Chemical energetics

IGCSE Chemistry

Exothermic and endothermic reactions

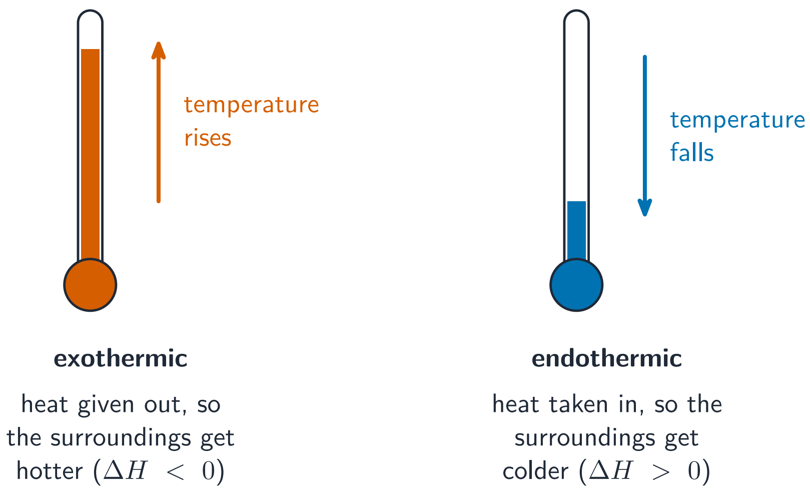
Burning wood is exothermic, releasing heat to the surroundings.

Image: Jon Sullivan, Public domain (commons.wikimedia.org)

In every chemical reaction, energy is transferred. The reaction is either exothermic or endothermic, depending on which way the energy moves.

- An **exothermic reaction** 放热反应 gives out **thermal energy** 热能 to the **surroundings** 环境. So the temperature of the surroundings goes **up**.
- An **endothermic reaction** 吸热反应 takes in thermal energy from the surroundings. So the temperature of the surroundings goes **down**.

Examples of exothermic reactions are **combustion** 燃烧 (burning a fuel) and **neutralisation** 中和 (an acid reacting with an alkali). An example of an endothermic reaction is the thermal **decomposition** 分解 of a compound (breaking it down using heat).



An exothermic reaction warms the surroundings; an endothermic reaction cools them

Enthalpy change, ΔH

The amount of thermal energy transferred in a reaction is called the **enthalpy change** 焓变. It is written as ΔH and has these signs:

- ΔH is **negative** for an exothermic reaction, because energy leaves the chemicals.
- ΔH is **positive** for an endothermic reaction, because energy is taken in.

Activation energy

Particles do not react every time they meet. The **activation energy** 活化能 (E_a) is the smallest amount of energy that **colliding** 碰撞 **particles** 粒子 must have before they can react. It is like a hill the particles must get over before the reaction can happen.

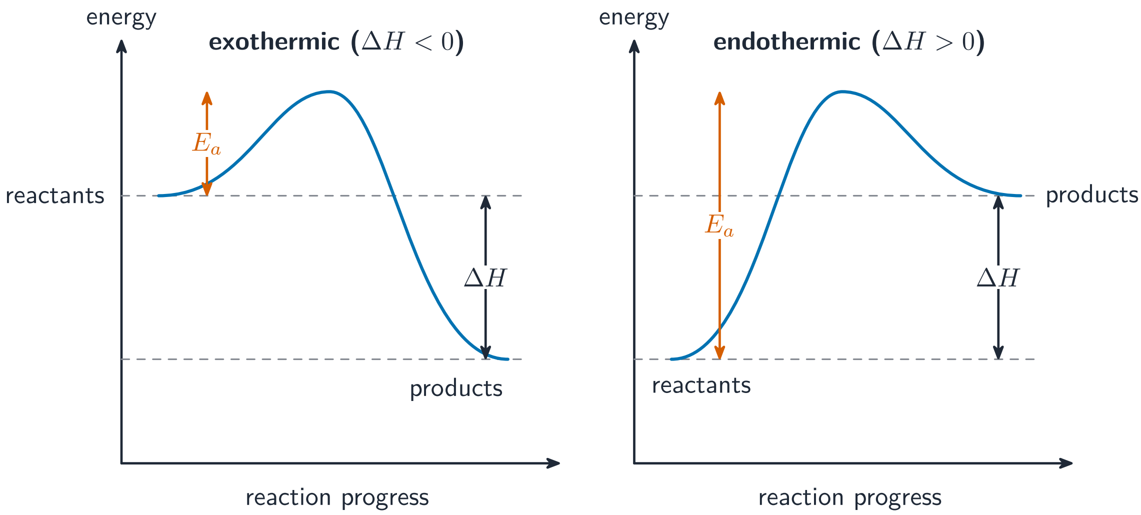
Reaction pathway diagrams

A **reaction pathway diagram** 反应进程图 shows how the energy changes as a reaction happens. Energy is on the vertical axis, and the progress of the reaction is on the horizontal axis.

- The line starts at the energy level of the **reactants** 反应物.
- It rises over a 'hill' —the height of this hill is the activation energy E_a.
- It then falls or rises to the energy level of the **products** 生成物.
- The gap between the reactant level and the product level is the enthalpy change ΔH.

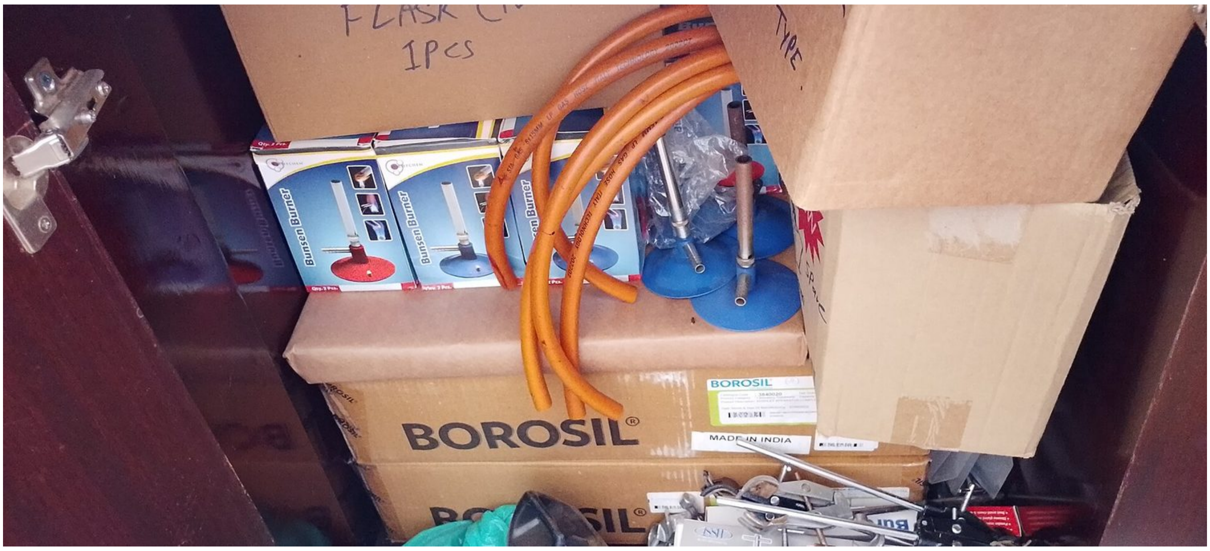
For an **exothermic** reaction, the products are **lower** than the reactants, so energy is given out and ΔH is negative.

For an **endothermic** reaction, the products are **higher** than the reactants, so energy is taken in and ΔH is positive.



Exothermic reactions end lower than they start ($\Delta H < 0$); endothermic reactions end higher ($\Delta H > 0$)

Bonds and energy



Breaking and making bonds transfers energy —the flame supplies it here.

A reaction involves breaking the bonds in the reactants and making new bonds in the products.

- **Bond breaking** 断键 takes in energy, so it is an endothermic step.
- **Bond making** 成键 gives out energy, so it is an exothermic step.

The **bond energy** 键能 is the energy needed to break one mole of a particular bond. You can use bond energies to find the enthalpy change:

$$\Delta H = (\text{energy to break all bonds}) - (\text{energy released making all bonds})$$

If more energy is given out making bonds than is taken in breaking bonds, the reaction is exothermic (ΔH negative). If less energy is given out, it is endothermic (ΔH positive).

Worked example

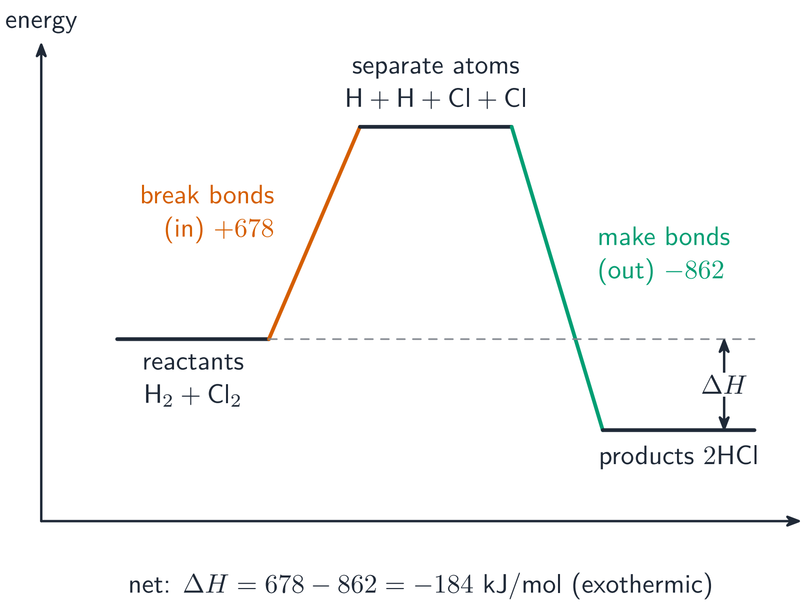
For the reaction $H_2 + Cl_2 \rightarrow 2HCl$, use these bond energies (in kJ/mol): H–H = 436, Cl–Cl = 242, H–Cl = 431.

Bonds broken: one H–H and one Cl–Cl = 436 + 242 = 678.

Bonds made: two H–Cl = $2 \times 431 = 862$.

$$\Delta H = 678 - 862 = -184 \text{ kJ/mol}$$

The answer is negative, so this reaction is exothermic.



Breaking bonds takes energy in (+678); making bonds gives more out (−862); so $\Delta H = -184$ kJ/mol

Exam tips

- **Exothermic** gives out heat, so the surroundings warm up and ΔH is *negative*; **endothermic** takes in heat, so the surroundings cool and ΔH is *positive*.
- **Bond breaking** takes energy in (endothermic); **bond making** gives energy out (exothermic). Use ΔH = (energy to break bonds) − (energy released making bonds).
- If more energy is released making bonds than is used breaking them, the reaction is exothermic. Always check the sign of your final answer.
- On a **reaction pathway diagram**, an exothermic reaction ends *lower* than it starts; an endothermic one ends *higher*. The height of the hill is the **activation energy**.