How fast? The rate of chemical change

Reactivity 2.2 · SL

Why does food last longer in a fridge?

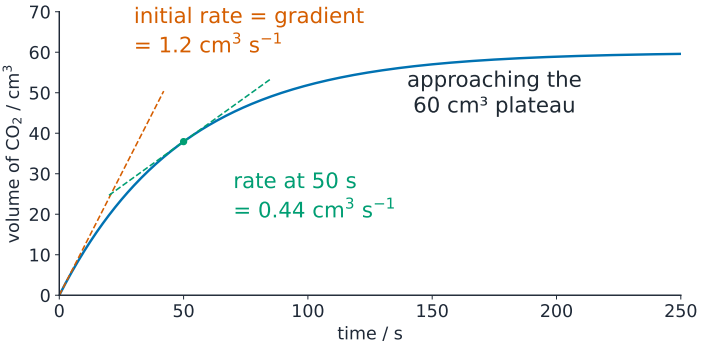
Temperature changes how fast a reaction goes.

- Cooling slows many deterioration reactions; storage life depends on the food and conditions.
- A firework burns in a second; iron rusts over months.
- This unit: measuring rate $\rightarrow$ collisions $\rightarrow$ controlled conditions.

Following a reaction

What changes	Method
gas given off	gas syringe, volume every 10 s
gas escapes	mass loss on a balance
colour	colorimeter
ions	conductivity or pH meter
precipitate	time for a cross to disappear

Reading a rate from a graph



The **initial rate** is the gradient at $t = 0$.

Three conditions for reaction

- Particles must collide.
- With energy at least E_a, and the right orientation.

> **Activation energy** the minimum energy that colliding particles need for a reaction

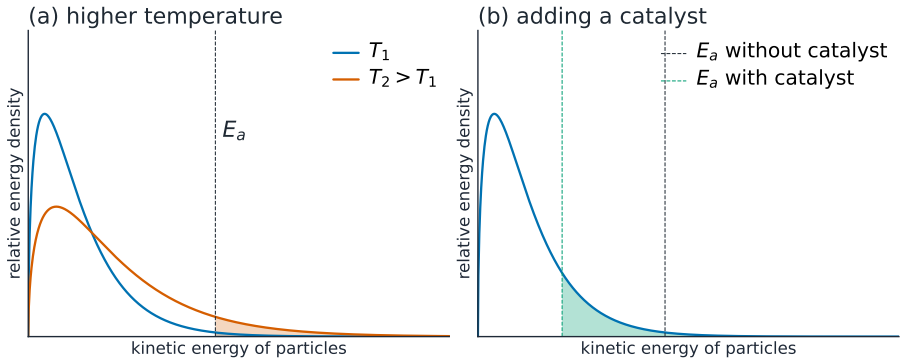
Use kelvin for mean kinetic energy

1. **Compare.** Heat from 20 °C to 40 °C: temperatures are 293.15 K and 313.15 K.
2. **Mean energy.** Factor 313.15/293.15=1.068, an increase about 6.8%, rather than a doubling.
3. **Rate.** The high-energy tail changes too; this mean-energy ratio alone does not determine the rate factor.

Decision

Temperature ratios for kinetic energy use kelvin.

The Maxwell–Boltzmann distribution



Above-threshold energy is necessary; orientation and pathway still matter.

Concentration, pressure and surface area

Change	Why it is faster
higher concentration	more particles per dm^3
compress the reactant gases	higher reactant concentration at fixed temperature
smaller pieces	more particles exposed

Check: why does temperature matter so much?

Your turn

What is the main reason a higher temperature speeds up a reaction?

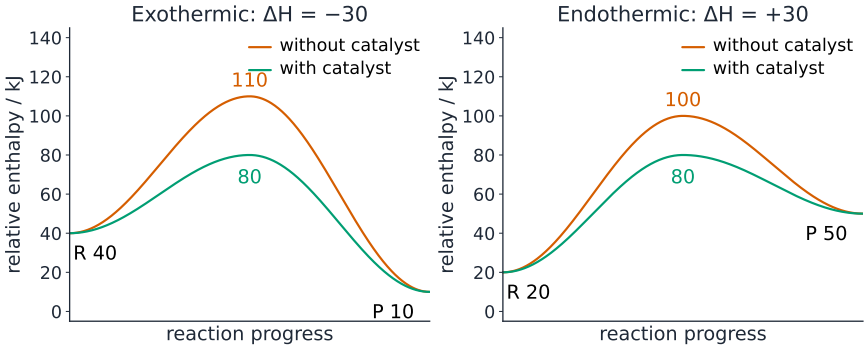
A. Particles collide a little more often.

B. A much larger fraction of collisions has energy at least E_a.

C. The activation energy falls.

D. The enthalpy change becomes more negative.

Catalysts



A **catalyst** does not change ΔH or the equilibrium position.

Distinguish a mean from a tangent gradient

1. **Invented interval.** Gas rises from 10.0 to 34.0 cm^3 between 20 and 60 s: $(34-10)/(60-20)=0.600$ cm^3/s.
2. **Invented tangent.** Points on the **tangent**: (30 s,22 cm^3) and (70 s,46 cm^3). Gradient$=(46-22)/(70-30)=0.600$ cm^3/s.
3. **Interpret.** A secant averages an interval; a tangent estimates one instant. These two values happen to coincide.

Decision

Use points on the tangent, rather than two arbitrary curve points.

A coefficient changes the species disappearance rate

1. **Equation.** 2A $\rightarrow$ B at fixed volume; [A] falls by 0.030 mol/dm^3 over 5.0 s.
2. **A disappearance.** $0.030/5.0 = 0.0060$ mol/dm^3/s.
3. **B formation.** Divide by two: 0.0030 mol/dm^3/s, also the coefficient-normalized reaction rate.

Decision

State which species and rate convention the data use.

A plateau needs an explanation

Possible chemistry

Limiting reagent exhausted in a complete reaction.

Dynamic equilibrium with equal forward and reverse rates.

Possible measurement limit

Leaks, sensor saturation or a change smaller than resolution.

The curve records net measured change.

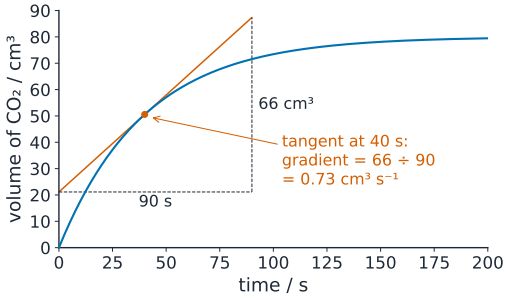
A fixed threshold makes 1/t an approximate proxy

1. **Comparable trials.** Cross-disappearance times are 40 s and 25 s; use the same optical path and threshold.
2. **Relative factor.** $(1/25)/(1/40)=1.6$: the second trial has a 1.6-fold proxy rate.
3. **Limitation.** Changed threshold, path length or subjective timing breaks the comparison.

Decision

This proxy does not directly give an instantaneous concentration rate.

Rate from a tangent



Rate ≈ 0.73 cm^3 s^{-1}

Four ways to follow a rate

gas syringe: gas-tight joints, fit at once (early gas is fastest)

mass loss: gas must escape; account for evaporation and spray

colorimeter: calibrate; fixed wavelength, path, working range

pH or conductivity: pH is logarithmic; all ions conduct

change one factor, control the rest, repeat to estimate variability

Each has its own caveat

Read the endothermic barriers in both directions

1. **Invented levels.** Reactants 20, products 50 and uncatalysed peak 100 kJ per reaction amount.
2. **Differences.** $\Delta H = +30$; forward Ea=80 and reverse Ea=50 kJ.
3. **Catalysed peak 80.** Forward Ea=60, reverse Ea=30; ΔH remains +30 kJ.

Decision

At the same temperature the thermal-energy distribution is unchanged.

Exam tips

> Keep equal area for the same particle count; the ideal tail approaches zero.

- Draw tangents long; read two far-apart points.
- Concentration changes collision frequency; temperature changes the energy fraction.

Check yourself

Try these

Explain why powdered $CaCO_3$ reacts faster than lumps.

Sketch Maxwell–Boltzmann curves at two temperatures and explain the rise in rate.

Explain how a catalyst works, with an energy profile.