

AQA GCSE Combined Science: Trilogy — Chemistry

Topic 12

Energy changes

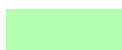
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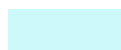
Revision notes for one topic, free to download.

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 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 Surroundings

- everything outside the reacting particles themselves (the solution, the container and the air), whose temperature change you measure.

12.1 Exothermic and endothermic reactions**12.1.1 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	Combustion , many oxidation reactions, neutralisation ; also displacement and most metal–acid reactions	Thermal decomposition ; the reaction of citric acid and sodium hydrogencarbonate
Everyday uses	Self-heating cans (e.g. of coffee) and hand warmers	Some sports injury packs (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.

NOTE

The spec limits this section to **measurement of temperature change**. Calculation of energy changes or ΔH is **not required** here (bond energy calculations in 12.1.3 are the only calculation, and they are **HT ONLY**).

ANALOGY

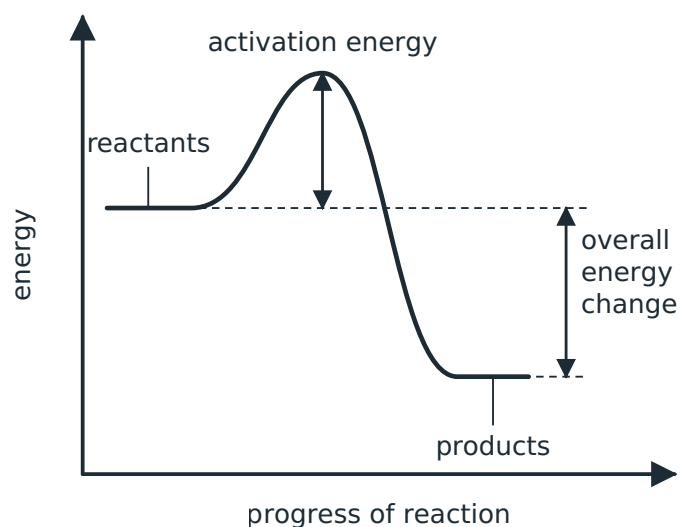
Exothermic reactions are a bonfire; endothermic reactions are an ice pack. Stand near a bonfire and *you* — the surroundings — get warmer, because the reaction is giving energy out. Hold an instant cold pack and *your hand* gets colder, because the reaction is pulling energy in from you. Always describe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

12.1.2 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.
- You should also be able to explain that the activation energy is the energy needed for a reaction to occur — without it, colliding particles simply bounce apart unchanged.

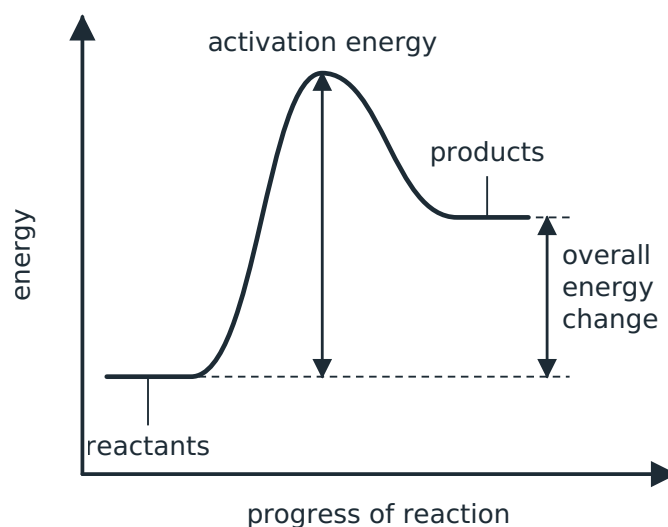
Reaction profiles for exothermic and endothermic reactions

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

12.1.3 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.

**Bonds broken in the reactants**

energy must be supplied — endothermic

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

total energy in	678 kJ/mol
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Bonds made in the products

energy is released — exothermic

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

total energy out	862 kJ/mol
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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 — 2H₂O means **four** O–H bonds.