Hydrogen - Will you be using it in the future?

What is Hydrogen?

Hydrogen (H) is a colourless, odourless, tasteless, and highly flammable gaseous substance, representing the simplest member of the chemical elements. Its atom consists of a nucleus containing a single proton with a positive electrical charge, which orbits an electron carrying a negative charge. In standard conditions, hydrogen gas exists as loosely bound hydrogen molecules, each comprising a pair of atoms forming a diatomic molecule, H2. Notably, hydrogen's earliest recognised chemical property is its ability to combine with oxygen to produce water (H2O), a trait reflected in its name derived from Greek roots meaning "maker of water."

Despite being the most abundant element in the universe, surpassing even helium, hydrogen constitutes only around 0.14 percent of Earth's crust by weight. However, it exists in vast quantities within water bodies, including oceans, ice caps, rivers, lakes, and the atmosphere. It is also ubiquitous in countless carbon compounds, being present in all animal and plant tissues as well as in petroleum. While carbon is often credited with forming the most known compounds, hydrogen's presence in nearly all carbon compounds and its ability to create numerous compounds with other elements suggest that hydrogen compounds might outnumber those of carbon.

Industrially, elemental hydrogen is primarily used in the production of ammonia (NH3), a compound formed from hydrogen and nitrogen, and in processes such as the hydrogenation of carbon monoxide and various organic compounds.

Hydrogen exhibits three known isotopes, each characterised by distinct mass numbers: 1, 2, and 3. The most prevalent isotope, with a mass number of 1, is commonly referred to as hydrogen (symbol H or 1H) and also known as protium. The isotope with a mass number of 2, featuring a nucleus comprising one proton and one neutron, is termed deuterium or heavy hydrogen (symbol D or 2H), constituting approximately 0.0156 percent of the typical hydrogen mixture. Tritium (symbol T or 3H), possessing one proton and two neutrons in its nucleus, represents the mass 3 isotope and accounts for approximately 10^-15 to 10^-16 percent of hydrogen. The distinct naming of hydrogen isotopes is justified by their notable differences in properties.

How to make Hydrogen?

Electrolysis

Obtaining hydrogen from water, H2O, can be achieved easily through a process called electrolysis, which separates water into hydrogen and oxygen gas.

Materials Required:
Water
9-volt battery
2 paperclips
Another container filled with water

Steps:
1) Straighten the paperclips and attach one to each terminal of the battery.
2) Submerge the free ends of the paperclips, ensuring they do not touch, into a container of water.
3) Bubbles will form at both wire ends. The wire generating more bubbles is producing pure hydrogen, while the other bubbles consist of impure oxygen.
4) To verify the gas, ignite a match or lighter above the container. Hydrogen bubbles will burn, but oxygen bubbles won't.
5) Collect the hydrogen gas by placing an inverted tube or jar filled with water over the wire generating hydrogen. This prevents air from entering the container, as air contains 20% oxygen, making it dangerously flammable.
6) Avoid mixing the gases by collecting them separately; combining them could lead to explosive combustion.
7) Seal the container before inverting it to prevent air exposure, and disconnect the battery to complete the process.

Thermochemical

Thermochemical water splitting harnesses high temperatures, derived from concentrated solar power or the residual heat from nuclear reactions, along with chemical reactions, to extract hydrogen and oxygen from water. Representing a long-termtechnological approach, it holds the promise of minimal to zero greenhouse gas emissions.

These processes involve subjecting water to intense heat (ranging from 500° to 2,000°C) to initiate a sequence of chemical transformations resulting in hydrogen production. Notably, the substances utilised in these reactions are recycled within each cycle, establishing a closed-loop system that utilises solely water while yielding hydrogen and oxygen as outputs.

Biological

Microorganisms such as bacteria and microalgae have the capacity to generate hydrogen through biological processes, leveraging sunlight or organic materials. While these technological avenues are currently undergoing research and development, with pilot demonstrations underway, they hold promise for sustainable, low-carbon hydrogen production in the future.

Is Hydrogen flammable?

Hydrogen poses no greater or lesser risk than other flammable fuels, such as fuel or natural gases. In fact, some of hydrogen's unique characteristics offer safety advantages compared to traditional fuels. However, responsible handling is essential for all flammable substances. Like fuel and natural gas, hydrogen is flammable and can present hazards under specific circumstances. Nonetheless, hydrogen can be managed safely by adhering to simple guidelines and understanding its behavior.

Hydrogen is lighter than air and disperses rapidly. With a diffusion rate 3.8 times faster than natural gas, released hydrogen quickly dilutes into non-flammable concentrations. It ascends twice as fast as helium and six times faster than natural gas, traveling at nearly 45 mph (20 m/s). Therefore, if in a poorly ventilated space, hydrogen swiftly rises and disperses, minimising the risk of accumulation near a leak or individuals using hydrogen-based equipment. Thus, confining hydrogen, being the lightest element, proves challenging, influencing the design of structures in hydrogen-utilising industries to facilitate its upward dispersion in case of a release.

Hydrogen flames emit low radiant heat, primarily generating heat and water vapor upon combustion. This is attributed to the absence of carbon and the presence of water vapour, which absorbs heat during hydrogen combustion, resulting in significantly lower radiant heat compared to hydrocarbon fires. As a result, the risk of secondary fires is diminished, which holds considerable importance for both the general public and rescue personnel.

Despite its combustibility, containing and creating a combustible scenario with hydrogen proves challenging due to its buoyancy, diffusivity, and small molecular size. For a hydrogen fire to occur, an adequate concentration of hydrogen, an ignition source, and the right amount of oxidiser, such as oxygen, must converge simultaneously. Hydrogen exhibits a wide flammability range (474% in air), with the energy required for ignition being very low (0.02mJ). However, at low concentrations (below 10%), the ignition energy is relatively high.

Under conditions where hydrogen concentration approaches the stoichiometric mixture of 29% hydrogen in air, the ignition energy decreases to approximately one-fifteenth of that required for natural gas (or one-tenth for fuel), making hydrogen more easily ignitable.

5 areas where Hydrogen is being used

Hydrogen's versatility and utility extend across a wide array of industries, contributing to its growing adoption and integration into modern technological advancements. Here's a closer look at some key sectors where hydrogen plays a significant role:

1) Transportation: Hydrogen is increasingly being utilised as a clean energy source in the transportation sector. Hydrogen fuel cells power various vehicles, including cars, buses, trucks, and trains. These fuel cells convert hydrogen gas into electricity through an electrochemical process, providing a sustainable alternative to traditional internal combustion engines. Additionally, hydrogen is being explored for use in aviation, with research and development efforts focused on developing hydrogen-powered aircraft, which could significantly reduce emissions in the aviation industry.

2) Energy Storage: One of the most promising applications of hydrogen is its role as an energy storage medium. Renewable energy sources such as wind and solar power often generate excess electricity that cannot be immediately utilised. Hydrogen can be produced through electrolysis using this surplus electricity, storing it in the form of hydrogen gas. This stored hydrogen can then be converted back into electricity when demand is high, providing a reliable and efficient means of energy storage for grid balancing and backup power generation.

3) Industrial Processes: Hydrogen serves as a crucial feedstock in various industrial processes across sectors such as petroleum refining, ammonia production for fertilisers, and methanol production. It is also utilised in food processing, electronics manufacturing, and metal refining. Its use in these processes contributes to increased efficiency, reduced emissions, and overall process optimisation.

4) Power Generation: Hydrogen combustion can be directly used to generate electricity in gas turbines or internal combustion engines. By burning hydrogen, heat is produced, which is then converted into mechanical energy to drive generators and produce electricity. This process offers a low-emission alternative to traditional fossil fuels, helping to reduce greenhouse gas emissions and mitigate climate change.

5) Heating and Cooling: Hydrogen can be used as a fuel for heating buildings and water, either through combustion or in fuel cells that generate both heat and electricity simultaneously. Additionally, hydrogen-powered air conditioning and refrigeration systems are being explored as a sustainable solution for cooling applications.

Use of Hydrogen in the UK

In the United Kingdom, hydrogen is increasingly recognised as a key component of the country's efforts to achieve its climate and energy goals. Many Hydrogen Hubs are opening up in the UK, you can find a few of the biggest in the UK below.

'Bradford hydrogen energy hub plans approved'

Plans have been approved to build one of the country's biggest hydrogen refuelling stations in Bradford.

The facility at the Birkshall gas storage site on Bowling Back Lane will have the capacity to produce about 12.5 tonnes of hydrogen per day. Operator Hygen said the site could achieve the decarbonisation equivalent of removing 800 diesel-fuelled buses a day from West Yorkshire's roads. Hygen director Jamie Burns said the HyBradford facility would "provide enormous benefits to the people of Bradford".

The project, which has received millions in government funding, is a partnership between Hygen and N-GEN and was approved by Bradford Council this week, according to the Local Democracy Reporting Service.

The facility "will provide enormous benefits to the people of Bradford", Hygen says
Hydrogen is increasingly seen as a greener way of fuelling larger vehicles such as HGVs, buses and coaches.

Gareth Mills, managing director at N-Gen, said: "We are extremely proud to be bringing a flagship hydrogen production facility and significant investment to Bradford. "We expect the facility to be a valuable addition to the Bradford economy, providing a viable way for local businesses to decarbonise, as well as attracting new companies and jobs to the area, by placing the city at the forefront of the transition to clean energy."

Businesses and other users will be able to use refuelling facilities at the site when it opens.

Source: BBC News

'£69m boost for Cranfield University 'Hydrogen Hub"

The largest hydrogen research hub at any UK airport will be built at a Bedfordshire university.

Science and Technology specialists at an airport run by Cranfield University have successfully bid for £69m to continue examining how the fuel can help meet zero emissions targets.

It is the largest research funding win in the university's history and cash will also be used for equipment and staffing to support the project. Prof Karen Holford said: "It's a very exciting prospect for our researchers, partners and for the aviation industry."

As the only university in Europe with its own airport, Cranfield has a controlled airside environment which can demonstrate, test and advance new technologies.

With the Government setting domestic aviation a target of achieving net zero emissions by 2040, the Cranfield Hydrogen Integration Incubator (CH2i) will support the industry in moving towards the use of the fuel at scale.

It will provide an environment to develop the production of technologies as well as storage tanks, aircraft designs and engines that are urgently required to accelerate the adoption of hydrogen in a net zero world.

The project includes building new labs to create an on-site Hydrogen Integration Research Centre. There will also be an upgrade of test areas to support hydrogen and liquid hydrogen activity, plus development of Cranfield Airport's infrastructure, increasing its capability for safe operation and testing.

Cranfield claims to be the only university in Europe with its own airport, which can demonstrate, test and advance new technologies.

Prof Holford said: "Working with research and industry partners nationally and internationally, we will unlock some of the most significant technical challenges around the future development and deployment of hydrogen in aviation.

Source: BBC News

'Saltend: Hydrogen energy site given the green light'

Plans for a hydrogen and carbon capture plant which could create thousands of jobs have been approved for a site in East Yorkshire.

Equinor, an energy company based in Norway, is behind the plans for "H2H Saltend".

The idea is to cut emissions at the Saltend Chemicals Park by up to a third - the equivalent of taking around 500,000 cars off the road. It is understood work could begin by 2026 and create about 2,200 jobs. The plant is being described as "one of the UK's key decarbonisation projects" according the Local Democracy Reporting Service (LDRS).

Under the plans a 600-megawatt, low-carbon hydrogen plant will be built at the existing energy park to the east of Hull. The hydrogen produced will be used by companies on the park and directly replace natural gas in a number of industrial facilities. The proposals aim to make the Humber net-zero by 2040. The site will also create a carbon capture and storage facility. It's hoped almost 900,000 tonnes of CO_2 will also be captured and sent for storage below the North Sea.

The Humber region produces about 12.4m tonnes of CO_2 every year, and Saltend Chemicals Park produces roughly the same amount of emissions as the whole of Merseyside.

Equinor said: "These proposals aim to make the Humber, the UK's most carbon intensive industrial region, net-zero by 2040."

Cllr Anne Handley, the leader of East Riding of Yorkshire Council, said: "We welcome major energy projects from global companies like Equinor, which help to demonstrate the ability of our area to attract investment, leading to more jobs, supply chain contracts and opportunities for local people.

"We should be proud that East Yorkshire can be a leading light in the transition to a net zero economy."

Source: BBC News

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