Helium

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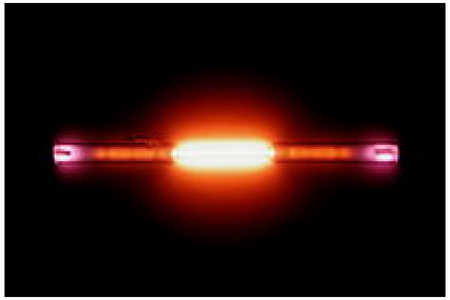
Helium is a chemical element with symbol **He** and atomic number 2. It is a colorless, odorless, tasteless, non-toxic, inert, monatomic gas, the first in the noble gas group in the periodic table. Its boiling point is the lowest among all the elements.

After hydrogen, helium is the second lightest and second most abundant element in the observable universe, being present at about 24% of the total elemental mass, which is more than 12 times the mass of all the heavier elements combined. Its abundance is similar to this figure in the Sun and in Jupiter. This is due to the very high nuclear binding energy (per nucleon) of helium-4 with respect to the next three elements after helium. This helium-4 binding energy also accounts for why it is a product of both nuclear fusion and radioactive decay. Most helium in the universe is helium-4, and is believed to have been formed during the Big Bang. Large amounts of new helium are being created by nuclear fusion of hydrogen in stars.

Helium is named for the Greek god of the Sun, Helios. It was first detected as an unknown yellow spectral line signature in sunlight during a solar eclipse in 1868 by French astronomer Jules Janssen. Janssen is jointly credited with detecting the element along with Norman Lockyer. Janssen observed during the solar eclipse of 1868 while Lockyer observed from Britain. Lockyer was the first to propose that the line was due to a new element, which he named. The formal discovery of the element was made in 1895 by two Swedish chemists, Per Teodor Cleve and Nils Abraham Langlet, who found helium emanating from the uranium ore cleveite. In 1903, large reserves of helium were found in natural gas fields in parts of the United States, which is by far the largest supplier of the gas today.

Liquid helium is used in cryogenics (its largest single use, absorbing about a quarter of production), particularly in the cooling of superconducting magnets, with the main commercial application being in MRI scanners. Helium's other industrial uses—as a pressurizing and purge gas, as a protective atmosphere for arc welding and in processes such as growing crystals to make silicon wafers—account for half of the gas produced. A well-known but minor use is as a lifting gas in balloons and airships.[4] As with any gas whose density differs from that of air, inhaling a small volume of helium temporarily changes the timbre and quality of the human voice. In scientific research, the behavior of the two fluid phases of helium-4 (helium I and

Helium, $_2$He



Spectral lines of helium

General properties

Name, symbol	helium, He
Pronunciation	/ˈhiːliəm/ *HEE-lee-əm*
Appearance	colorless gas, exhibiting a red-orange glow when placed in an electric field

Helium in the periodic table

Atomic number (*Z*)	2
Group, block	group 18 (noble gases), s-block
Period	period 1
Element category	□ noble gas
Standard atomic weight (±) (A_r)	4.002602(2)[1]
Electron	$1s^2$

helium II) is important to researchers studying quantum mechanics (in particular the property of superfluidity) and to those looking at the phenomena, such as superconductivity, produced in matter near absolute zero.

On Earth it is relatively rare—5.2 ppm by volume in the atmosphere. Most terrestrial helium present today is created by the natural radioactive decay of heavy radioactive elements (thorium and uranium, although there are other examples), as the alpha particles emitted by such decays consist of helium-4 nuclei. This radiogenic helium is trapped with natural gas in concentrations as great as 7% by volume, from which it is extracted commercially by a low-temperature separation process called fractional distillation. Previously, terrestrial helium—a non-renewable resource, because once released into the atmosphere it readily escapes into space—was thought to be in increasingly short supply.[5][6][7] However, recent studies suggest that helium produced deep in the earth by radioactive decay can collect in natural gas reserves in larger than expected quantities,[8][9] in some cases having been released by volcanic activity.[10]

Characteristics

Helium in quantum mechanics

In the perspective of quantum mechanics, helium is the second simplest atom to model, following the hydrogen atom. Helium is composed of two electrons in atomic orbitals surrounding a nucleus containing two protons and (usually) two neutrons. As in Newtonian mechanics, no system that consists of more than two particles can be solved with an exact analytical mathematical approach (see 3-body problem) and helium is no exception. Thus, numerical mathematical methods are required, even to solve the system of one nucleus and two electrons. Such computational chemistry methods have been used to create a quantum mechanical picture of helium electron binding which is accurate to within < 2% of the correct value, in a few computational steps.[47] Such models show that each electron in helium partly screens the nucleus from the other, so that the effective nuclear charge *Z* which each electron sees, is about 1.69 units, not the 2 charges of a classic "bare" helium nucleus.

The related stability of the helium-4 nucleus and electron shell

configuration	
per shell	2
Physical properties	
Phase	gas
Melting point	0.95 K (−272.20 °C, −457.96 °F) (at 2.5 MPa)
Boiling point	4.222 K (−268.928 °C, −452.070 °F)
Density at stp (0 °C and 101.325 kPa)	0.1786 g/L
when liquid, at m.p.	0.145 g/cm^3
when liquid, at b.p.	0.125 g/cm^3
Triple point	2.177 K, 5.043 kPa
Critical point	5.1953 K, 0.22746 MPa
Heat of fusion	0.0138 kJ/mol
Heat of vaporization	0.0829 kJ/mol
Molar heat capacity	20.78[2] J/(mol·K)

Vapor pressure (defined by ITS-90)

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)			1.23	1.67	2.48	4.21

Atomic properties	
Oxidation states	**0**
Electronegativity	Pauling scale: no data
Ionization energies	1st: 2372.3 kJ/mol 2nd: 5250.5 kJ/mol
Covalent radius	28 pm
Van der Waals radius	140 pm

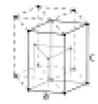
The nucleus of the helium-4 atom is identical with an alpha particle. High-energy electron-scattering experiments show its charge to decrease exponentially from a maximum at a central point, exactly as does the charge density of helium's own electron cloud. This symmetry reflects similar underlying physics: the pair of neutrons and the pair of protons in helium's nucleus obey the same quantum mechanical rules as do helium's pair of electrons (although the nuclear particles are subject to a different nuclear binding potential), so that all these fermions fully occupy 1s orbitals in pairs, none of them possessing orbital angular momentum, and each cancelling the other's intrinsic spin. Adding another of any of these particles would require angular momentum and would release substantially less energy (in fact, no nucleus with five nucleons is stable). This arrangement is thus energetically extremely stable for all these particles, and this stability accounts for many crucial facts regarding helium in nature.

For example, the stability and low energy of the electron cloud state in helium accounts for the element's chemical inertness, and also the lack of interaction of helium atoms with each other, producing the lowest melting and boiling points of all the elements.

In a similar way, the particular energetic stability of the helium-4 nucleus, produced by similar effects, accounts for the ease of helium-4 production in atomic reactions that involve either heavy-particle emission or fusion. Some stable helium-3 (2 protons and 1 neutron) is produced in fusion reactions from hydrogen, but it is a very small fraction compared to the highly favorable helium-4.

The unusual stability of the helium-4 nucleus is also important cosmologically: it explains the fact that in the first few minutes after the Big Bang, as the "soup" of free protons and neutrons which had initially been created in about 6:1 ratio cooled to the point that nuclear binding was possible, almost all first compound atomic nuclei to form were helium-4 nuclei. So tight was helium-4 binding that helium-4 production consumed nearly all of the free neutrons in a few minutes, before they could beta-decay, and also leaving few to form heavier atoms such as lithium, beryllium, or boron. Helium-4 nuclear binding per nucleon is stronger than in any of these elements (see nucleogenesis and binding energy) and thus, once helium had been formed, no energetic drive was available to make elements 3, 4 and 5. It was barely energetically favorable for helium to fuse into the next element with a lower energy per nucleon, carbon. However, due to lack of intermediate elements, this process requires three helium nuclei striking each other nearly simultaneously (see triple alpha process). There was thus no time for significant carbon to be formed in the few minutes after the Big Bang, before the early expanding universe cooled to the temperature and pressure

Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Speed of sound	972 m/s
Thermal conductivity	0.1513 W/(m·K)
Magnetic ordering	diamagnetic[3]
CAS Number	7440-59-7

History

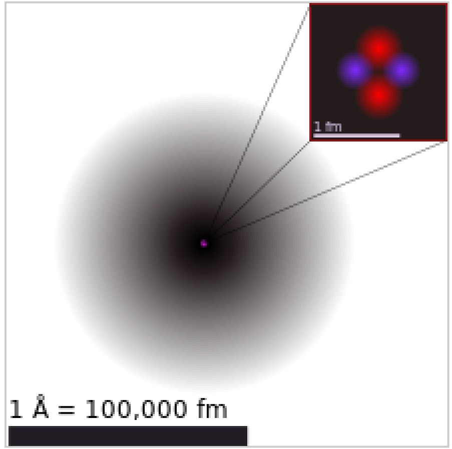
Naming	after Helios, Greek god of the Sun
Discovery	Pierre Janssen, Norman Lockyer (1868)
First isolation	William Ramsay, Per Teodor Cleve, Abraham Langlet (1895)

Most stable isotopes of helium

iso	NA	half-life	DM	DE (MeV)	DP
^{3}He	0.0002%	is stable with 1 neutron			
^{4}He	99.9998%	is stable with 2 neutrons			

point where helium fusion to carbon was no longer possible. This left the early universe with a very similar ratio of hydrogen/helium as is observed today (3 parts hydrogen to 1 part helium-4 by mass), with nearly all the neutrons in the universe trapped in helium-4.

All heavier elements (including those necessary for rocky planets like the Earth, and for carbon-based or other life) have thus been created since the Big Bang in stars which were hot enough to fuse helium itself. All elements other than hydrogen and helium today account for only 2% of the mass of atomic matter in the universe. Helium-4, by contrast, makes up about 23% of the universe's ordinary matter—nearly all the ordinary matter that is not hydrogen.



The helium atom. Depicted are the nucleus (pink) and the electron cloud distribution (black). The nucleus (upper right) in helium-4 is in reality spherically symmetric and closely resembles the electron cloud, although for more complicated nuclei this is not always the case.

Source

- Wikipedia: Helium (https://en.wikipedia.org/wiki/Helium)