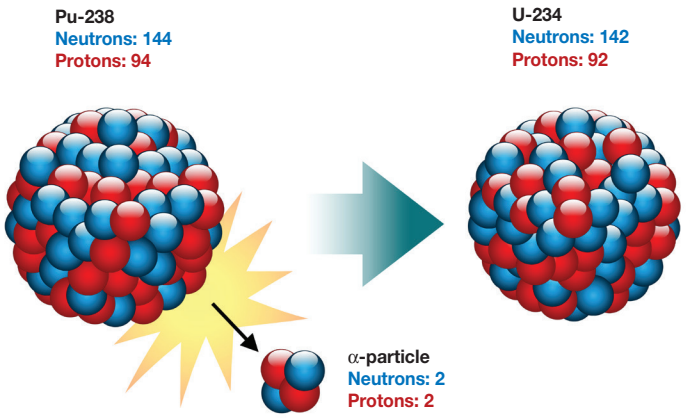
- Availability: While there are isotopes of other elements that offer similar characteristics, the United States can produce Pu-238 safely and in sufficient quantities to power space missions.

Why is Pu-238 safe to use in an RPS?

- For use as fuel in an RPS, Pu-238 is processed with other materials into a ceramic form called plutonium dioxide. In the unlikely event of a launch or reentry accident that released the fuel, this ceramic form—similar to the material in a coffee mug—would break primarily into large, non-inhalable pieces rather than fine particles that could be harmful to human health or the environment.

- In addition, the ceramic form of the plutonium dioxide fuel has a high melting temperature (4,820 degrees Fahrenheit or 2,660 degrees Celsius) and a very low solubility in water. These features greatly limit the movement of any material that might be released in the environment, further reducing the chance that anyone could be exposed to it.

Pu-238 has been used safely in RPS for space exploration for more than 50 years, and the core General Purpose Heat Source module in a modern RPS has over three decades of design and safety testing behind it. Every RPS launched by NASA has worked precisely as it was designed, with some powering missions for more than 35 years and counting.



Radioactive decay of a Pu-238 atom emits an alpha particle (identical to a helium nucleus). This process, occuring constantly within a sample of plutonium, heats the material.

For more information about radioisotope power systems, visit **rps.nasa.gov**