

Cool as helium

Owing to peculiar properties, helium has taken both the main and supporting roles in scientific discoveries over the years. **Christine Herman** explores just what makes it such a cool element.

I was one of those starry-eyed children who loved helium because it sent colourful balloons into the sky and made me speak with a squeaky voice. As a chemist, I have learnt there are a myriad of other reasons scientists get excited about the odourless, colourless second element in the periodic table. Helium is a cool element. Literally.

It has the lowest melting and boiling points of all the elements — and below 2 K, it enters a superfluid state with no apparent viscosity and extremely high thermal conductivity. These qualities make it a fantastic cryogen for cooling superconducting magnets, rendering them free of electrical resistance. Physicists, physicians and nuclear engineers alike rely on liquid helium to run atom-smashing experiments, carry out magnetic resonance imaging, and cool nuclear reactors to suitably low temperatures.

Helium was discovered in 1868 by the astronomers Jules Janssen and Norman Lockyer, who independently observed its yellow spectral line signature from the Sun. Lockyer — the first editor of *Nature* — named it after the Greek word for the Sun, helios. It was the Scottish chemist Sir William Ramsay who first isolated helium in 1895, by treating the uranium mineral cleveite with mineral acids and removing nitrogen and oxygen — only to notice the same yellow spectral line that had been observed from the Sun three decades earlier. That same year, Swedish chemists Per Teodor Cleve and Abraham Langlet also isolated helium, independently, and determined its atomic weight.

Although helium is the second most abundant element in the universe after hydrogen, it is not bound by the Earth's gravitational force and so the atmosphere contains only about 0.0005% by volume. In contrast, the atmosphere of Uranus boasts 15% by volume, or 26% by mass, which is also approximately what our galaxy consists of. Helium accumulates in natural gas fields in the form of alpha particles (He^{2+}), which



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are a by-product of the natural decay of heavy radioactive elements. On extraction, natural gas can contain up to 7% helium by volume, which commercial suppliers isolate by fractional distillation.

In addition to playing a supporting role as a cryogen for physics, medicine and nuclear-energy applications, helium serves numerous other purposes in industry, research and everyday life: arc welders use it as an inert protective shield, rocket scientists to pressurize fuel tanks, and deep-sea divers use it mixed with oxygen to keep from suffering nitrogen narcosis during long dives. Scientists study the quantum mechanical phenomenon of superfluidity in the various forms of helium and, because radioactive decay produces helium nuclei, paleontologists determine the age of rocks by measuring the ratio of helium to uranium and thorium. Helium–neon lasers are widely used in applications that require visible-wavelength coherent light. In fact, the first commercial optical disc storage medium in 1978 used a HeNe laser to read the information. More recently, scientists have demonstrated the use of helium ion beams for the fabrication and imaging of nano-electronic and nanophotonic devices¹.

An inert gas, helium does not readily combine with other elements — but that hasn't stopped chemists from trying. Investigations into the preparation of HeF_2 through the β -decay of tritium² began in

the 1960s, but with no success yet. Synthetic chemists have made a step in that direction, however, with the preparation of fullerenes — carbon cage molecules — that are able to non-covalently encapsulate a helium atom at their core³. Helium can also combine with other elements to form excimers — short-lived dimeric or heterodimeric molecules. Excimers composed of helium and another element, for example, iodine, tungsten or sulfur, form under conditions of high pressure and electrical stimulation. They are most commonly used to make lasers for applications such as semiconductor processing and eye surgery.

In more recent news helium's antimatter cousin, antihelium, took the spotlight for being the largest antimatter atom ever observed⁴. Particle beams made of gold ions were smashed together at nearly the speed of light, yielding a spray of trillions of particles, among which were the as-yet-unobserved antihelium particles. This experiment came exactly a century after Ernest Rutherford performed the reverse experiment; colliding an alpha particle beam with gold foil, to discover the nucleus in 1911⁵.

From providing an inert atmosphere and cooling systems at very low temperatures to advances in quantum models to applications in medicine, the diversity of the roles adopted by helium in scientific discoveries makes me inclined to pronounce it, both literally and figuratively, the coolest element. □

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