

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.

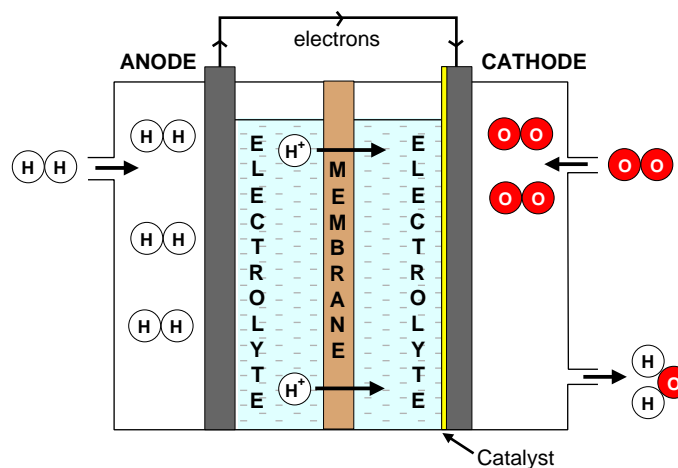
- Structure**
- fuel cells consist of two electrodes, a negative anode and a positive cathode
 - electrodes are separated by a solid or liquid electrolyte
 - electrically charged particles move between the two electrodes
 - catalysts (e.g. Pt) are often used to speed up the reactions at the electrodes
 - 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 (-) $2H_2(g) \rightarrow 4H^+(aq) + 4e^-$ $E^\circ = 0.00V$ **OXIDATION**

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

overall reaction $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ $E^\circ = +1.23V$

- 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 $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$
- 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 NO_x, CO, unburnt hydrocarbons)
- produce less CO₂
- 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 in general 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 near future, which method do you think 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?