Summary Article: hydrogen
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(hi’dräjən) [Gr., =water forming], gaseous chemical element; symbol H; at. no. 1; interval in which at. wt. ranges 1.00784–1.00811; m.p. −259.14 degrees Celsius; b.p. −252.87 degrees Celsius; density 0.08988 grams per liter at STP; valence usually +1.

The Isotopes and Forms

Atmospheric hydrogen is a mixture of three isotopes. The most common is called protium (mass no. 1, atomic mass 1.007822); the protium nucleus (protium ion) is a proton. A second isotope of hydrogen is deuterium (mass no. 2, atomic mass 2.0140), the so-called heavy hydrogen, often represented in chemical formulas by the symbol D. The deuterium nucleus, or ion, is called the deuteron; it consists of a proton plus a neutron. The two isotopes are found in atmospheric hydrogen in the proportion of about 1 atom of deuterium to every 6,700 atoms of protium. Protium and deuterium differ slightly in their chemical and physical properties; for example, the boiling point of deuterium is about 3 degrees Celsius lower than protium. The properties of compounds they form differ depending on the ratio of the two isotopes present.

Deuterium oxide (D₂O), the so-called heavy water, is present in ordinary water; the concentration of deuterium oxide is increased by electrolysis of the water. The melting point (3.79 degrees Celsius), boiling point (101.4 degrees Celsius), and specific gravity (1.107 at 25 degrees Celsius) of deuterium oxide are higher than those of ordinary water. Deuterium oxide is used as a moderator in nuclear reactors. Deuterium is also of importance because of the wide use it has found in scientific research; for example, chemical reaction mechanisms have been studied by the use of deuterium atoms as tracers (i.e., deuterium is substituted for atoms of ordinary hydrogen in compounds), making it possible to follow the course of individual molecules in a reaction.

Tritium (mass no. 3, atomic mass 3.016), a third hydrogen isotope, is a radioactive gas with a half-life of about 12 1/4 years; it is often represented in chemical formulas by the symbol T. It is produced in nuclear reactors and occurs to a very limited extent in atmospheric hydrogen. It is used in the hydrogen bomb, in luminous paints, and as a tracer. The tritium nucleus, or ion, is called the triton; it consists of a proton plus two neutrons. Tritium oxide (T₂O) has a melting point (4.49 degrees Celsius) higher than that of deuterium oxide.

Besides being a mixture of three isotopes, hydrogen is a mixture of two forms, an ortho form and a para form, which differ in their electronic and nuclear spins. At room temperature atmospheric hydrogen is about 3/4 ortho-hydrogen and 1/4 para-hydrogen. The two forms differ slightly in their physical properties.

Properties

Under ordinary conditions hydrogen is a colorless, odorless, tasteless gas that is only slightly soluble in water; it is the least dense gas known. It is the first element in Group 1 of the periodic table. Ordinary hydrogen gas is made up of diatomic molecules (H₂) that react with oxygen to form water (H₂O) and hydrogen peroxide (H₂O₂), usually as a result of combustion. A jet of hydrogen burns in air with a very
hot blue flame. The flame produced by a mixture of oxygen and hydrogen gases (as in the oxyhydrogen blowpipe) is extremely hot and is used in welding and to melt quartz and certain glasses. Hydrogen gas must be used with caution because it is highly flammable; it forms easily ignited explosive mixtures with oxygen or with air (because of the oxygen in the air). At high temperatures hydrogen is a chemically active mixture of monohydrogen (atomic hydrogen) and the normal diatomic hydrogen (see allotropy).

Hydrogen has a great affinity for oxygen and is a powerful reducing agent (see oxidation and reduction). It reacts with nitrogen to form ammonia. With the halogens it forms compounds (hydrogen halides) that are strongly acidic in water solution. With sulfur it forms hydrogen sulfide (H₂S), a colorless gas with an odor like rotten eggs; with sulfur and oxygen it forms sulfuric acid. It combines with several metals to form metal hydrides such as calcium hydride. Combined with carbon (and usually other elements) it is a constituent of a great many organic compounds, such as hydrocarbons, carbohydrates, fats, oils, proteins, and organic acids and bases.

It is theoretically possible for hydrogen to exhibit the properties of a metal, such as electrical conductivity. Although researchers have been able to squeeze hydrogen into liquid and crystalline solid states through applications of intense heat, cold, and pressure, the metallic form eluded them until 1996. By compressing liquid hydrogen to nearly 2 million atmospheres pressure and a temperature of 4,400 degrees Kelvin, a team at the Lawrence Livermore National Laboratory created metallic hydrogen for a millionth of a second. While there is no practical application for the accomplishment, proof of the existence of a metallic form of hydrogen may have implications for theories of how Jupiter’s magnetic field is produced.

**Sources and Commercial Preparation**

While hydrogen is only about one part per million in the atmosphere, it is the most abundant element in the universe. It is believed that hydrogen makes up about three quarters of the mass of the universe, or over 90% of the molecules. It is found in the sun and in other stars, where it is the major fuel in the fusion reactions (see nucleosynthesis) from which stars derive their energy.

Hydrogen is prepared commercially by catalytic reaction of steam with hydrocarbons, by the reaction of steam with hot coke (carbon), by the electrolysis of water, and by the reaction of mineral acids on metals. Millions of cubic feet of hydrogen gas are produced daily in the United States alone.

**Uses**

Hydrogen was formerly used for filling balloons, airships, and other lighter-than-air craft, a dangerous practice because of hydrogen’s explosive flammability; there were disastrous fires, e.g., the immolation of the German airship Hindenburg at its mooring at Lakehurst, N.J., in 1937. Helium is preferable for use in lighter-than-air craft since it is not flammable. Hydrogen is used in the Haber process for the fixation of atmospheric nitrogen, in the production of methanol, and in hydrogenation of fats and oils. It is also important in low-temperature research. It can be liquefied under pressure and cooled; when the pressure is released, rapid evaporation takes place and some of the hydrogen solidifies.

**Discovery of Hydrogen and Its Isotopes**

Although hydrogen was prepared many years earlier, it was first recognized as a substance distinct from other flammable gases in 1766 by Henry Cavendish, who is credited with its discovery; it was named by A. L. Lavoisier in 1783. Deuterium was discovered by H. C. Urey, F. G. Brickwedde, and G. M. Murphy in 1932, although its existence had been suspected for some years. Deuterium oxide was also
discovered by Urey and was first obtained in nearly pure form by G. N. Lewis. Tritium was synthesized by Ernest Rutherford, L. E. Oliphant, and Paul Harteck in 1935.

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