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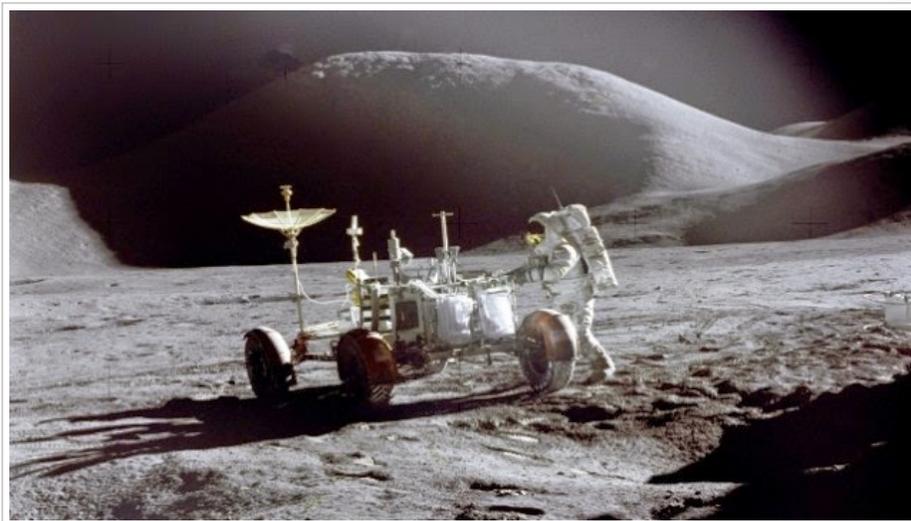
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Helium-3

18
Apr
2014



Helium-3 (He-3) is a light, non-radioactive isotope of **helium** with two **protons** and one neutron. It is rare on Earth, and it is sought for use in **nuclear fusion** research. The abundance of helium-3 is thought to be greater on the Moon (embedded in the upper layer of **regolith** by the solar wind over billions of years), though still lower in quantity (28 ppm of lunar regolith is helium-4 and from one ppb to 50 ppb is helium-3) than the **solar system's gas giants** (left over from the original solar nebula).

The **helion**, the **nucleus** of a helium-3 atom, consists of two protons but only one neutron, in contrast with two neutrons in common helium. Its hypothetical existence was first proposed in 1934 by the Australian **nuclear physicist Mark Oliphant** while he was working at the **University of Cambridge Cavendish Laboratory**. Oliphant had performed experiments in which fast **deuterons** collided with deuteron targets (incidentally, the first demonstration of **nuclear fusion**).

Helium-3 was hypothesized to be a **radioactive isotope** until helions were also found in samples of natural helium, which is mostly **helium-4**, taken both from the terrestrial atmosphere and from **natural gas** wells. This was done by **Luis W. Alvarez** and **Robert Cornog** in **cyclotron** experiments at the **Lawrence Berkeley National Laboratory** in **California** in 1939.

Although helium-3 was found to be about 10,000 times rarer than helium-4 in the helium from the gas wells, its significant presence in underground gas deposits implied that either it did not decay, or else it had a very

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long **half-life** – billions of years. **Hydrogen-1** and helium-3 are the only stable nuclides that contain more protons than neutrons.

Helium-3 occurs as a primordial nuclide, escaping from the Earth's crust into the atmosphere and into **outer space** over millions of years. Helium-3 is also thought to be a natural **nucleogenic** and **cosmogenic nuclide**, one produced when lithium is bombarded by natural neutrons. Those are released by **spontaneous fission** and by **nuclear reactions** with **cosmic rays**. Some of the helium-3 found in the terrestrial atmosphere is also a relic of atmospheric and underwater **nuclear weapons testing**, conducted by the three big nuclear powers before 1963. Most of this comes from the decay of **tritium** (hydrogen-3), which decays into helium-3 with a **half life** of 12.3 years. Furthermore, some **nuclear reactors** (landbound or shipbound) periodically release some helium-3 and tritium into the atmosphere. The **nuclear reactor disaster at Chernobyl** released a huge amount of radioactive tritium into the atmosphere, and smaller problems cause smaller releases. Furthermore, significant amounts of tritium and helium-3 have been deliberately produced in national arsenal nuclear reactors by the irradiation of **lithium-6**. The tritium is used to "boost" **nuclear weapons**, and some of this inevitably escapes during its production, transportation, and storage. Hence, helium-3 enters the atmosphere both through its direct release and through the **radioactive decay** of tritium. The vast majority of these two gases have been produced and leaked by the former Soviet Union, Russia, the United Kingdom, and France. ^[*citation needed*]

Helium-3 is proposed as a second-generation fuel for **nuclear fusion** in hypothetical **fusion power plants**, but such plants are still very early in their development—especially since first generation reactors have not yet entered into service. Helium-3 can be used in instruments for the detection of free neutrons, such as neutrons leaking from **nuclear reactors**.

Because of its lower atomic mass of 3.02 **atomic mass units**, helium-3 has some **physical properties** different from those of helium-4, with a mass of 4.00 atomic mass units. Because of the weak, induced dipole–dipole interaction between helium atoms, their macroscopic physical properties are mainly determined by their **zero-point energy** (ground-state kinetic energy). Also, the microscopic properties of helium-3 cause it to have a higher zero-point energy than helium-4. This implies that helium-3 can overcome dipole–dipole interactions with less thermal energy than helium-4 can.

The **quantum mechanical** effects on helium-3 and helium-4 are significantly different because with two protons, two neutrons, and two electrons, helium-4 has an overall **spin** of zero, making it a **boson**, but with one fewer neutron, helium-3 has an overall spin of one half, making it a **fermion**.



Helium-3 boils at 3.19 **K** compared with helium-4 at 4.23 **K**, and its **critical point** is also lower at 3.35 **K**, compared with helium-4 at 5.2 **K**. Helium-3 has less than one-half of the density when it is at its boiling point: 59 gram per liter compared to the 125 gram per liter of helium-4 — at a pressure of one atmosphere. Its latent heat of vaporization is also considerably lower at 0.026 **kilojoule per mole** compared with the 0.0829 **kilojoule per mole** of helium-4.



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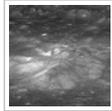
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