FUEL CELLS

Introduction Fuel cells **generate electricity from an electrochemical reaction** in which oxygen (from air) and a fuel (e.g. hydrogen) combine to form water.

The electricity produced can be used to power cars, buses, laptops and mobile phones. The by-product, heat, can also be used.

Structure

- fuel cells consist of two electrodes, a **negative anode** and a **positive cathode**
- electrodes are separated by a solid or liquid electrolyte
- electrically charged particles move between the two electrodes
- catalysts (e.g. Pt) are often used to speed up the reactions at the electrodes
- electricity is generated when oxygen and hydrogen combine to form water

Example

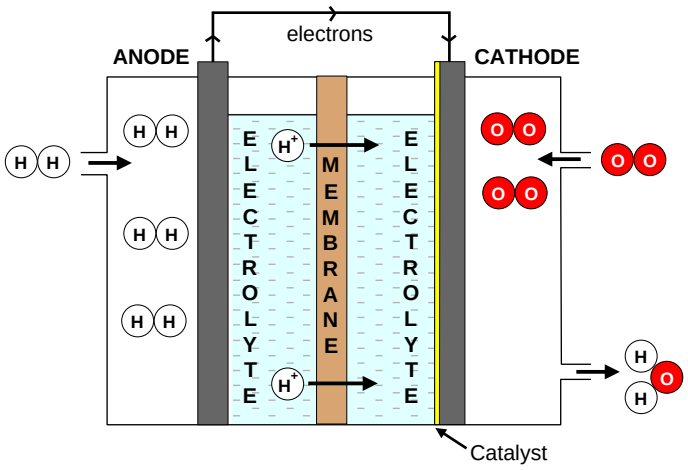
Name **Proton Exchange Membrane Fuel Cell - PEMFC**

Fuel hydrogen

Catalyst platinum

Operation

- hydrogen is oxidised to H^+ ions (protons) at the anode
- protons move through the electrolyte
- electrons pass through the external circuit
- oxygen is reduced at the cathode
- water is produced
- a catalyst accelerates the reactions at the electrodes



Anode (-) $2H_2(g) \longrightarrow 4H^+(aq) + 4e^-$ E° = 0.00V **OXIDATION**

Cathode (+) $O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$ E° = +1.23V **REDUCTION**

overall reaction $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ E° = +1.23V

Electrolyte

- carries charged particles from one electrode to the other.
  It must allow only the appropriate ions to pass between the electrodes If other substances travel through the electrolyte, they can disrupt the chemical reaction.

Why use them?

- our society is dependent upon the three main fossil fuels: coal, oil and gas
- fossil fuels are a non-renewable energy resource
- fuel prices are rising and resources dwindling
- food, transport and electricity costs are affected by fuel prices
- the atmosphere is becoming more and more polluted
- carbon dioxide contributes to climate change and the greenhouse effect

Limitations

- storage of hydrogen - *safety considerations*
- transportation of hydrogen - *low density so expensive to deliver*
- feasibility of liquefied hydrogen under pressure - *safety considerations*
- limited life of adsorber / absorber - *economic considerations*
- limited life cycle of cell - *economic considerations*
- high production costs - *economic considerations*
- use toxic chemicals in cell production - *environmental considerations*

Manufacture of hydrogen

- ideally from non-polluting and renewable resources; (solar, wind or hydro power)
- from hydrocarbon fuels by **reforming**
- from natural gas (methane) or ethanol **$CH_4 + H_2O \longrightarrow CO + 3H_2$**
- electrolysis of water

Reforming

Most of today's hydrogen is generated by **steam reforming**. Unfortunately it uses non-sustainable, natural resources.

Fuel is mixed with steam in the presence of a metal catalyst to produce hydrogen and carbon monoxide.

This method is cost effective and efficient with conversion rates of 70-80%.

Storage of hydrogen

- liquid stored under pressure *or*
- adsorbed on the surface of a solid *or*
- absorbed within a solid

Fuelled cell vehicles (FCV's)

- produce less pollution from exhaust gases (no NOx, CO, unburnt hydrocarbons)
- produce less CO_2
- are more efficient

Q.1 *Who invented the fuel cell?*

ADVANTAGES - DISADVANTAGES OF FUEL CELLS

Pros
- eliminates pollution caused by burning fossil fuels; the only by-product is water
- eliminates greenhouse gases if the hydrogen used comes from electrolysis of water
- eliminates economic dependence on politically unstable countries for fossil fuel
- have a higher efficiency than diesel or gas engines
- most operate silently compared to internal combustion engines
- some have low heat transmission - ideal for military applications
- operating times are much longer than with batteries
- maintenance is simple since there are few moving parts in the system

Cons
- production, transportation, distribution and storage of hydrogen is difficult
- reforming is technically challenging and not environmentally friendly
- refuelling and starting times of fuel cell vehicles (FCV's) are longer
- driving range of cars is shorter than in a traditional vehicles
- fuel cells are generally slightly bigger than comparable batteries or engines
- currently expensive to produce, since most units are hand-made
- some use expensive materials
- the technology is not yet fully developed and few products are available

The future Limited supplies of fossil fuels may cause us to move to a 'hydrogen economy'.

However
- greater acceptance by the public and politicians is necessary
- handling and maintenance of hydrogen systems must be safe
- improvements to hydrogen manufacturing must be made

Q.2 *State the advantages and disadvantages of generating hydrogen from...*

- *hydrocarbon fuels*

- *electrolysis of water*

- *ethanol*

Q.3 *In the near future, which method do you think will will be used to generate hydrogen for fuel cells?*

Q.4 *What effect, if any, will fuel cells have on the world's oil producing countries?*

TYPES OF FUEL CELL

Fuel cells are classified according to the nature of the electrolyte.

Alkaline Fuel Cells (AFC)

- uses an alkaline electrolyte such as potassium hydroxide
- used by NASA in space shuttles

Direct Methanol Fuel Cells (DMFC)

- uses a polymer membrane as an electrolyte
- a catalyst on the anode draws hydrogen from liquid methanol
- eliminates need for a fuel reformer, so pure methanol can be used as fuel

Molten Carbonate Fuel Cells (MCFC)

- uses a molten carbonate salt as the electrolyte.
- has the potential to be fuelled with coal-derived fuel gases, methane or natural gas

Phosphoric Acid Fuel Cells (PAFC)

- anode and a cathode made of a finely dispersed platinum catalyst on carbon
- has a silicon carbide structure that holds the phosphoric acid electrolyte
- used to power many commercial premises and large vehicles, such as buses

Proton Exchange Membrane Fuel Cells (PEMFC)

- uses a polymeric membrane as the electrolyte, with platinum electrodes
- operate at relatively low temperatures.
- can vary their output to meet shifting power demands.
- best for cars, for buildings and smaller applications

Solid Oxide Fuel Cells (SOFC)

- use a solid ceramic electrolyte, such as zirconium oxide stabilised with yttrium oxide
- work at high temperatures
- can reach efficiencies of around 60 per cent
- are expected to be used for generating electricity and heat in industry
- have potential for providing auxiliary power in vehicles

Regenerative Fuel Cells (RFC)

- produce electricity from hydrogen and oxygen
- can be reversed to produce hydrogen and oxygen; effectively storing energy or electricity

Metal Air Fuel Cells (MAFC)

- not fuel cells in a conventional way
- work like batteries, generating electricity using metal and oxygen
- rechargeable.