# Hydrogen

Contributed by Administrator
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- ← hydrogen → helium -
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H
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Li periodic table
General Name, Symbol, Number hydrogen, H, 1
Chemical series nonmetals Group, Period, Block 1, 1,
s Appearance colorless
Atomic mass 1.00794(7) g/mol Electron configuration 1s1
Electrons per shell 1 Physical properties Phase gas
Density (0 °C, 101.325 kPa)
0.08988 g/L Melting point 14.01 K
(-259.14 °C, -434.45 °F) Boiling point 20.28 K
(-252.87 °C, -423.17 °F) Triple point 13.8033 K, 7.042 kPa Heat of
fusion (H2) 0.117 kJ/mol Heat of vaporization (H2) 0.904 kJ/mol
Heat capacity (25 °C) (H2)
28.836 J/(mol·K) Vapor pressure P/Pa 1 10 100 1 k
10 k 100 k at T/K 15 20
Critical temperature 32.19 K Critical pressure 1.315 MPa Critical density
30.12 g/L Atomic properties Crystal structure hexagonal
Oxidation states 1, -1
(amphoteric oxide) Electronegativity 2.20 (Pauling scale)
Ionization energies 1st: 1312.0 kJ/mol Atomic radius 25 pm Atomic
radius (calc.) 53 pm (Bohr radius) Covalent radius 37 pm Van
der Waals radius 120 pm Miscellaneous Magnetic ordering ???
Thermal conductivity (300 K) 180.5 mW/(m·K) Speed of sound (gas, 27 °C) 1310 m/s
CAS registry number 1333-74-0 Notable isotopes Main article:
Isotopes of hydrogen iso NA half-life DM
DE (MeV) DP 1H 99.985% H is stable with 0
neutrons 2H 0.015% H is stable with 1 neutrons
3H trace 12.32 y β- 0.019 3He
References

Hydrogen (Latin: hydrogenium, from Greek: hydro: water, genes: forming) is a chemical element in the periodic table that has the symbol H and atomic number 1. At standard temperature and pressure it is a colorless, odorless, nonmetallic, univalent, tasteless, highly flammable diatomic gas. Hydrogen is the lightest and most abundant element in the universe. It is present in water, all organic compounds (rare exceptions exist, such as buckminsterfullerene) and in all living organisms. Hydrogen is able to react chemically with most other elements. Stars in their main sequence are overwhelmingly composed of hydrogen in its plasma state. The element is used in ammonia production, as a lifting gas, as an alternative fuel, and more recently as a power source of fuel cells.

Despite its ubiquity in the universe, hydrogen is surprisingly difficult to produce in large quantities on the Earth. In the laboratory, the element is prepared by the reaction of acids on metals such as zinc. The electrolysis of water is a simple method of producing hydrogen, but is economically inefficient for mass production. Large-scale production is usually achieved by steam reforming natural gas. Scientists are now researching new methods for hydrogen production; if they succeed in developing a cost-efficient method of large-scale production, hydrogen may become a viable alternative to greenhouse-gas-producing fossil fuels. One of the methods under investigation involves the use of green algae; another promising method involves the conversion of biomass derivatives such as glucose or sorbitol at low temperatures using a catalyst. Yet another method is the "steaming" of carbon, whereby hydrocarbons are broken down with heat to release hydrogen. Contents

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## Basic features

Hydrogen is the lightest chemical element; its most common isotope comprises just one negatively charged electron, distributed around a positively charged proton (the nucleus of the atom). The electron is bound to the proton by the Coulomb force, the electrical force that one stationary, electrically charged nanoparticle exerts on another. The hydrogen atom has special significance in quantum mechanics as a simple physical system for which there is an exact solution to the Schrödinger equation; from that equation, the experimentally observed frequencies and intensities of hydrogen's spectral lines can be calculated. Spectral lines are dark or bright lines in an otherwise uniform and continuous spectrum, resulting from an excess or deficiency of photons in a narrow frequency range, compared with the nearby frequencies.

At standard temperature and pressure, hydrogen forms a diatomic gas, H2, with a boiling point of only 20.27 K and a melting point of 14.02 K.[1] Under extreme pressures, such as those at the centre of gas giants, the molecules lose their identity and the hydrogen becomes a metal (metallic hydrogen). Under the extremely low pressure in space—virtually a vacuum—the element tends to exist as individual atoms, simply because there is no way for them to combine. However, clouds of H2 and possibly singular hydrogen atoms are said to form in H I and H II regions and are associated with star formation. Hydrogen plays a vital role in powering stars through the proton–proton and carbon–nitrogen cycle. These are nuclear fusion processes, which release huge amounts of energy in stars and other hot celestial bodies as hydrogen atoms combine into helium atoms.

At high temperatures, hydrogen gas can exist as a mixture of atoms, protons, and negatively charged hydride ions. This mixture has a high emissivity and absorptivity in the visible light range, and plays an important part in the emission of light from the sun and other stars.

H2 is highly soluble in water, alcohol, and ether. It has a high capacity for adsorption, in which it is attached to and held to the surface of some substances. It is an odorless, tasteless, colorless, and highly flammable gas that burns at concentrations as low as 4% H2 in air. It reacts violently with chlorine and fluorine, forming hydrohalic acids that can damage the lungs and other tissues. When mixed with oxygen, hydrogen explodes upon ignition. A unique property of hydrogen is that its flame is completely invisible in air. This makes it difficult to tell if a leak is burning, and carries the added risk that it is easy to walk into a hydrogen fire inadvertently.

See also: hydrogen atom. [edit]

## Applications

Large quantities of hydrogen are needed in the chemical and petroleum industries, notably in the Haber process for the production of ammonia, which by mass ranks as the world's fifth most produced industrial compound. Hydrogen is used in the hydrogenation of fats and oils (found in items such as margarine), and in the production of methanol. Hydrogen is used in hydrodealkylation, hydrodesulfurization, and hydrocracking[2]. The element has several other important uses.

- The element is used in the manufacture of hydrochloric acid, in welding processes, and in the reduction of metallic ores.
- It is an ingredient in rocket fuels.
- It is used as the rotor coolant in electrical generators at power stations, because it has the highest thermal conductivity of any gas.
- Liquid hydrogen is used in cryogenic research, including superconductivity studies.
- The triple point temperature of equilibrium hydrogen is a defining fixed point on the ITS-90 temperature scale.
- Since hydrogen is 14.5 times lighter than air, it was once widely used as a lifting agent in balloons and airships. However, this use was curtailed when the Hindenburg disaster convinced the public that the gas was too dangerous for this purpose.
- Deuterium, an isotope of hydrogen (hydrogen-2), is used in nuclear fission applications as a moderator to slow neutrons, and in nuclear fusion reactions. Deuterium compounds have applications in chemistry and biology in studies of reaction isotope effects.
- Tritium (hydrogen-3), produced in nuclear reactors, is used in the production of hydrogen bombs, as an isotopic label in the biosciences, and as a radiation source in luminous paints.

There are no "hydrogen wells" or "hydrogen mines" on Earth, so hydrogen cannot be considered a primary energy source such as fossil fuels or uranium. Hydrogen can however be burned in internal combustion engines, an approach advocated by BMW's experimental hydrogen car. However, it is currently difficult and dangerous to store and handle in sufficient quantity for motor fuel use. Hydrogen fuel cells are being investigated as mobile power sources with lower emissions than hydrogen-burning internal combustion engines. The low emissions of hydrogen in internal combustion engines and fuel cells are currently offset by the pollution created by hydrogen production. This may change if the substantial amounts of electricity required for water electrolysis can be generated primarily from low pollution sources such as nuclear energy or wind. Research is being conducted on hydrogen as a replacement for fossil fuels. It could become the link between a range of energy sources, carriers and storage. Hydrogen can be converted to and from electricity (solving the electricity storage and transport issues), from biofuels, and from and into natural gas and diesel fuel. All of this can theoretically be achieved with zero emissions of CO2 and toxic pollutants. [edit]

History

Hydrogen was first produced by Theophratus Bombastus von Hohenheim (1493–1541)—also known as Paracelsus—by mixing metals with acids. He was unaware that the explosive gas produced by this chemical reaction was hydrogen. In 1671, Robert Boyle described the reaction between two iron fillings and dilute acids, which results in the production of gaseous hydrogen.[3] In 1766, Henry Cavendish was the first to recognize hydrogen as a discrete substance, by identifying the gas from this reaction as "inflammable" and finding that the gas produces water when burned in air. Cavendish stumbled on hydrogen when experimenting with acids and mercury. Although he wrongly assumed that hydrogen was a compound of mercury—and not of the acid—he was still able to accurately describe several key properties of hydrogen.

Antoine Lavoisier gave the element its name and proved that water is composed of hydrogen and oxygen. One of the first uses of the element was for balloons. The hydrogen was obtained by mixing sulfuric acid and iron. In 1931, Harold C. Urey discovered deuterium, an isotope of hydrogen, by repeated distilling the same sample of water. For this discovery, Urey received the Nobel Prize in Chemistry in 1934. In the same year, the third isotope, tritium, was discovered. Because of its relatively simple structure, hydrogen has often been used in models of how an atom works. [edit]

Electron energy levels

The ground state energy level of the electron in a hydrogen atom is 13.6 eV, which is equivalent to an ultraviolet photon of roughly 92 nm.

With the Bohr Model, the energy levels of hydrogen can be calculated fairly accurately. This is done by modeling the electron as revolving around the proton, much like the earth revolving around the sun. Except the sun holds earth in orbit with the force of gravity, but the proton holds the electron in orbit with the force of electromagnetism. Another difference between the Earth-Sun system and the electron-proton system is that, in this model, due to quantum mechanics the electron is allowed to only be at very specific distances from the proton. Modeling the hydrogen atom in this fashion yields the correct energy levels and spectrum. [edit]

Occurrence

NGC 604, a giant H II region in the Triangulum Galaxy.

Hydrogen is the most abundant element in the universe, making up 75% of normal matter by mass and over 90% by number of atoms. [4] This element is found in great abundance in stars and gas giant planets. It is very rare in the Earth's atmosphere (1 ppm by volume), because being the lightest gas causes it to escape Earth's gravity, though when compounds are considered, it is the tenth most abundant element on Earth. The most common source for this element on Earth is water, which is composed two parts hydrogen to one part oxygen (H2O). Other sources include most forms of organic matter including coal, natural gas, and other fossil fuels. Methane (CH4) is an increasingly important source of hydrogen.

Throughout the universe, hydrogen is mostly found in the plasma state whose properties are quite different to molecular hydrogen. As a plasma, hydrogen's electron and proton are not bound together, resulting in very high electrical conductivity, even when the gas is only partially ionized. The charged particles are highly influenced by magnetic and electric fields, for example, in the solar wind they interact with the Earth's magnetosphere giving rise to Birkeland currents and the aurora.

Hydrogen can be prepared in several different ways: steam on heated carbon, hydrocarbon decomposition with heat, reaction of a strong base in an aqueous solution with aluminium, water electrolysis, or displacement from acids with certain metals. Commercial bulk hydrogen is usually produced by the steam reforming of natural gas. At high temperatures (700–1100 °C), steam reacts with methane to yield carbon monoxide and hydrogen. $CH_4$ + $H_2O$ → CO + 3 $H_2$

Additional hydrogen can be recovered from the carbon monoxide through the water-gas shift reaction: CO + $H_2O$ → $CO_2$ + $H_2$ [edit]

Compounds

The lightest of all gases, hydrogen combines with most other elements to form compounds. Hydrogen has an electronegativity of 2.2, so it forms compounds where it is the more nonmetallic and where it is the more metallic element. The former are called hydrides, where hydrogen either exists as $H^-$ ions or just as a solute within the other element (as in palladium hydride). The latter tend to be covalent, since the $H^+$ ion would be a bare nucleus and so has a strong tendency to pull electrons to itself. These both form acids. Thus even in an acidic solution one sees ions like hydronium ($H_3O^+$) as the protons latch on to something. Although exotic on earth, one of the most common ions in the universe is the $H_3^+$ ion.

Hydrogen combines with oxygen to form water, $H_2O$, and releases significant amounts of energy in doing so, burning explosively in air. Deuterium oxide, or $D_2O$, is commonly referred to as heavy water. Hydrogen also forms a vast array of compounds with carbon. Because of their association with living things, these compounds are called organic compounds, and the study of the properties of these compounds is called organic chemistry.

First tracks observed in Liquid hydrogen bubble chamber. [edit]

Forms

Under normal conditions, hydrogen gas is a mix of two different kinds of molecules which differ from one another by the relative spin of the nuclei.[5] These two forms are known as ortho- and para-hydrogen (this is different from isotopes, see below). In ortho-hydrogen the nuclear spins are parallel and form a triplet, while in para they are antiparallel and form a singlet. At standard conditions hydrogen is composed of about 25% of the para form and 75% of the ortho form (the so-called "normal" form). The equilibrium ratio of these two forms depends on temperature, but since the ortho form has higher energy (is an excited state), it cannot be stable in its pure form. At low temperatures (around boiling point), the equilibrium state is comprised almost entirely of the para form.

The conversion process between the forms is slow, and if hydrogen is cooled down and condensed rapidly, it contains large quantities of the ortho form. It is important in preparation and storage of liquid hydrogen, since the ortho-para conversion produces more heat than the heat of its evaporation, and a lot of hydrogen can be lost by evaporation in this way during several days after liquefying. Therefore, some catalysts of the ortho-para conversion process are used during hydrogen cooling. The two forms have also slightly different physical properties. For example, the melting and boiling points of parahydrogen are about 0.1 K lower than of the "normal" form. [edit]

Isotopes Main Article: Isotopes of hydrogen

Hydrogen is the only element that has different names for its isotopes. (During the early study of radioactivity, various heavy radioactive isotopes were given names, but such names are no longer used, although one element, radon, has a name that originally applied to only one of its isotopes.) The symbols D and T (instead of 2H and 3H) are sometimes used for deuterium and tritium, although this is not officially sanctioned. (The symbol P is already in use for phosphorus and is not available for protium.) 1H

The most common isotope of hydrogen, this stable isotope has a nucleus consisting of a single proton; hence the descriptive, although rarely used, name protium. The spin of a protium atom is 1/2+. [6] 2H

The other stable isotope is deuterium, with an extra neutron in the nucleus. Deuterium comprises 0.0184%–0.0082% of all hydrogen (IUPAC); ratios of deuterium to protium are reported relative to the VSMOW standard reference water. The spin of a deuterium atom is 1+. 3H

The third naturally occurring hydrogen isotope is the radioactive tritium. The tritium nucleus contains two neutrons in addition to the proton. It decays through beta decay and has a half-life of 12.32 years. Tritium occurs naturally due to cosmic rays interacting with atmospheric gases. Like ordinary hydrogen, tritium reacts with the oxygen in the atmosphere to form $T_2O$. This radioactive "water" molecule constantly enters the Earth's seas and lakes in the form of slightly radioactive rain, but its half-life is short enough to prevent a buildup of hazardous radioactivity. The spin of a tritium atom is 1/2+. 4H

Hydrogen-4 was synthesized by bombarding tritium with fast-moving deuterium nuclei. It decays through neutron emission and has a half-life of 9.93696x10-23 seconds. The spin of a hydrogen-4 atom is 2-. 5H

In 2001 scientists detected hydrogen-5 by bombarding a hydrogen target with heavy ions. It decays through neutron emission and has a half-life of 8.01930x10-23 seconds. 6H

Hydrogen-6 decays through triple neutron emission and has a half-life of 3.26500x10-22 seconds. 7H

In 2003 hydrogen-7 was created (article) at the RIKEN laboratory in Japan by colliding a high-energy beam of helium-8 atoms with a cryogenic hydrogen target and detecting tritons—the nuclei of tritium atoms—and neutrons from the breakup of hydrogen-7, the same method used to produce and detect hydrogen-5. [edit]

Biology

Scientists from the University of Colorado at Boulder discovered in 2005 that microbes living in the hot waters of Yellowstone National Park gain their sustenance from molecular hydrogen. [edit]

See also

- Antihydrogen
- Deuterium
- Fuel cell
- Hydrogen atom
- Hydrogen bomb
- Hydrogen bond
- Hydrogen car
- Hydrogen cycle
- Hydrogen economy
- Hydrogen line
- Hydrogen molecule
- Hydrogen spectral series
- Hydrogen station
- Liquid Hydrogen
- Periodic table
- Photohydrogen
- Tritium [edit]

References


- ^ A PDF file from commonsensescience.org on hydrogen. URL accessed on September 15, 2005.
- ^ Los Alamos National Laboratory – Hydrogen. URL accessed on September 15, 2005.
- ^ Webelements – Hydrogen historical information. URL accessed on September 15, 2005.
- ^ Universal Industrial Gases, Inc. – Hydrogen (H2) Applications and Uses. URL accessed on September 15, 2005.
- ^ Jefferson Lab – Hydrogen. URL accessed on September 15, 2005.
- ^ Lawrence Berkeley National Laboratory – Hydrogen isotopes. URL accessed on September 15, 2005.
- RIKEN Beam Science Laboratory, Japan - Heavy hydrogen research
- Nuclides and Isotopes Fourteenth Edition: Chart of the Nuclides, General Electric Company, 1989

Book references

- Stwertka, Albert (2002). A Guide to the Elements, Oxford University Press, New York, NY. ISBN 0195150279.
- Krebs, Robert E. (1998). The History and Use of Our Earth's Chemical Elements : A Reference Guide, Greenwood Press, Westport, Conn.. ISBN 0313301239.
- Newton, David E. (1994). The Chemical Elements, Franklin Watts, New York, NY. ISBN 0531125017.
- Rigden, John S. (2002). Hydrogen : The Essential Element, Harvard University Press, Cambridge, MA. ISBN 0531125017.