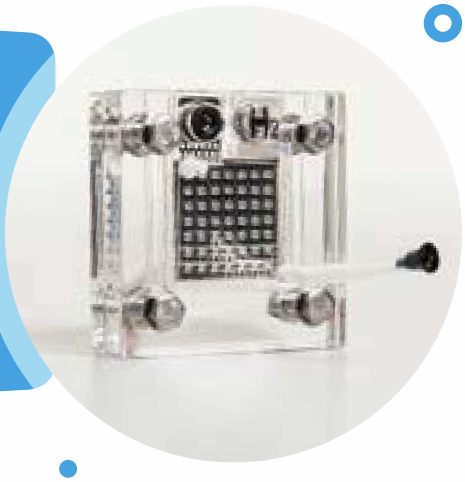
15. Hydrogen fuel cells

Burning hydrogen without a flame



Overview

Clean energy transfer, from chemical to electrical.

How it works

Inside the fuel cell are electrochemical cells, similar to what you'd find inside a battery. There are two electrodes: a positively-charged cathode, and a negatively-charged anode. In a proton-exchange membrane fuel cell (the type provided), there are two routes from the anode to the cathode:

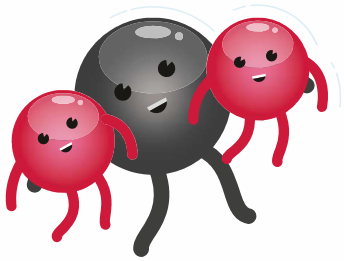
i) A conducting route for negatively-charged electrons (e-) to move through, creating current.

ii) A non-conducting route, through a membrane, for positively-charged hydrogen ions (H+, aka protons). Their movement continually rebalances the charges across the system.

Why is this important?

These portable fuel cells are a way of producing electrical energy from a chemical reaction. Compared with batteries, the main difference is that the source of fuel for a battery is inside the battery itself, and once it's finished, the battery needs to be recharged or replaced. With a fuel cell, the source of fuel is fed in from an external source (such as the Hydrostik or hydrogen balloon provided) and combined with oxygen from the air to provide energy.

These fuel cells are great for things like buses, as they do not pollute their local environment, and mass transportation systems such as buses are one area that hydrogen fuel cells are beginning to be used around the UK (see activity 18 for more on this). In The Secret World of Gases, these hydrogen fuel cells are used to power the hydrogen powered bus, the hydrogen powered car, and the Hydrogen house.



> Fuel cells are great for things like buses

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Where does the hydrogen go?

Once it has been fed into the fuel cell, the hydrogen gas is stripped of its electrons at the anode:

$H_2 \rightarrow 2\ H^+ + 2e^-$

Both products travel to the cathode. Electrons (e-) travel through the conducting pathway, creating electrical current as they flow. Hydrogen ions (H+) diffuse across the membrane.

At the cathode, electrons and hydrogen ions can meet again, in the presence of oxygen (from air). Hydrogen ions, electrons and oxygen all combine to form water:

$4\ H^+ + O_2 + 4e^- \rightarrow 2\ H_2O$

So, the hydrogen from the gas ends up within water molecules; a very clean waste product! This is the same overall reaction that occurs when you burn hydrogen in air with a flame.

Where does the energy come from?

Atoms 'like' being bonded. It takes energy to break them apart, and energy is released when they re-bond. Different types of bond have different energies. The products in this reaction are 'happier' (in a lower energy state) than the reactants. This means that overall some energy is released in the process, in what is called an exothermic reaction.

Are there any drawbacks to using hydrogen?

Currently, most hydrogen gas used worldwide is produced from industrial processes that liberate hydrogen from fossil fuels. You can make H_2 from water, but this requires energy (it's an endothermic reaction); see Water electrolysis (Activity 17). It's quite possible that transport systems in particular will focus on hybrid systems utilising both battery technology and fuel cell technology in the future.

Maintenance

The hydrogen fuel cells provided with the car kit are reversible, meaning they need to be kept from 'drying out' to ensure optimum performance. Keep the cell in one of the zip-loc bags contained within the kit, and ensure that a small amount of water is injected using the syringe to the O_2 side of the fuel cell before being stored.