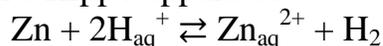


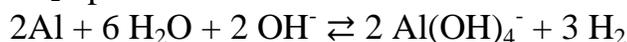
PRODUCTION OF HYDROGEN

Laboratory preparations

In the laboratory, H₂ can be prepared by the action of a dilute non-oxidizing acid on a reactive metal such as zinc, with a Kipp's apparatus.



Aluminium can produce H₂ upon treatment with bases:



The electrolysis of water is another simple method of producing hydrogen. A low voltage current is passed through the water, and gaseous dioxygen forms at the anode while gaseous hydrogen forms at the cathode. Typically the cathode is made from platinum or other inert metal when producing hydrogen for storage. If, however, the gas is to be burnt on site, oxygen is desirable to assist the combustion, and so both electrodes would be made from inert metals. (Iron, for instance, would oxidize, and thus decrease the amount of oxygen given off.) The theoretical maximum efficiency (electricity used versus energetic value of hydrogen produced) is in the range 80-94%.

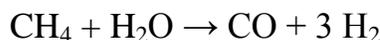


In 2007, it was discovered that an alloy of aluminium and gallium in pellet form added to water could be used to generate hydrogen. The process creates alumina, but the expensive gallium, which prevents the formation of an oxide skin on the pellets, can be re-used. This has important potential implications for a hydrogen economy, as hydrogen could be produced on-site without the need of being transported.

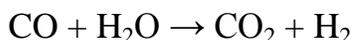
Industrial preparation of hydrogen

[Steam reforming](#) is a method for producing hydrogen, carbon monoxide or other useful products from hydrocarbon fuels such as natural gas. This is achieved in a processing device called a reformer which reacts steam at high temperature with the fossil fuel.

At high temperatures (700 - 1100 °C) and in the presence of a metal-based catalyst (nickel), steam reacts with methane to yield carbon monoxide and hydrogen.



In order to produce more hydrogen from this mixture, more steam is added and the water gas shift reaction is carried out:



The mixture of CO and H₂ is called "[synthesis gas or syngas](#)". Syngas is used as an

intermediate in producing synthetic petroleum for use as a fuel or lubricant via the Fischer-Tropsch process and previously the Mobil methanol to gasoline process.

Enzymatic route from xylose

In 2013 a low-temperature, 50 °C, atmospheric-pressure, enzyme-driven process to convert xylose into hydrogen with nearly 100% of the theoretical yield was announced. The process employed 13 enzymes, including a novel polyphosphate xylulokinase (XK).

It was noted that: "Approximately 50 million metric tons of dihydrogen are produced annually from nonrenewable natural gas, petroleum, and coal. H₂ production from water remains costly. Technologies for generating H₂ from less costly biomass, such as microbial fermentation, enzymatic decomposition, gasification, steam reforming, and aqueous phase reforming, all suffer from low product yields."

Compounds of Hydrogen

The chemistry of hydrogen depends mainly on four processes:

1. donation of the valency electron to form the hydrogen ion, H⁺
2. accepting an electron to form the hydride ion H⁻
3. sharing the electron with a partner atom to form a pair bond (covalent bond) H-H
4. sharing the electron with an ensemble of atoms to form a metallic bond H·

While H₂ is not very reactive under standard conditions, it does form compounds with most elements. Hydrogen can form compounds with elements that are more electronegative, such as halogens (e.g., F, Cl, Br, I), or oxygen; in these compounds hydrogen takes on a partial positive charge. When bonded to fluorine, oxygen, or nitrogen, hydrogen can participate in a form of medium-strength noncovalent bonding called hydrogen bonding, which is critical to the stability of many biological molecules. Hydrogen also forms compounds with less electronegative elements, such as the metals and metalloids, in which it takes on a partial negative charge. These compounds are often known as hydrides.

The term "hydride" suggests that the H atom has acquired a negative or anionic character, denoted H⁻, and is used when hydrogen forms a compound with a more electropositive element. The existence of the hydride anion, suggested by [Gilbert N. Lewis](#) in 1916 for group I and II salt-like hydrides, was demonstrated by Moers in 1920 by the electrolysis of molten lithium hydride (LiH), producing a stoichiometry quantity of hydrogen at the anode.

Although hydrides can be formed with almost all main-group elements, the number and combination of possible compounds varies widely; for example, there are over 100 binary borane hydrides known, but only one binary aluminium hydride. A simple binary indium hydride has not yet been identified, although larger complexes exist.

The position of H in the Periodic Table

In some respects, H does not seem to have a perfect position in the Periodic Table and so many designers have it in more than one position, e.g. in Group 1 or Group 17 and even in Group 14.

Ionization energy of hydrogen

Hydrogen has a single outer electron, like the alkali metals, but they all form positive ions quite readily whereas hydrogen has little tendency to do so. Hydrogen often tends to share its electron with nonmetals rather than losing it to them.

The first ionization energies for H, Li, Na and K are 1312, 520.2, 495.8 and 418.8 kJmol⁻¹. The high IE for H (even bigger than for Xe) can be attributed to the very small size of the atom and the strong attractive force between the proton and electron.



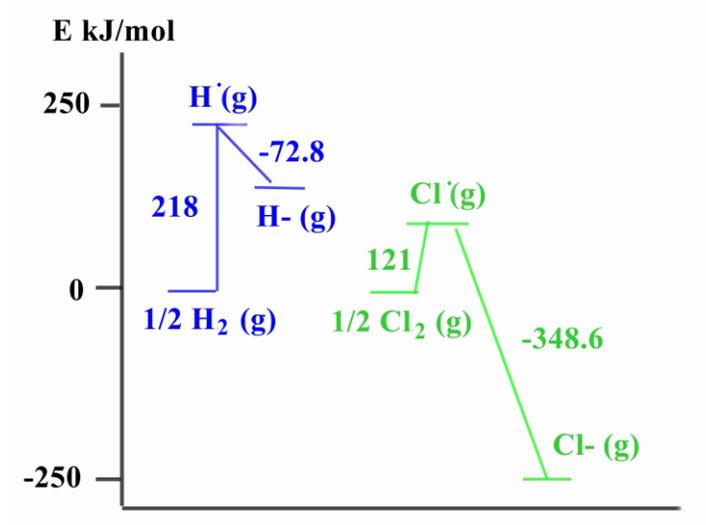
The free proton can only be obtained under extreme conditions such as by an electric arc or in a discharge tube and even then only exists for about half a second. H⁺ can be found in solvated form where the solvation energy provides the energy needed to overcome the very high ionization energy. Examples are in ammonia, alcohol or water with species like NH₄⁺, ROH₂⁺ and H₃O₄⁺ being formed.

The hydrated proton (H₃O₄⁺) will be covered in [Lecture 6 on acid-base chemistry](#).

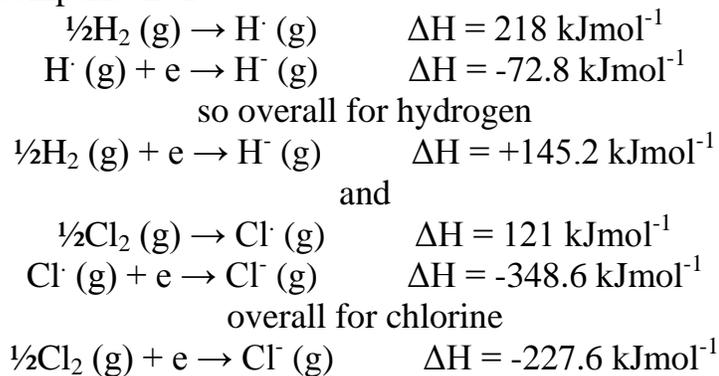
Electron affinity of hydrogen

Hydrogen, like the halogens, exists as diatomic molecules and H atoms have electron configurations with one electron short of a filled outer shell hence the idea of placing H in Group 17. However unlike the halogens with large EA values, the EA for hydrogen is quite small. The formation of H⁻ is much less favourable than the formation of a chloride ion, as seen from the thermodynamic profiles below and it is rare whereas halide ions are

common and stable. In addition H has a lower electronegativity value than any of the halogens.



Much more energy is required as well to break the H-H bond compared to the Cl-Cl bond where the steps for comparison are:



As a result, only the most active elements, whose Ionization Energies are low, can form ionic hydrides, e.g. NaH.

The covalent radius for H is 37 pm and the estimated radius for H^- is ~140 pm indicating a substantial increase. This comes about as a result of the interelectronic repulsion when a second electron is added to the 1s atomic orbital. All the alkali metal hydrides crystallize with the [NaCl-type structure](#) and are all considered ionic. They are sometimes called "saline" hydrides.

Source :

http://wwwchem.uwimona.edu.jm:1104/courses/CHEM1902/IC10K_MG_hydrogen.html