17. Water electrolysis

A hydrogen – powered car

Overview

This car runs on hydrogen gas, which is made by splitting water into hydrogen and oxygen.

What's happening?

An electrical current from either a solar cell or battery pack is fed into a reversible fuel cell, which separates water into hydrogen gas and oxygen gas. These are stored in small transparent tanks on the vehicle; the design of the car allows audiences to see the gases being produced. Roughly twice the amount of hydrogen will be produced compared to oxygen, which is a nice demonstration of the proportions of these elements to each other in water. It takes 15-20 minutes to produce enough hydrogen gas to run the car for 3-5 minutes. Once there is enough hydrogen gas, the power source is removed, and the hydrogen gas is fed back into the fuel cell, which splits the gas into protons and electrons, providing an electrical current for the motor to run.

Why is this important?

It is surprising that water comprises two elements that are usually thought of as gases. Children may be familiar with phase transitions but not that elements like hydrogen and oxygen can form molecules with such different properties. This demonstration can help people gain a basic understanding of how atoms and molecules relate.

Electricity is the flow of electrons. Electrons are also central to the structure of atoms. This demonstration offers a way to visualise their dual role, as we see their flow through the system affecting the properties of the substances. The demonstration also gives an opportunity to discuss how negative and positive charges attract.

More stories to tell

What is water, and why does it conduct electricity?

Each water molecule contains two hydrogen atoms and one oxygen atom (H_2O), which are held together by nuclear forces. These atoms contain negatively-charged electrons, which are involved in bonding. H_2O molecules do not conduct electricity, but they can dissociate into H^+ and OH^- ions, which leads to a small amount of conductivity. This conductivity is overwhelmingly due to the presence of impurities, and electrolytes like salts or acids are often used in electrolysis demos to help mediate the movement of electrons.

So what is electrolysis?

It means 'splitting by electricity'. The differently-charged electrodes attract different parts of the dissociated molecule, and oxidise/reduce these so that they cannot recombine. This involves movement of electrons from the cathode to the anode through the liquid, completing the circuit.

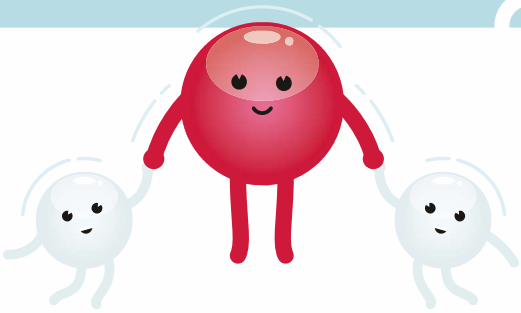
What is happening at the electrodes? At the positively charged electrode (anode), water ($2\ H_2O$) is dissociating. Negatively-charged electrons ($4e^-$) are lost to the anode, leaving oxygen gas (O_2) and hydrogen ions ($4\ H^+$). The gas bubbles up out of solution while the ions remain in solution. Losing electrons is called 'oxidation', so water is oxidised at the anode.

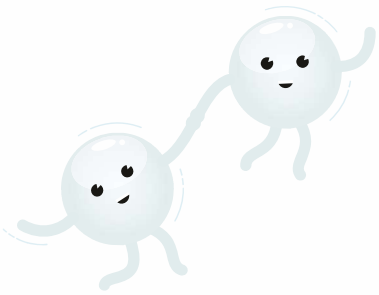
At the negatively-charged electrode, positively-charged hydrogen ions ($2\ H^+$) from the solution gain negatively-charged electrons ($2e^-$) from the cathode to form hydrogen gas (H_2). Gaining electrons is called 'reduction'. Hydrogen ions are also known as protons, because hydrogen atoms only contain one proton and one electron. These hydrogen ions are reduced at the cathode to form hydrogen gas.

The Activity

The car is an interactive piece of kit; best suited to small groups or meet the expert sessions. You can challenge people to predict how much of each gas will be liberated. It should be possible to see that there is approximately twice the amount of hydrogen as oxygen (be aware this will not be exact due to the nature of the reaction).

The car will run for around 3-5 minutes, after around 15-20 minutes of electrolysis from either a solar cell or battery pack. As a result, it's not really suitable for use in a show, but presents a nice talking point for small demos or 'meet the expert' sessions. It will run without being controlled, and will 'feel' its way around obstacles placed in its path.





Extra information

Electrolysis is seldom used in industry as hydrogen can be produced more easily from fossil fuels, and producing the energy required to electrolyse water often outweighs the benefits of the energy produced.

Troubleshooting

If the gases are not appearing in the tanks, there may be a loose connection with either the pipes or the vessels inside the gas tanks. Check the full troubleshooting guide in the supplied instructions.

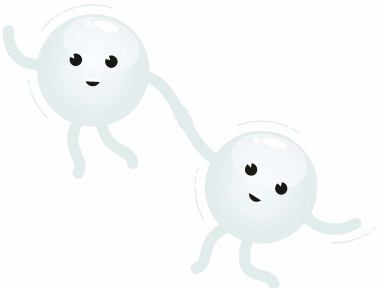
The car will run best on a smooth surface, such as a table top or laminate floor.

Health and Safety

Every delivery centre must undertake their own risk assessments for the specific audiences, locations and conditions they are presenting in. Sample assessments are available on The Secret World of Gases website. Below is a guide to the key risks and hazards:

1. Hydrogen is a flammable gas; therefore keep this piece of equipment away from naked flames.

2. Because the car is an open and transparent design, it is fairly delicate, and contains small parts. These can present a choke hazard for very young children.



SECRET GAS FACT

With 1/6th gravity of the Earth, our Moon has water ice. Electrolysis of this water to produce oxygen and hydrogen to refuel rockets, is an exciting prospect for the future of space exploration.