Fuel Cells

Indicates a Flash activity.
Indicates an accompanying worksheet.
Indicates a virtual experiment.
Indicates that there are teacher's notes.
Indicates that 'How Science Works' skills are covered.
For more detailed instructions, see the Getting Started presentation.
Fuel Cells

- Introducing fuel cells
- Inside hydrogen fuel cells
- Uses of fuel cells
- Summary activities
Fuel cells are devices that convert the chemical energy from a fuel into electricity.

In the fuel cell, fuel reacts with oxygen or another oxidizing agent. Fuel cells do not store fuel, so when the fuel is used up it needs to be replenished.

A hydrogen fuel cell uses hydrogen as a fuel. The hydrogen reacts with oxygen to form water, producing electrical energy in the process.
The reaction which takes place in a hydrogen fuel cell is:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Water is the only product of this reaction. It is released as water vapour.

Hydrogen fuel cells do not directly produce pollutants, such as carbon dioxide, sulfur dioxide or carbon particles, which are produced by some other fuel sources.

What happens to the water vapour after it is released?
Where does hydrogen come from?

The concentration of hydrogen gas ($H_2$) in the atmosphere is very small, so the hydrogen used by fuel cells needs to be manufactured.

There are two main methods of producing hydrogen. Both of these are currently reliant on fossil fuels, either as a raw material or as an energy source.

<table>
<thead>
<tr>
<th>method of production</th>
<th>disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>splitting hydrocarbons</td>
<td>carbon dioxide is produced during the reaction</td>
</tr>
<tr>
<td>(cracking)</td>
<td></td>
</tr>
<tr>
<td>electrolysis of</td>
<td>electricity is often produced by fossil fuel power</td>
</tr>
<tr>
<td>acidified water</td>
<td>stations</td>
</tr>
</tbody>
</table>

Environmental impact of fuel cells

Hydrogen fuel cells could be seen as a cleaner alternative to fossil fuels for the production of electricity. However, they still produce some pollutants.

Press start to begin.
Fuel Cells

- Introducing fuel cells
- Inside hydrogen fuel cells
- Uses of fuel cells
- Summary activities
Hydrogen fuel cells generate electricity by reacting hydrogen with oxygen.

Press **play** to find out more.
Label the fuel cell

Where does each species occur in a fuel cell?

- a
- b
- c
- d
- e

anode

membrane

cathode

e−
Electrode equations

Electrode equations are used to show separately the reactions which occur at each of the electrodes of a hydrogen fuel cell.

Press "play" to find out how.
The reaction which occurs within a fuel cell is an example of a **redox reaction**:

At the negative electrode:

\[
\text{H}_2(\text{g}) \rightarrow 2\text{H}^+(_{\text{aq}}) + 2\text{e}^- 
\]

This is an example of an **oxidation** reaction as the hydrogen atoms **lose** electrons.

At the positive electrode:

\[
4\text{H}^+(_{\text{aq}}) + \text{O}_2(\text{g}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})
\]

This is an example of a **reduction** reaction as the hydrogen ions and oxygen atoms **gain** electrons.
Calculating the energy

**Bond energies** can be used to calculate the amount of energy given out by the reaction in a hydrogen fuel cell. Energy is taken in to break bonds, and released when bonds are created.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond Energy (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H–H</td>
<td>432</td>
</tr>
<tr>
<td>O=O</td>
<td>498</td>
</tr>
<tr>
<td>O–H</td>
<td>463</td>
</tr>
</tbody>
</table>

**energy for bond-breaking**

\[
= 2\text{H–H} + \text{O}=\text{O} \\
= 2 \times 432 + 498 \\
= 1362 \text{kJ}
\]

**energy from bond-making**

\[
= 4\text{H–O} \\
= 4 \times 463 \\
= 1852 \text{kJ}
\]

**total energy change**

\[
= \text{energy in} – \text{energy out} \\
= 1362 \text{kJ} – 1852 \text{kJ} = -490 \text{kJ}
\]
Energy level diagram for the reaction between hydrogen and oxygen in a fuel cell

What is the energy change involved in the reaction between hydrogen and oxygen in a fuel cell?

Press "play" to find out.
Fuel Cells

- Introducing fuel cells
- Inside hydrogen fuel cells
- Uses of fuel cells
- Summary activities
Fuel cells in space

One of the first applications of fuel cells was to provide electrical power for spacecraft.

Fuel cells were first used in spacecraft in the 1960s for NASA’s Gemini program.

The early Gemini flights used batteries to supply electrical power, whilst the later flights used fuel cells.

The success of Gemini led to the use of fuel cells in the Apollo flights, which landed the first humans on the moon.
Advantages of fuel cells

Fuel cells were an attractive choice for spacecraft as they had several advantages:

- they produced clean water, which could be used by astronauts
- they were compact
- they were lightweight compared to batteries
- they contained no moving parts, which made them reliable.
Fuel cells in cars and buses

Fuel cell technologies are being developed for use in cars and buses, and some manufacturers have issued trial vehicles.

Why are hydrogen fuel cells an attractive alternative to petrol or diesel engines?

- hydrogen vehicles produce no carbon dioxide emissions
- petrol and diesel are non-renewable fuels
- hydrogen is low density, so vehicles are light and efficient.
What are some of the advantages and disadvantages of using hydrogen fuel cells?

Press "start" to begin.

start
Are hydrogen fuel cells a good alternative to fossil fuels for powering cars?

0 yes
0 unsure
0 no
Fuel Cells

- Introducing fuel cells
- Inside hydrogen fuel cells
- Uses of fuel cells
- Summary activities
Glossary of keywords: fuel cells

**anode** – The positive electrode in a hydrogen fuel cell.

**battery** – An electrochemical device that converts stored chemical energy into electrical energy.

**bond energy** – A measure of the strength of a chemical bond.

**carbon dioxide** – A gas which exists naturally in the atmosphere at low concentrations. It can also be produced by human activities. Carbon dioxide is a greenhouse gas, and contributes to the greenhouse effect.
Multiple-choice quiz

Can you power your way through this quiz on fuel cells?

Press "start" to begin.

start