Energy Changes

Exothermic & Endothermic Reactions

Exothermic reactions transfer energy to the surroundings and the temperature of the surroundings **increases**. **Endothermic reactions take in energy** and the temperature of the surroundings **decreases**.

Examples of exothermic reactions include:
- **combustion** reactions
- many **oxidation** reactions
- most **neutralisation** reactions.

Everyday uses of exothermic reactions include self-heating cans and hand warmers.

Examples of endothermic reactions include:
- **thermal decomposition** reactions
- the reaction of citric acid and sodium hydrogen carbonate.

Everyday uses of endothermic reactions include instant ice packs which can be used to treat sports injuries.

Bond Energy *[Higher tier]*

During a chemical reaction the difference between the energy needed to break bonds and the energy released when new bonds are made determines the type of reaction.
A reaction is **exothermic** if more heat energy is released in making bonds in the products than is taken in when breaking bonds in the reactants. It is **endothermic** if less heat energy is released in making bonds in the products than is taken in when breaking bonds in the reactants.

To calculate an energy change for a reaction:
- add together the bond energies for all the bonds in the **reactants** - this is the 'energy in'
- add together the bond energies for all the bonds in the **products** - this is the 'energy out'
- energy change = energy in - energy out.

Bond	Bond energy
H–H	436 kJ/mol
Cl–Cl	243 kJ/mol
H–Cl	432 kJ/mol

Example

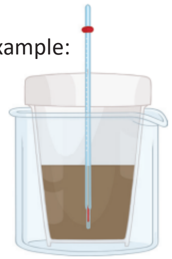
hydrogen + chlorine → hydrogen chloride:

H–H + Cl–Cl → 2 × (H–Cl)

Energy in = 436 + 243 = 679 kJ/mol
Energy out = (2 × 432) = 864 kJ/mol
Energy change = 679 - 864 = -185 kJ/mol
The energy change is **negative.** This shows that the reaction is **exothermic.**

Required Practical: Temperature Change

Aim: To investigate the variables that affect temperature changes in reacting solutions.
Context: You could investigate one or more chemical reactions, for example:
- acids reacting with metals, metal carbonates or with alkalis
- displacement reactions of metals.



Method: Reacting two solutions, e.g. acid and alkali
1. Place the polystyrene cup inside the glass beaker for stability.
2. Measure an appropriate volume of each liquid, e.g. 25 cm^3.
3. Place one of the liquids in a polystyrene cup.
4. Record the temperature of the solution.
5. Add the second solution and record the highest or lowest temperature obtained.
6. Change your **independent variable** and repeat the experiment. Your independent variable could be the concentration of one of the reactants, or the type of acid/alkali being used, or the type of metal/metal carbonate being used.

Analysis: The bigger the temperature change in the reaction, the more energy is absorbed or released.
Evaluation: The biggest source of error in this experiment is unwanted heat transfer. Using a lid can help to reduce this.

Hazards, risks and precautions

Hazard	Possible harm	Possible precaution
Dilute acids and alkalis	May irritate the skin or eyes	Avoid contact with skin, rinse off skin if necessary, wear eye protection
Solutions of metal salts (used in displacement reactions)	Dangerous to the environment	Dispose of metal salt solutions as advised by teacher.

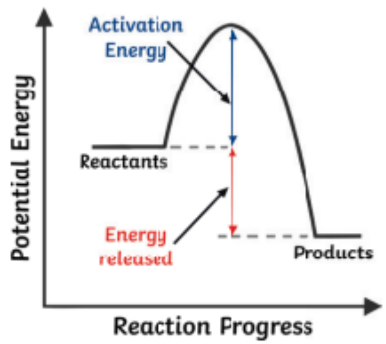
Reaction Profiles

A reaction profile shows whether a reaction is **exothermic** or **endothermic**. It shows the energy in the **reactants** and **products**, and the difference in energy between them. It also includes the **activation energy**, which is the minimum energy needed by particles when they collide for a reaction to occur. The activation energy is shown as a 'hump' in the line, which:
- starts at the energy of the reactants
- is equal to the difference in energy between the top of the 'hump' and the reactant.

The overall change in energy in a reaction is the difference between the energy of the reactants and products.

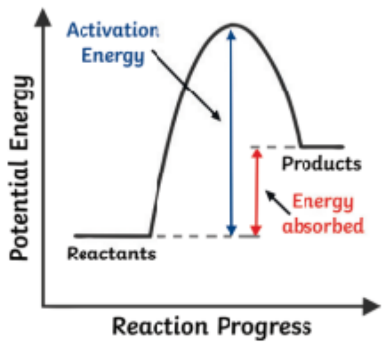
Exothermic reaction

The energy level decreases in an exothermic reaction. This is because energy is given out to the surroundings.



Endothermic reaction

The energy level increases in an endothermic reaction. This is because energy is taken in from the surroundings.



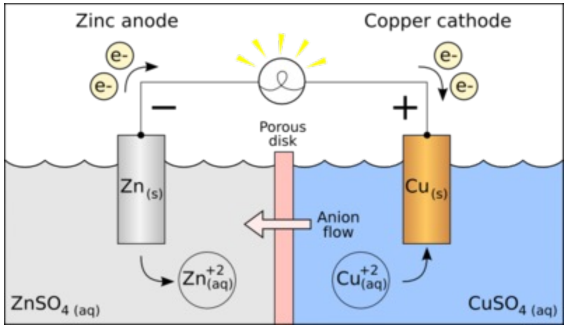
Chemical Cells *(Separate Chemistry Only)*

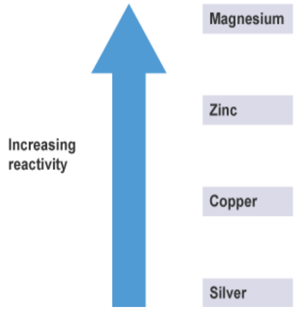
Chemical cells use chemical reactions to transfer energy by **electricity**. The **voltage** of a cell depends upon a number of factors, including what the **electrodes** are made from, and the substance used as the **electrolyte**.

A simple cell can be made by connecting two different metals in contact with an electrolyte. A number of cells can be connected in series to make a **battery**, which has a higher voltage than a single cell.

In non-rechargeable cells, e.g. alkaline cells, a **voltage** is produced until one of the **reactants** is used up. When this happens, we say the battery 'goes flat'.
In rechargeable cells and batteries, like the one used to power your mobile phone, the chemical reactions can be reversed when an **current** is supplied.

If we connect different combinations of these metals to make a cell, we find that the voltage changes.
Swapping the two electrodes means that the recorded voltage becomes negative. The biggest voltage occurs when the difference in the reactivity of the two metals is the largest. A cell made from magnesium and copper has a higher voltage than magnesium and zinc, for example.





Evaluating Cells *(Separate Chemistry Only)*

Fuel cells have different strengths and weaknesses, depending on the intended use. For example, fuel cells are used in spacecraft and vehicles.

Fuel cells in spacecraft

Hydrogen-oxygen fuel cells are used in spacecraft. In addition to the strengths in the table to the right, the water they produce is useful as drinking water for astronauts.
Hydrogen-oxygen fuel cells must be supplied with hydrogen **fuel** and oxygen. This could be a problem once a spacecraft leaves the Earth. However, spacecraft in orbit, such as the **International Space Station**, have **solar cells**. These convert light into **electricity**, so the hydrogen and oxygen can be replaced by the **electrolysis** of water.
Solar cells only work when they are in the light, so the fuel cells allow electricity to be produced even when the spacecraft is in the dark.

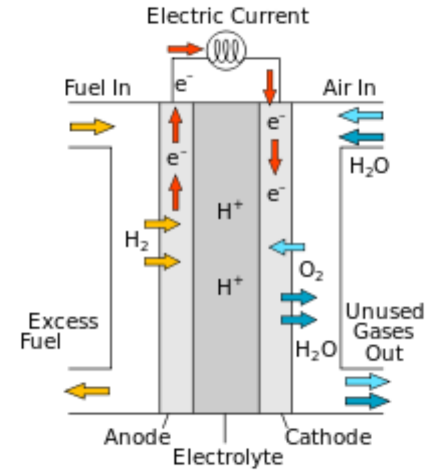
Fuel Cells *(Separate Chemistry Only)*

Fuel cells work in a different way than chemical cells. Fuel cells produce **voltage** continuously, as long as they are supplied with:
- a constant supply of a suitable **fuel**
- oxygen, e.g. from the air

The fuel is **oxidised** electrochemically, rather than being burned, so the reaction takes place at a lower temperature than if it was to be burned. Energy is released as electrical energy, not **thermal energy** (heat).

Hydrogen-oxygen fuel cells

Hydrogen-oxygen fuel cells are an alternative to rechargeable cells and batteries.
In a hydrogen-oxygen fuel cell, hydrogen and oxygen are used to produce a voltage.
Water is the only product.
The overall reaction in a hydrogen-oxygen fue cell is:
hydrogen + oxygen → water
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$



Electrode half equations

At the negative electrode:
$2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$
At the positive electrode:
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
When you add these two half equations together, you get the following overall equation:

$$2H_2 + 4OH^- + O_2 + 2H_2O + 4e^- \rightarrow 4H_2O + 4e^- + 4OH^-$$

The hydroxide ions, electrons and two H_2O molecules will now cancel because they are on both sides, leaving the overall equation:

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

Type of cell	Pros	Cons
Alkaline cell	Cheaper to manufacture	May end up in landfill sites once fully discharged; recyclable though it is expensive
Rechargeable cell	Can be recharged many times before being recycled, reducing the use of resources	Costs more to manufacture
Hydrogen fuel cell	Easy to maintain as there are no moving parts; small size; water is the only chemical product	Very expensive to manufacture; need a constant supply of hydrogen fuel, which is a flammable gas