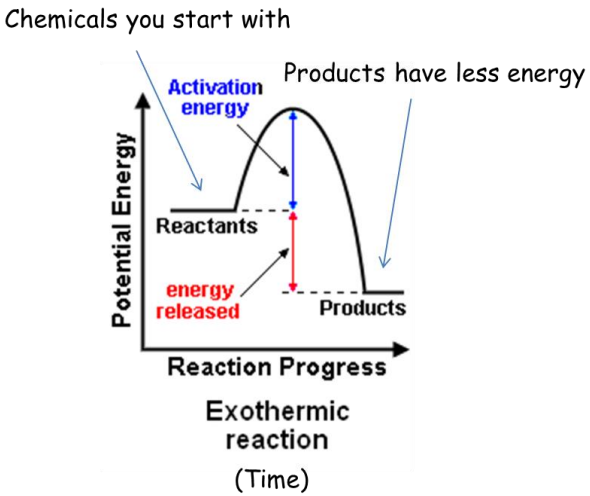
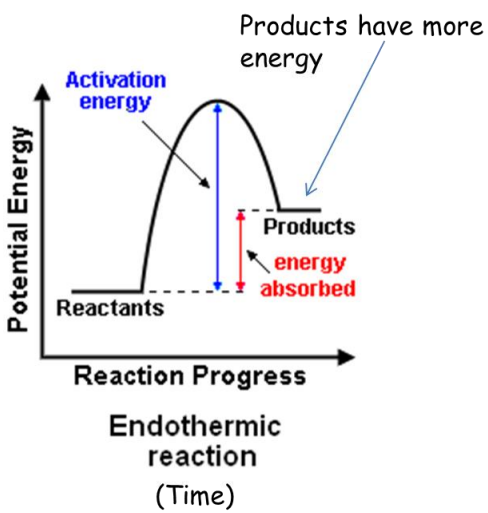
Energy changes

Exothermic reaction



Endothermic reaction



An exothermic reaction is one that transfers energy to the surroundings so the temperature of the surroundings increases.

An endothermic reaction is one that takes in energy from the surroundings so the temperature of the surroundings decreases.

Law of Conservation of Energy

- Energy cannot be created or destroyed, just transferred.
- During chemical reactions energy used to break chemical bonds between atoms in the reactants, when new bonds are formed to make the products energy is released.
- If overall energy is released to the surroundings the reaction is exothermic.
- If overall energy is absorbed from the surroundings the reaction is endothermic.

Exothermic	Endothermic
Combustion (burning)	Citric acid + sodium hydrogen carbonate
Neutralisation (acid + base)	Thermal Decomposition (splitting up a substance using heat)
Oxidation	
Hand Warmers	
Self Heating Cans	

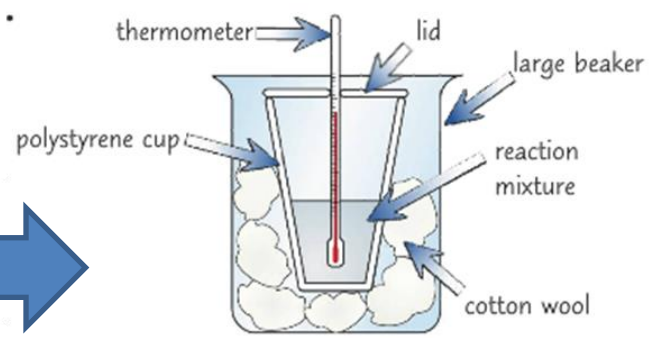
Investigating Energy Changes

- The experiment must be designed to stop heat energy entering or exiting.
- Lid prevents heat escaping by convection.
- Cotton wool and polystyrene cup prevent heat escaping by conduction/radiation.

Method

1. Add one of the reactants to the polystyrene cup. Measure and record the temperature with a thermometer.
2. Add the second reactant. Record the temperature every 30 seconds and record the maximum/minimum temperature.
3. Calculate the temperature change from the results.
4. Repeat, discard anomalies and calculate the mean.

Q. Explain how you could investigate how the concertation of acid effected the temperature rise when magnesium and hydrochloric acid were reacted together.



Energy Changes Separate Science Chemistry

To calculate bond energy

1. Add together the bond energies for all the bonds in the **reactants** – this is the 'energy in'.
2. Add together the bond energies for all the bonds in the **products** – this is the 'energy out'.
3. Calculate the energy change = energy in – energy out.

Worked example – an exothermic reaction

Hydrogen and chlorine react to form hydrogen chloride gas:

H–H + Cl–Cl → 2 × (H–Cl)

Bond	Bond Energy (kJ/mol)
H–H	436
Cl–Cl	243
H–Cl	432

1. Energy in = 436 + 243 = 679 kJ/mol
2. Energy out = 2 × 432 = 864 kJ/mol
3. Energy change = in – out = 679 – 864 = **–185 kJ/mol**

The energy change is negative, showing that energy is released to the surroundings in an **exothermic** **reaction**.

Worked example – an endothermic reaction

Hydrogen bromide **decomposes** to form hydrogen and bromine:

2 × (H–Br) → H–H + Br–Br

Bond	Bond Energy (kJ/mol)
H–Br	366
H–H	436
Br–Br	193

1. Energy in = 2 × 366 = 732 kJ/mol
2. Energy out = 436 + 193 = 629 kJ/mol
3. Energy change = in – out = 732 – 629 = **+103 kJ/mol**

The energy change is positive, showing that energy is taken in from the surroundings in an **endothermic** **reaction**.

Exothermic Reactions
A reaction is exothermic overall if less energy is absorbed when bonds are broken than released when the bonds are made.

Endothermic Reactions
A reaction is endothermic overall if more energy is absorbed when bonds are broken than released when the bonds are made.

During a chemical reaction:
•• energy must be supplied to break bonds in the reactants – endothermic – these have + energy change values as energy has entered the reaction.
•• energy is released when bonds in the products are formed – exothermic – these have – energy change values as energy has exited the reaction.

Energy Change = Break - Make

Explaining energy changes in terms of bonds…
Endothermic Reactions
If more energy was needed to break the bonds than was released when the bonds were formed the reaction is endothermic.
Exothermic Reactions
If more energy was released when the bonds were formed than was needed to break the bonds the reaction is exothermic.

Questions:
1. What happens to energy in reactions?
2. Compare exothermic and endothermic reactions.
3. Explain how you could investigate how the concertation of acid effected the temperature rise when magnesium and hydrochloric acid were reacted together.
4. Explain why reactions are exothermic or endothermic in terms of bonds made and bonds broken.

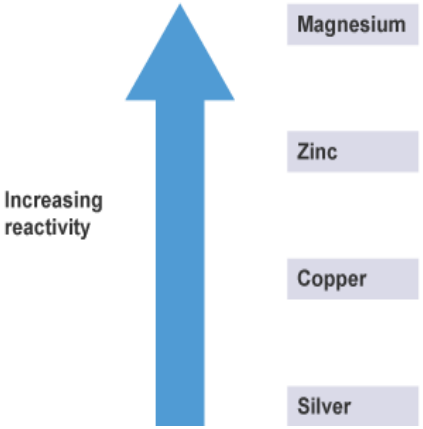
Chemical cells

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.

What affects the voltage of a cell?
Look at the reactivity series
If you connect different combinations of these metals to make a cell, the voltage changes. In the below table, the positive electrodes and what they are made from are listed along the top and the negative electrodes along the side.

Fuel cells
Fuel cells produce a 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, 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).



	Magnesium -2.37	Zinc -0.76	Copper +0.34
Magnesium	0.00 V	1.61 V	+2.71
Zinc	-1.61 V	0.00 V	+1.10 V
Copper	2.71 V	-1.10 V	0.00 V

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 either of the other two combinations.

Hydrogen-oxygen fuel cells are an alternative to rechargeable cells and batteries, they use hydrogen and oxygen to produce a voltage.
Water is the only product.
The overall reaction in a hydrogen-oxygen fuel 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:
$2H_2 + O_2 \rightarrow 2H_2O$

Evaluating Fuel Cells

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

Questions:
1. Why do energy level diagrams for exothermic and endothermic reactions look different?
2. What is activation energy? Sketch an energy level diagram for the same reaction with and without a catalyst.