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REVIEW ARTICLE

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Role and Important of Hydrogen in Plant Metabolism

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ABSTRACT

Hydrogen is the simplest and most abundant element in the entire universe. According to astrophysicist David Palmer, about 75 percent of all the known elemental matter that exists is composed of hydrogen. The nucleus of a hydrogen atom is made out of a single proton, which is a positively charged particle. One electron orbits around the outside of the nucleus. Neutrons, which can be found in all other elements, do not exist in the most common form of hydrogen.Hydrogen peroxide (H2O2) is produced predominantly in plant cells during photosynthesis and photorespiration, and to a lesser extent, in respiration processes. It is the most stable of the so-called reactive oxygen species (ROS), and therefore plays a crucial role as a signalling molecule in various physiological processes. Intra- and intercellular levels of H2O2 increase during environmental stresses. Hydrogen peroxide interacts with thiol-containing proteins and activates different signalling pathways as well as transcription factors, which in turn regulate gene expression and cell-cycle processes. Genetic systems controlling cellular redox homeostasis and H2O2 signalling are discussed. In addition to photosynthetic and respiratory metabolism, the extracellular matrix (ECM) plays an important role in the generation of H2O2, which regulates plant growth, development, acclimatory and defense responses. During various environmental stresses the highest levels of H2O2 are observed in the leaf veins.

Most of our knowledge about H2O2 in plants has been obtained from obligate C3 plants. The potential role of H2O2 in the photosynthetic mode of carbon assimilation, such as C4 metabolism and CAM (Crassulacean acid metabolism) is discussed. We speculate that early in the evolution of oxygenic photosynthesis on Earth, H2O2 could have been involved in the evolution of modern photosystem II.
Key words: H2O2, Hydrogen and Plant metabolism.

INTRODUCTION

The amount of hydrogen in the soil affects pH and the availability of other elements. The best pH range for most nutrients to be available is from 6.0 to 7.0. Nutrient deficiencies can be observed at both high and low pH values. So hydrogen plays a key role in the development of plants. Let's look at all of these elements briefly:

• CARBON – All living beings contain carbon. Plants get carbon dioxide (CO2) from the air. With the help of water and sunlight, they produce starches and sugars by photosynthesis. Animals and humans absorb carbon dioxide from the atmosphere; eat the products of photosynthesis as food and convert carbon into carbon dioxide during respiration and release carbon dioxide back into the atmosphere.

• Hydrogen – As we all know, life cannot exist without water. Hydrogen comes from splitting water (H2O) into hydrogen gas and oxygen. Hydrogen is used by plants which combine it with carbon during the photosynthesis process and release oxygen into the atmosphere which is used by all living beings. In the early 1500s the alchemist Paracelsus noted that the bubbles given off when iron filings were added to sulfuric acid were flammable. In 1671 Robert Boyle made the same observation. Neither followed up their discovery of hydrogen, and so Henry Cavendish gets the credit. In 1766 he collected the bubbles and showed that they were different from other gases. He later showed that when hydrogen burns it forms water, thereby ending the belief that water was an element. The gas was given its name hydro-gen, meaning water-former, by Antoine Lavoisier.

Hydrogen is a unique atom, because it has only two spots in its outermost electron level. Helium has two electrons and exhibits the properties of a noble gas. Hydrogen's valence number is one, because it has only one valence electron and needs only one shared electron to fill its energy levels. This means it can bond with many elements. For example, four hydrogen atoms can bond with a carbon atom, which has four valence electrons, to form methane. Similarly, three hydrogen atoms can bond with a nitrogen atom, which has five valence electrons, to form ammonia. Because hydrogen can either share an electron or lose an electron to have a full or empty outer shell, it can form ionic bonds as well. Hydrogen can give its lone electron to a chemical like fluorine or chlorine which has seven electrons in their outermost shells. Similarly, because hydrogen has properties of both group one and group seven on the periodic table, it can bond with itself to make hydrogen molecules. Hydrogen can also lose its valence electron in solution to make a positive hydrogen ion, which is what causes acidity in solution Arrhenius 1921.

Hydrogen and all the other atoms in group one of the periodic table (including lithium, sodium and potassium) have a valence of one. Group two atoms (including beryllium, magnesium, calcium, strontium and barium) have a valence of two. Atoms with more than two valence electrons can have more than one valence, but their maximum valence is usually the same number as their valence electrons. Groups three through 12 (the transition elements, including most metals) have varying valences between one and seven. Group 13 atoms (including boron and aluminum) have a maximum valence of three. Group 14 atoms (including carbon, silicon and germanium) have a maximum valence of four. Group 15 atoms (including nitrogen, phosphorus and arsenic) have a maximum valence of five. Group 16 atoms (including oxygen, sulfur and selenium) have a maximum valence of six. Group 17 atoms (including fluorine, chlorine and bromine) have a maximum valence of seven. Group 18 atoms, the noble gases (including neon and argon), have eight valence electrons, but because they almost never share these electrons, they are said to have a valence of zero Cain 1931 .

Table 1. Characterization of Isotope Hydrogen.

Isotope	Atomic mass	Natural abundance (%)	Half life	Mode of decay
1H	1.008	99.9885	-	-
2H	2.014	0.0115	-	-
3H	3.016	-	12.31y	B-

In 1931, Harold Urey and his colleagues at Columbia University in the US detected a second, rarer, form of hydrogen. This has twice the mass of normal hydrogen, and they named it deuterium Eyrolle-Boyer et al. 2014.

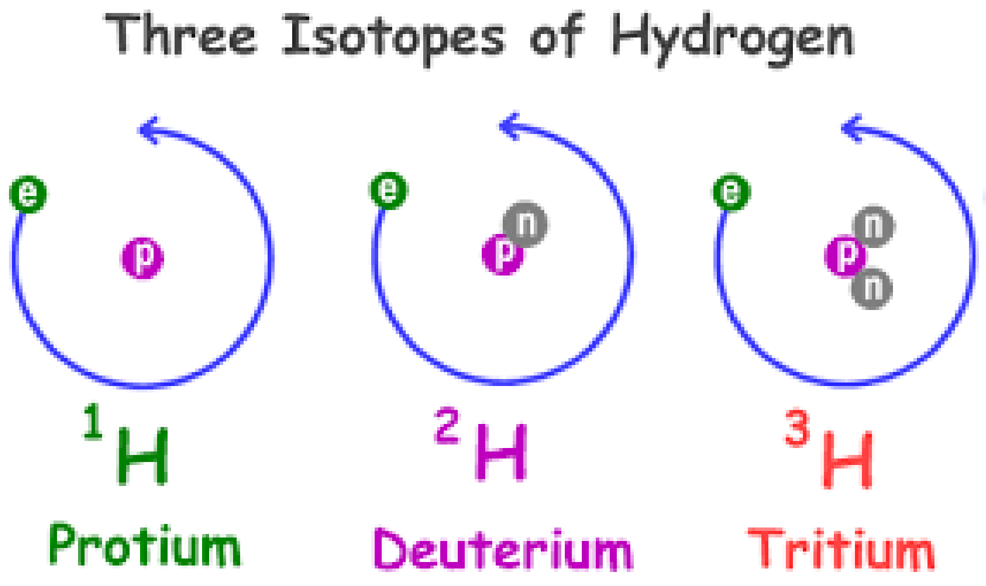

Fig 1. Three Isotopes of hydrogen.

• Oxygen – All living beings need oxygen for respiration. Air contains about 20% oxygen. During the day (or artificial light at night), plants absorb carbon dioxide from the atmosphere and release oxygen.

• Nitrogen – Like carbon, hydrogen and oxygen, all living beings also need nitrogen to make proteins. Even though air consists of about 80% nitrogen, it cannot be used by plants directly as gas. Many bacteria in the soil convert nitrogen from the atmosphere into compounds that can be absorbed by the plants. Also Rhizhobia on legumes, like those in the root nodules of soybeans, convert nitrogen into nitrates, a form of nitrogen that can be used by plants.

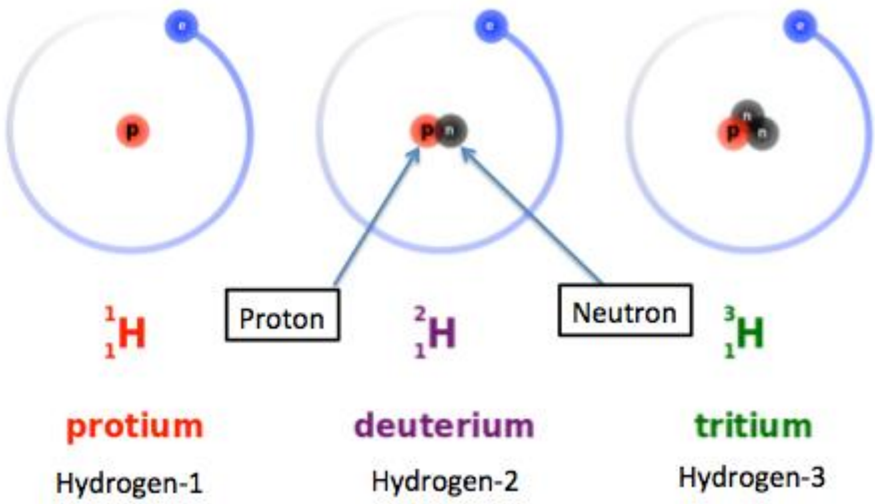

Fig 2. Three Isotopes of hydrogen and their uses.

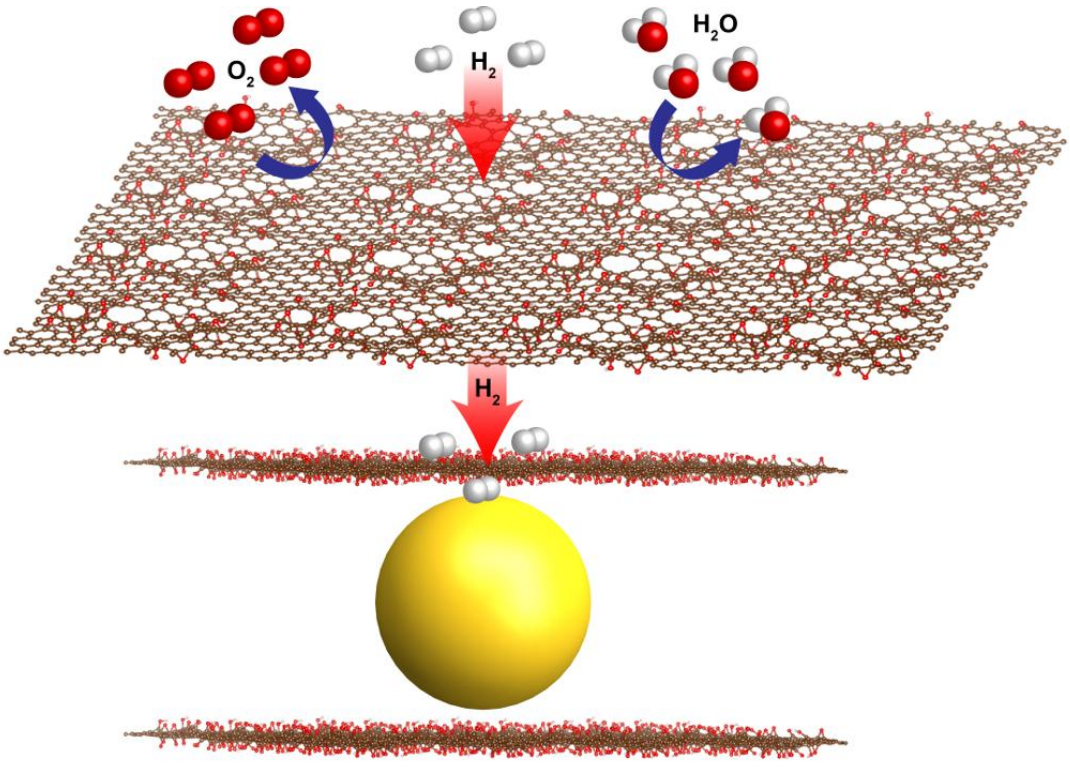

Fig 3. Graphene-wrapped Nanocrystals Power.

Fig 3 show thin sheets of graphene oxide (red sheets) have natural, atomic-scale defects that allow hydrogen gas molecules to pass through while blocking larger molecules such as oxygen (O2) and water (H2O). Berkeley Lab researchers encapsulated.

In living organisms, carbon and hydrogen make easy partners. The element carbon has two orbiting layers, called shells, surrounding its nucleus. The outer shell contains four electrons. These four electrons can form separate covalent bonds with other elements, which means that they bond together by sharing electrons. Hydrogen has only electron to share, so it can bond only once, but up to four hydrogen atoms can bond to one carbon atom. However, hydrogen has some unique properties. Sometimes it shares electrons unequally with an electronegative atom, such as oxygen or nitrogen. When this happens, hydrogen develops a slight positive charge, which attracts other negatively charged particles. Because opposites attract, they bond together without sharing electrons. This is called a hydrogen bond. They are weak but useful in living organisms for forming short-lived and easy connections.
The way in which carbon bonds to hydrogen, as well as other elements, such as oxygen and phosphorus, is called an organic molecule, which is a fundamental molecule that constitutes all life. Carbon is ultimately the cornerstone for life because its bonding patterns create complex structures that fold, bend, chain together or form rings. Carbon and hydrogen atoms are so prevalent in living organisms that there are molecules called hydrocarbons that are made up almost entirely of carbon and hydrogen.

Complex organic structures form large macromolecules, such as carbohydrates, lipids, proteins and nucleic acids that are composed of thousands of atoms in the form of small units bonded together. Think of the winding double helix of DNA. This molecule is composed of two twisting strands bound together by hydrogen bonds. When DNA needs to unwind so that it can be read, the weak hydrogen bonds are broken. In carbohydrates, however, hydrogen atoms actually act as placeholders. Once the hydrogen is removed, two sugars bond together and form long repeating chains of a strongly linked unit. This also holds true for many fatty lipids and proteins. Besides acting as an important structural element, hydrogen has a hand in nearly every single physiological function of living organisms due to its usefulness and abundance. In the task of digestion, hydrogen bonds with chlorine to form hydrochloric acid, which breaks down fat and protein in the stomach. In the task of aerobic respiration, the movement of free-floating hydrogen atoms helps stimulate the production of energy; this is similar to the way in which a water pump can create energy potential that can do work. Next to carbon, there is probably no other element used quite so often and for so many important functions.

Most research into hydrogen storage is focused on storing hydrogen as a lightweight, compact energy carrier for mobile applications. Liquid hydrogen or slush hydrogen may be used, as in the Space Shuttle. However liquid hydrogen requires cryogenic storage and boils around 20.268 K (−252.882 °C or −423.188 °F). Hence, its liquefaction imposes a large energy loss (as energy is needed to cool it down to that temperature). The tanks must also be well insulated to prevent boil off but adding insulation increases cost. Liquid hydrogen has less energy density by volume than hydrocarbon fuels such as gasoline by approximately a factor of four. This highlights the density problem for pure hydrogen: there is actually about 64% more hydrogen in a liter of gasoline (116 grams hydrogen) than there is in a liter of pure liquid hydrogen (71 grams hydrogen). The carbon in the gasoline also contributes to the energy of combustion. Compressed hydrogen, by comparison, is stored quite differently. Hydrogen gas has good energy density by weight, but poor energy density by volume versus hydrocarbons, hence it requires a larger tank to store. A large hydrogen tank will be heavier than the small hydrocarbon tank used to store the same amount of energy, all other factors remaining equal. Increasing gas pressure would improve the energy density by volume, making for smaller, but not lighter container tanks (see hydrogen tank). Compressed hydrogen costs 2.1% of the energy content to power the compressor. Higher compression without energy recovery will mean more energy lost to the compression step. Compressed hydrogen storage can exhibit very low permeation

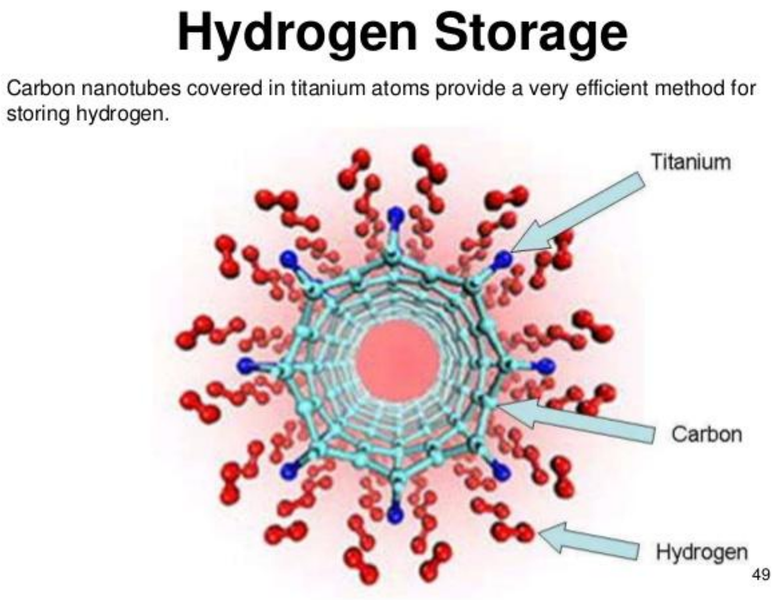

Fig 4. Carbon nanotubes covered in titanium atoms provide a very efficient method for storing hydrogen.

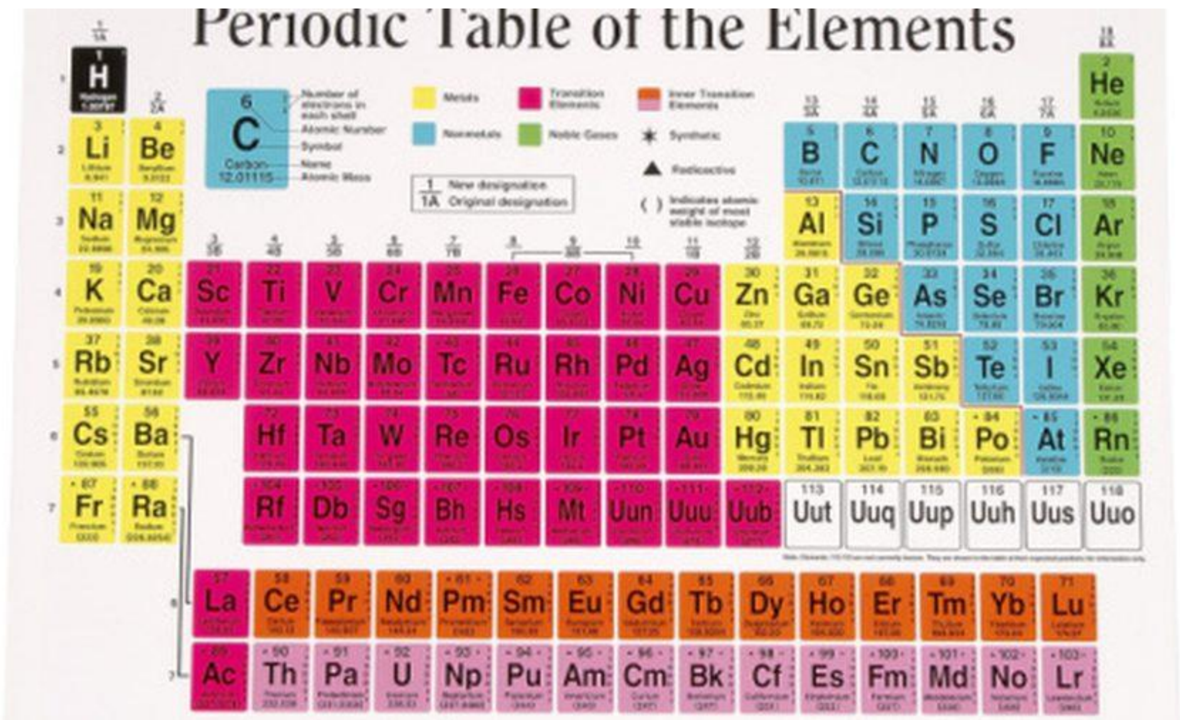

Fig 5. Periodic table of the elements.

CONCLUSION

As different as each living organism may appear to be on the surface, all life is made up of basically the same molecules at the core. These molecules are formed by the way in which carbon, hydrogen, oxygen and other elements bond together. Hydrogen, which is the same element that makes up gas clouds and huge stars, also plays an important role in the composition of life. Variability of the soil reaction apparently depends to a considerable extent on the amount of organic material, the degree of leaching, and the plant cover. The soil was mostacid under the hemlocks and least acid under beech and birch.

The majority of plants studied showed a fairly wide range, within certain limits, of reaction tolerance. The herbaceousplants appeared to be somewhat more sensitive to soil acidity than the trees as a group. Of the microflora, the molds were more acid tolerant than the bacteria in soils with a pH less.

Hydrogen also has many other uses. In the chemical industry it is used to make ammonia for agricultural fertilizer (the Haber process) and cyclohexane and methanol, which are intermediates in the production of plastics and pharmaceuticals. It is also used to remove sulfur from fuels during the oil-refining process Epstei et al. 1976.

Scientists had been producing hydrogen for years before it was recognized as an element. Written records indicate that Robert Boyle produced hydrogen gas as early as 1671 while experimenting with iron and acids. Composed of a single proton and a single electron, hydrogen is the simplest and most abundant element in the universe. It is estimated that 90% of the visible universe is composed of hydrogen Diagnac et al. 2005..

Hydrogen is the raw fuel that most stars 'burn' to produce energy. The same process, known as fusion, is being studied as a possible power source for use on earth. The sun's supply of hydrogen is expected to last another 5 billion years. Hydrogen is a commercially important element. Large amounts of hydrogen are combined with nitrogen from the air to produce ammonia (NH_3) through a process called the Haber process. Hydrogen is also added to fats and oils, such as peanut oil, through a process called hydrogenation. Liquid hydrogen is used in the study of superconductors and, when combined with liquid oxygen, makes an excellent rocket fuel. Hydrogen combines with other elements to form numerous compounds. Some of the common ones are: water (H_2O), ammonia (NH_3), methane (CH_4), table sugar ($C_{12}H_{22}O_{11}$), hydrogen peroxide (H_2O_2) and hydrochloric acid (HCl) Haynes 2014.

Hydrogen has three common isotopes. The simplest isotope, called protium, is just ordinary hydrogen. The second, a stable isotope called deuterium, was discovered in 1932. The third isotope, tritium, was discovered in 1934.

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