

5 • Energy changes

AQA • GCSE • Chemistry

Energy changes: follow the energy transfer

A hand warmer heats its surroundings; an instant cold pack cools them. In both, energy is conserved. Follow where energy moves, then decide whether the evidence supports the product's intended use. This topic covers AQA Chemistry 8462 sections 4.5.1.1–4.5.2.2. Bond-energy calculations are **Higher Tier**; cells and fuel cells are **chemistry only**, with fuel-cell half-equations **Higher Tier**.

Exothermic and endothermic changes (4.5.1.1)

An **exothermic** reaction transfers energy from the reacting chemicals to the surroundings. The surroundings warm, and the products have less energy than the reactants by the amount transferred. Combustion, many oxidation reactions and neutralisation are examples. Hand warmers and self-heating cans use exothermic changes.

An **endothermic** reaction takes energy from the surroundings. The surroundings cool; the products have more energy than the reactants. Thermal decomposition and the reaction of citric acid with sodium hydrogencarbonate are examples. Some sports injury packs use endothermic changes. A temperature fall alone does not prove that a new substance formed: physical processes such as dissolving can also change temperature.

Worked temperature example. A reaction mixture changes from 21.0 °C to 15.5 °C without external heating or cooling. Temperature change = final – initial = 15.5 – 21.0 = –5.5 °C. The mixture cooled, supporting an endothermic interpretation: the reacting chemicals took energy from the surroundings. A thermometer measures temperature, not the reaction's energy change directly. No calculation of solution energy or ΔH is required here.

Evaluate a use with evidence. A warmer must reach a suitable temperature for long enough without leaking or overheating. An instant cold pack must cool sufficiently, be available when needed and limit waste. Compare given temperature, duration, storage, cost and reuse information. A chemical change being exothermic does not by itself make an effective hand warmer. A rechargeable battery and a hydrogen fuel cell need a similar purpose-based comparison later.

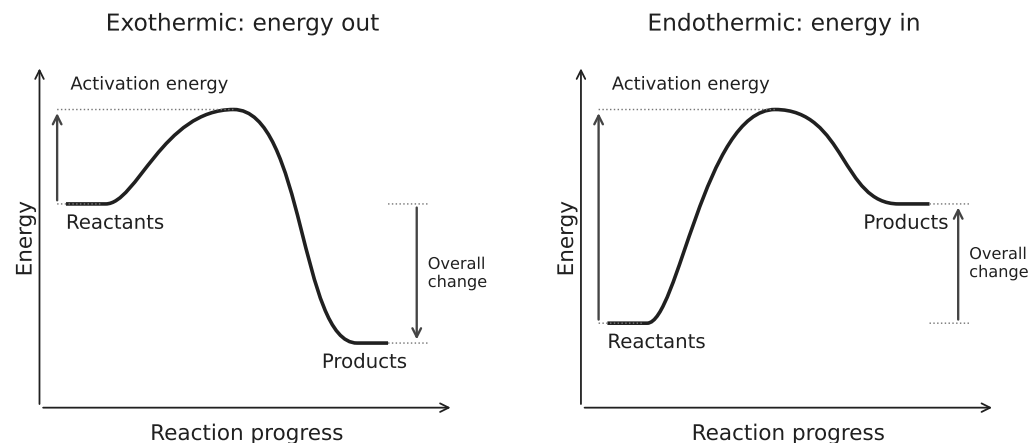
Required practical 4: temperature changes in reacting solutions. Choose one variable, for example the total alkali volume added to a fixed volume of acid. Use teacher-approved solutions, eye protection and an insulated cup supported safely in a beaker. Measure the initial temperature; add a measured alkali volume, replace the lid, stir gently and record the highest temperature. Add further measured portions and record total added volume and temperature. Keep the initial acid volume, concentrations, starting temperatures, cup and reading method comparable. Repeat

the investigation with fresh starting solutions and calculate means for corresponding volumes.

Plot temperature against total added volume. An increase followed by a decrease can locate a maximum; use appropriate best-fit lines on the two regions to estimate their intersection between readings. Do not call the highest measured point an exact end-point. Insulation and a lid reduce heat exchange, but do not remove it. Record actual observations and apparatus during supervised practical work; this written method does not replace that work. Other RP4 comparisons may use acids with metals/carbonates or displacement reactions.

Reaction profiles (4.5.1.2)

A **reaction profile** shows the relative energies of reactants and products as a reaction proceeds. Its horizontal axis is reaction progress, not time. Particles must collide with enough energy for reaction. **Activation energy** is the minimum energy particles need for a reaction to occur.



Draw labelled axes, then separate reactant and product levels. Join them with a smooth curve rising above both levels. Draw the activation-energy arrow from the reactant level to the peak; draw the overall-change arrow between reactant and product levels. Exothermic products are lower; endothermic products are higher. An endothermic reaction still has an activation barrier. A catalyst provides a route with a smaller activation energy; the reactant/product levels and overall change stay the same.

Worked profile reading. On a supplied relative-energy scale, reactants are at 40, the peak at 110 and products at 15. Activation energy is $110 - 40 = 70$ relative units. Overall change is $15 - 40 = -25$ relative units: the reaction is exothermic. Using the peak as the starting level for overall change would confuse the two arrows. These are illustrative profile readings, not a solution calorimetry calculation.

Bond energies – Higher Tier (4.5.1.3)

A **bond energy** gives the energy needed to break a mole of the stated bonds in the supplied model. Breaking reactant bonds requires energy; forming product bonds releases energy. Use the balanced equation to count bonds before calculating. A coefficient multiplies all the bonds in that molecule. Use a supplied double-bond value once for each double bond.

overall energy change = total energy to break bonds – total energy released forming bonds

For an exothermic reaction, forming releases more than breaking requires, so the result is negative. For an endothermic reaction, breaking requires more than forming releases, so the result is positive. Bond formation releases energy even in an endothermic reaction; it simply releases less than was required to break the reactant bonds.

Worked bond-count example. For $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, use $\text{H-H} = 436$, $\text{O=O} = 498$ and $\text{O-H} = 464$ kJ/mol. Break two H-H bonds and one O=O bond; form four O-H bonds.

$$\text{broken} = 2(436) + 498 = 1370 \text{ kJ/mol}$$

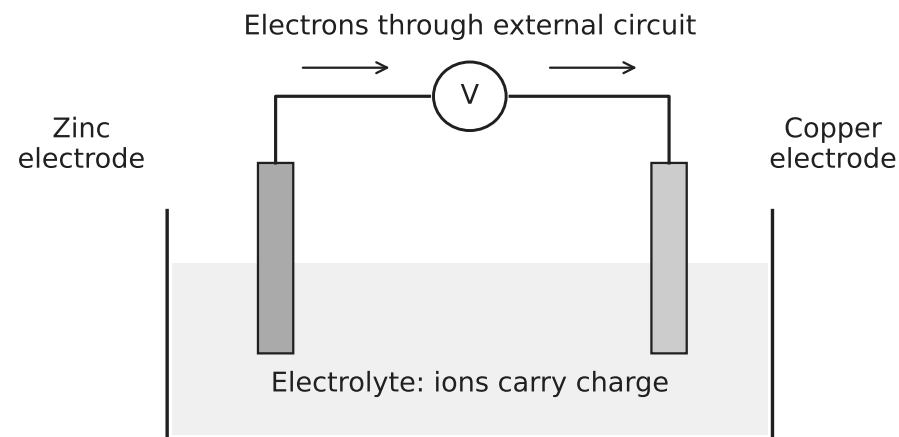
$$\text{formed} = 4(464) = 1856 \text{ kJ/mol}$$

$$\text{overall change} = 1370 - 1856 = -486 \text{ kJ/mol}$$

The reaction is exothermic for the quantities represented by the balanced equation. The supplied bond energies give an approximate model; do not use the thermometer practical to infer this number without another model.

Cells and batteries – chemistry only (4.5.2.1)

A **cell** contains chemicals that react to produce electricity. A simple cell uses two different metal electrodes in an **electrolyte**, connected through an external circuit. Ions carry charge in the electrolyte; electrons move through the wire. Measure the potential difference with a voltmeter. Voltage depends on the electrodes, electrolyte and conditions. Use supplied readings to compare particular cells; a metal's reactivity alone does not fix a universal voltage.



Illustrative Zn/Cu cell; voltage depends on electrolyte and conditions

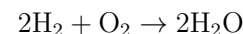
For a controlled comparison, change one electrode while keeping the other electrode, electrolyte and measuring conditions comparable. For example, if a supplied table gives $\text{Zn/Cu} = 1.10 \text{ V}$ and $\text{Fe/Cu} = 0.78 \text{ V}$ in the same electrolyte, Zn/Cu gives the greater voltage under those conditions. Changing the electrolyte is another factor, so it would prevent attributing a difference only to the metal.

A **battery** has two or more cells connected in series to provide a greater voltage when their orientations reinforce one another. Three identical 1.2 V cells connected that way give $3 \times 1.2 = 3.6 \text{ V}$ in the stated ideal model. Do not connect terminals directly together; actual school work needs approved equipment and procedures.

In a **non-rechargeable** cell, the reaction stops when a reactant is used up. Alkaline batteries are the specified example. In a **rechargeable** cell, supplying an external electrical current reverses the chemical reactions. Charging transfers energy into the cell; it does not create energy. Do not attempt to recharge a non-rechargeable cell. Evaluate a device using the given purchase cost, number of uses, charging access, waste, mass and performance. More uses may offset a higher initial cost, but do not automatically prove the lowest environmental impact.

Hydrogen fuel cells – chemistry only (4.5.2.2)

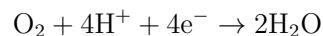
A **fuel cell** receives fuel and oxygen or air from an external supply. Hydrogen is oxidised electrochemically, producing a potential difference; the overall hydrogen–oxygen reaction produces water:



The cell can keep operating while suitable supplies continue. Water is the direct reaction product. Hydrogen production, transport and storage can have other environmental effects, so this equation does not prove zero lifetime emissions. Both

a rechargeable-battery vehicle and a hydrogen-fuel-cell vehicle can have no polluting exhaust at the vehicle. Use given data on refuelling/charging time, range, mass, infrastructure, fuel production and cost to choose for a stated purpose. Do not claim that a fuel cell is always cleaner or cheaper.

Higher Tier: one consistent acidic half-equation model. At the negative electrode, the anode, hydrogen loses electrons and is oxidised. At the positive electrode, the cathode, oxygen gains electrons and is reduced. Electrons flow through the external circuit from the hydrogen electrode to the oxygen electrode.



Each line conserves atoms and charge. Adding them cancels four electrons and four hydrogen ions, leaving the overall equation above. These signs describe a cell supplying electricity; do not copy the electrode signs from externally powered electrolysis. An alkaline model is also possible, but do not mix its hydroxide equations with this acidic pair. Use approved educational equipment or supplied observations; this lesson does not require improvised gas storage.

Check yourself

Classify a change from temperature evidence and explain where energy moves. Evaluate a given warmer/cold-pack design. Plan and interpret the RP4 temperature investigation. Draw both smooth reaction profiles with distinct arrows. For HT, count bonds before subtracting broken minus formed. For chemistry only, interpret cell data, explain series batteries and rechargeability, and compare hydrogen fuel cells with rechargeable cells using a stated evidence boundary. For HT fuel cells, balance both half equations and cancel equal electron numbers.