

AQA GCSE Chemistry — Chemistry

Topic 5

# Energy changes

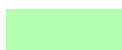
Specification 8462 · AQA

## Free edition

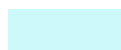
**Revision notes for one topic, free to download.**

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

## Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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**Define Exothermic reaction**

- a reaction that transfers energy to the surroundings, so the temperature of the surroundings increases.

**Define Conservation of energy**

- the amount of energy in the universe at the end of a chemical reaction is the same as before it.

**Define Reaction profile**

- a diagram showing the relative energies of the reactants and products, the activation energy and the overall energy change.

**HIGHER TIER****Define Bond energy**

- **HT ONLY** the energy needed to break one mole of a particular bond (the same amount is released when that bond forms).

**Define Battery**

- **CHEMISTRY ONLY** two or more cells connected together in series to provide a greater voltage.

**Define Fuel cell**

- **CHEMISTRY ONLY** a cell supplied by an external source of fuel and oxygen or air, in which the fuel is oxidised electrochemically to produce a potential difference.

**Define Endothermic reaction**

- a reaction that takes in energy from the surroundings, so the temperature of the surroundings decreases.

**Define Activation energy**

- the minimum amount of energy that particles must have to react.

**HIGHER TIER****Define Overall energy change**

- **HT ONLY** the difference between the energy needed to break bonds in the reactants and the energy released when bonds in the products are formed.

**Define Cell**

- **CHEMISTRY ONLY** a device containing chemicals which react to produce electricity.

**Define Rechargeable cell**

- **CHEMISTRY ONLY** a cell whose chemical reactions can be reversed by supplying an external electrical current.

**Define Electrolyte**

- **CHEMISTRY ONLY** the ionic solution or paste between the two electrodes of a cell.

**5.1 Exothermic and endothermic reactions****5.1.1 Energy transfer during exothermic and endothermic reactions**

- **Energy is conserved in chemical reactions:** the amount of energy in the universe at the end of a reaction is the same as before it. If a reaction transfers energy to the surroundings, the product molecules must have less energy than the reactants, by the amount transferred.
- You judge which type a reaction is from the **temperature change of the surroundings** — measured with a thermometer in the reaction mixture.

|                                 | Exothermic                                                                                                                   | Endothermic                                                                             |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Energy                          | Transferred to the surroundings                                                                                              | Taken in from the surroundings                                                          |
| Temperature of surroundings     | Increases                                                                                                                    | Decreases                                                                               |
| Energy of products vs reactants | Products have less energy                                                                                                    | Products have more energy                                                               |
| Examples                        | <b>Combustion</b> , many <b>oxidation</b> reactions, <b>neutralisation</b> ; also displacement and most metal–acid reactions | <b>Thermal decomposition</b> ; the reaction of citric acid and sodium hydrogencarbonate |
| Everyday uses                   | <b>Self-heating cans</b> (e.g. of coffee) and <b>hand warmers</b>                                                            | Some <b>sports injury packs</b> (instant cold packs)                                    |

- Self-heating cans hold two chemicals (e.g. calcium oxide and water) separated by a seal; pressing the button mixes them and the exothermic reaction heats the drink. Convenient and needing no power supply, but heavy, bulky, expensive and single-use.
- Hand warmers may use an exothermic reaction (single-use) or a reusable crystallisation pack that is reset by boiling it in water.
- Sports injury packs use an endothermic process, so the pack goes cold and reduces swelling. They cool instantly with no freezer needed, but most are single-use and do not stay cold for long.
- You should be able to evaluate uses and applications of exothermic and endothermic reactions given appropriate information — weigh up cost, convenience, how long the effect lasts and whether the pack is reusable.

#### HIGHER TIER

##### NOTE

The spec limits this section to **measurement of temperature change**. Calculation of energy changes or  $\Delta H$  is not required here (bond energy calculations in 5.1.3 are the only calculation, and they are **HT ONLY**).

##### ANALOGY

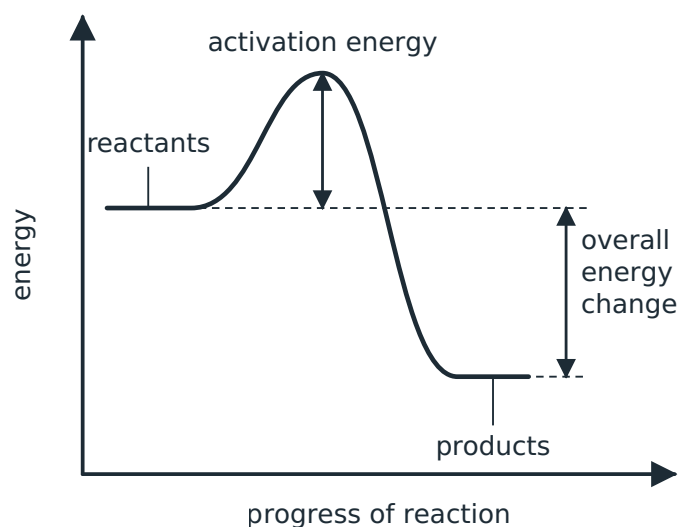
Exothermic reactions are a bonfire; endothermic reactions are an ice pack. Stand near a bonfire and *you* — the surroundings — get warmer, because the reaction is giving energy out. Hold an instant cold pack and *your hand* gets colder, because the reaction is pulling energy in from you. Always describe the temperature change of the **surroundings**, not of "the reaction".

### 5.1.2 Reaction profiles

- Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy.
- Reaction profiles show the relative energies of the reactants and products, the activation energy and the overall energy change.
- Drawing one: energy on the y-axis, progress of reaction on the x-axis, with a curved line rising from the reactants over a hump and down to the products.
- **Exothermic**: the products are below the reactants; the overall energy change is measured downwards from reactants to products.
- **Endothermic**: the products are above the reactants; the overall energy change is measured upwards.
- The **activation energy** is always measured from the reactants up to the top of the hump — never from the products.
- You should be able to use a reaction profile to identify a reaction as exothermic or endothermic: just compare the level of the products with the level of the reactants.

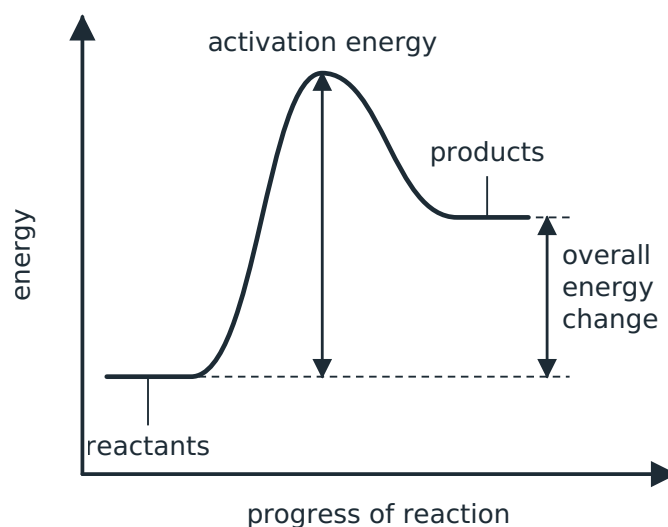
## Reaction profiles for an exothermic and an endothermic reaction

### Exothermic reaction



Products are lower in energy than the reactants, so the overall energy change is negative: energy is given out.

### Endothermic reaction



Products are higher in energy than the reactants, so the overall energy change is positive: energy is taken in.

#### ANALOGY

Activation energy is a hill in front of the finish line. Even if the finish is lower down the valley than where you started (exothermic), you still have to push the cart over the hill first. The hill height is the activation energy, and the difference between the start and finish heights is the overall energy change. A bigger hill means fewer particles have enough energy, so the reaction is slower.

#### HIGHER TIER

### 5.1.3 HT ONLY The energy change of reactions

- **HT ONLY** During a chemical reaction, energy must be supplied to break bonds in the reactants (endothermic step) and energy is released when bonds in the products are formed (exothermic step).
- **HT ONLY** In an exothermic reaction the energy released from forming new bonds is greater than the energy needed to break existing bonds; in an endothermic reaction the energy needed to break existing bonds is greater than the energy released from forming new bonds.

Higher tier only

**Bonds broken in the reactants**

energy must be supplied — endothermic

|           |            |
|-----------|------------|
| 1 × H—H   | 436 kJ/mol |
| 1 × Cl—Cl | 242 kJ/mol |

|                        |                   |
|------------------------|-------------------|
| <b>total energy in</b> | <b>678 kJ/mol</b> |
|------------------------|-------------------|

**Bonds made in the products**

energy is released — exothermic

|                        |                |
|------------------------|----------------|
| 2 × H—Cl               | 2 × 431 kJ/mol |
| (one bond in each HCl) | = 862 kJ/mol   |

|                         |                   |
|-------------------------|-------------------|
| <b>total energy out</b> | <b>862 kJ/mol</b> |
|-------------------------|-------------------|

**overall energy change = energy in (bonds broken) – energy out (bonds made)**

= 678 – 862 = –184 kJ/mol, which is negative, so the reaction is exothermic

More energy is released making the new bonds than is needed to break the old bonds, so energy is transferred to the surroundings. If the answer were positive the reaction would be endothermic.

**WATCH OUT**

**Breaking bonds never releases energy.** Breaking bonds always takes energy in; making bonds always gives energy out. A reaction is exothermic only when the energy out is the bigger of the two. Also, water contains two O–H bonds per molecule — 2H<sub>2</sub>O means four O–H bonds.

**5.2 CHEMISTRY ONLY Chemical cells and fuel cells**

### 5.2.1 CHEMISTRY ONLY Cells and batteries

- **CHEMISTRY ONLY** Cells contain chemicals which react to produce electricity.
- **CHEMISTRY ONLY** A simple cell can be made by connecting two different metals in contact with an electrolyte.
- **CHEMISTRY ONLY** The voltage produced by a cell depends on a number of factors including the type of electrode and the type of electrolyte.
- The bigger the difference in reactivity between the two metals, the **greater the voltage** produced. The more reactive metal is the negative electrode.
- You should be able to interpret data for the relative reactivity of different metals — e.g. a magnesium/ copper cell gives a larger voltage than a zinc/copper cell.
- **CHEMISTRY ONLY** Batteries consist of two or more cells connected together in series to provide a greater voltage.
- **CHEMISTRY ONLY** In non-rechargeable cells and batteries the chemical reactions stop when one of the reactants has been used up. The reactions cannot be reversed, so the battery must be thrown away. Alkaline batteries are non-rechargeable.
- **CHEMISTRY ONLY** Rechargeable cells and batteries can be recharged because the chemical reactions are reversed when an external electrical current is supplied. **CHEMISTRY ONLY Evaluating cells:** rechargeable cells cost more at first but are cheaper over their lifetime and create less waste; non-rechargeable cells hold their charge well in storage; all batteries eventually stop working and contain toxic materials needing careful disposal.

#### NOTE

You do not need to know the details of any cells and batteries other than those specified above.

### 5.2.2 CHEMISTRY ONLY Fuel cells

- **CHEMISTRY ONLY** Fuel cells are supplied by an external source of fuel (eg hydrogen) and oxygen or air.

The fuel is oxidised electrochemically within the fuel cell to produce a potential difference.

- **CHEMISTRY ONLY** A fuel cell keeps working for as long as the fuel is supplied — it is not "used up" like a battery and does not need recharging.
- **CHEMISTRY ONLY** The overall reaction in a hydrogen fuel cell involves the oxidation of hydrogen to produce water.
- **CHEMISTRY ONLY** Hydrogen fuel cells offer a potential alternative to rechargeable cells and batteries.

#### **CHEMISTRY ONLY Evaluating hydrogen fuel cells against rechargeable batteries**

- Advantages: no recharging time — you simply refill with fuel; they can be made in a wide range of sizes; water is the only waste product; they do not lose their charge when stored; fewer toxic metals to dispose of, and fewer polluting stages in manufacture.
- Disadvantages: hydrogen is a gas, so it is difficult to store and transport and is highly flammable; it must be manufactured, often from fossil fuels or by electrolysis using electricity that may itself come from fossil fuels; refuelling stations are rare and fuel cells are expensive. Rechargeable batteries use ordinary mains electricity and an established charging network, but take time to charge, last a limited number of charge cycles and lose capacity.