Chemical Reactions

IGCSE Chemistry ▪ Topic 6

IGCSE Chemistry

What we will cover

1 Change and rate

Physical vs chemical change

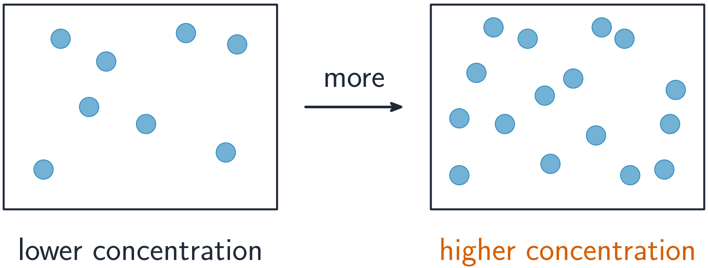
Iron rusting – a new substance forms

- A **physical change** 物理变化 makes no new substance – only the state or shape changes, and it usually reverses. Melting ice, dissolving sugar.
- A **chemical change** 化学变化 makes one or more new substances and is usually hard to reverse. Burning, rusting.
- Signs of a chemical change: a colour change, a gas given off, an energy change, or a **precipitate** 沉淀 forming.

Collision theory and rate

Collision theory 碰撞理论: particles must collide with enough energy ($\geq E_a$). Faster when collisions are more frequent or more energetic:

- more **concentration** 浓度 / pressure
- more **surface area** 表面积
- higher temperature

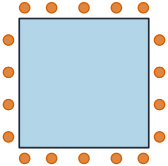


What a collision needs

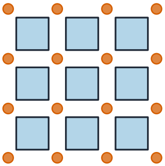
Rate of reaction	The **rate of reaction** 反应速率 is how fast the **reactants** 反应物 are used up, or the **products** 生成物 formed.
Frequency	More collisions per second – higher concentration, higher pressure, larger surface area – means a faster rate.
Energy	A collision only works if the particles have enough **kinetic energy** 动能 to react. Heating raises the average, so far more collisions succeed.
The other half	Temperature therefore acts twice, which is why it changes rate more sharply than concentration does.

Every rate factor is either *more collisions* or *more successful ones*. Say which, and the explanation is complete.

Surface area



one big lump
small surface
area $\longrightarrow$ slower

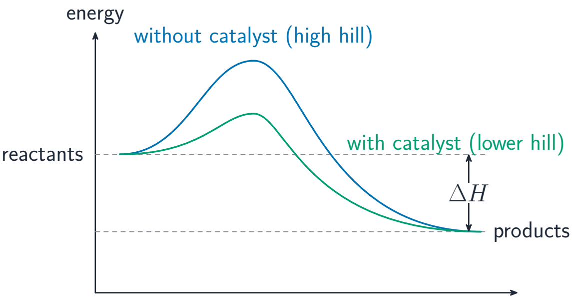


same mass
as powder
large surface
area $\longrightarrow$ faster

A powder has far more surface than one lump, so acid touches many more particles.

> More exposed particles $\Rightarrow$ more collisions $\Rightarrow$ a faster rate.

Catalysts

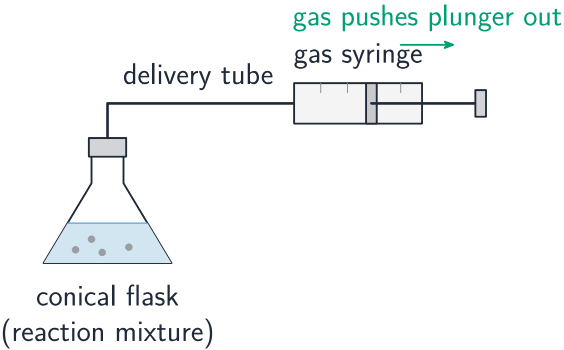


a catalyst lowers the activation energy; ΔH is unchanged

A **catalyst** 催化剂 speeds a reaction but is not used up.

- it lowers the **activation energy** 活化能
- ΔH is unchanged
- **enzymes** 酶 are biological catalysts

Measuring the rate



Follow a reaction by:

- loss of mass on a balance
- gas volume in a **syringe** 注射器
- time for a **precipitate** 沉淀 to hide a mark

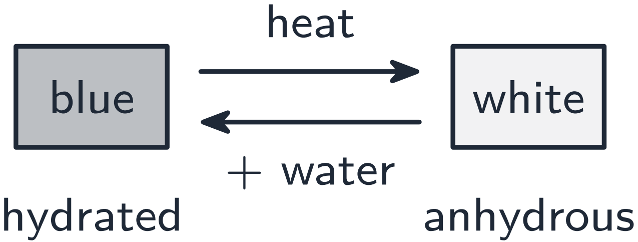
The graph is steepest at the start, then flat.

2 Equilibrium

Reversible reactions

A **reversible reaction** 可逆反应 ($\rightleftharpoons$) can go both ways.

> Blue **hydrated** 水合 $CuSO_4 \rightleftharpoons$ white **anhydrous** 无水 $CuSO_4$ + water. Adding water turns it blue – a test for water.



A reaction that runs both ways

Reverse reaction	In a reversible reaction the products re-form the reactants – the **reverse reaction** 逆反应 – and both run at once.
Equilibrium	At equilibrium the two rates are *equal*, so the amounts stop changing. Nothing has stopped happening.
A classic test	Hydrated copper(II) sulfate turns white when heated and blue again with water – reversible, and visible.
Redox in one line	A **redox reaction** 氧化还原反应 is any reaction where electrons transfer: one species is oxidised as another is reduced.

> Equilibrium is dynamic. Marks are lost by writing that the reaction "stops".

Equilibrium

At **equilibrium** 平衡 (closed system): rate forward = rate reverse

concentrations stop changing (but the reaction is still going)

To shift the position: **heat** → endothermic side; **pressure** → fewer-molecules side; **add a substance** → the other side. A catalyst does not shift it.

Industry: Haber and Contact

Haber 哈伯法 – ammonia

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

450°C, ∼200 atm, iron catalyst

Contact 接触法 – SO_3

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

450°C, ∼2 atm, V_2O_5 catalyst

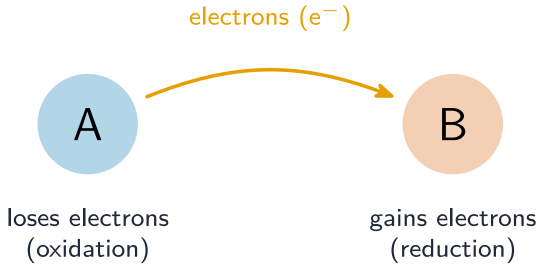
Conditions are a **compromise** 折中: medium pressure (safe), fairly high temperature (good rate).

Why these conditions are chosen

- A higher pressure would give more product, but very high pressure is dangerous and expensive, so a medium pressure is used.
- A lower temperature would give more product (both forward reactions are exothermic), but the reaction would be too slow, so a fairly high temperature is used to keep a good rate.
- The catalyst speeds up the reaction without changing the position of equilibrium, which lowers cost.

3 Redox

Redox



Oxidation 氧化 & **reduction** 还原 happen together.

> **OIL RIG**: Oxidation Is Loss, Reduction Is Gain – of electrons.

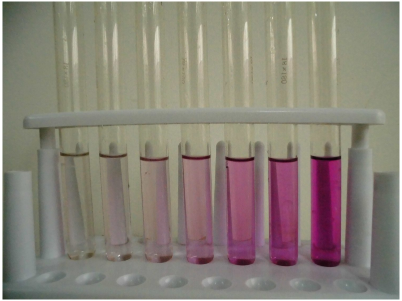
An **oxidising agent** 氧化剂 is itself reduced (purple MnO_4^- fades).

Oxidation number rules

The oxidation number is shown by a Roman numeral, as in iron(II) and iron(III).

- An element that is not combined has an oxidation number of 0.
- A single-atom ion has an oxidation number equal to its charge (so Na^+ is $+1$).
- The oxidation numbers in a compound add up to 0.
- The oxidation numbers in an ion add up to the charge on the ion.

Oxidising and reducing agents



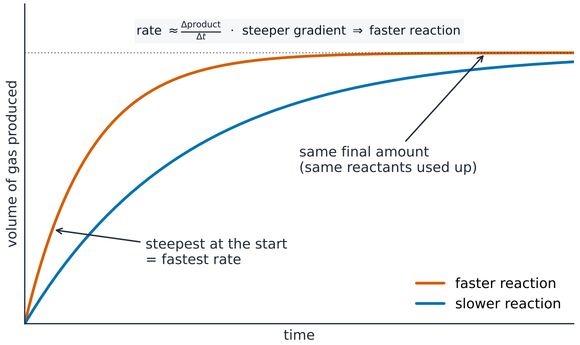
Potassium manganate(VII) is deep purple; as it is reduced (or diluted) the purple fades to colourless

A test you can see

The reaction	Chlorine displaces iodine from **potassium iodide 碘化钾**: $Cl_2 + 2KI \rightarrow 2KCl + I_2$.
What you see	The solution turns brown as **iodine 碘** is released – the more reactive halogen has taken the electrons.
Naming it	Chlorine is the oxidising agent (it gains electrons and is reduced); iodide is the reducing agent.
Also on the list	Reactions with **oxygen 氧气** are the everyday oxidation: burning, rusting, and the tarnishing of a fresh metal surface.

> An oxidising agent is the species that is *reduced*. The two words describe the same electron moving.

Measuring the rate, continued



> The rate is fastest at the start (steepest) and the line levels off when the reaction finishes

Measuring a rate, and the two industrial processes

change in mass	stand the flask on a balance – if a gas escapes, the mass falls. Record at regular times
volume of gas	collect it in a gas **syringe** 注射器 and read the volume at regular times
a colour change	time how long a cross under the flask takes to disappear
the Haber process	**hydrogen** 氢气 from **methane** 甲烷 (natural gas); **nitrogen** 氮气 from the air
its conditions	about $450\,^{\circ}$C, 200 atm, iron catalyst – a compromise between rate and yield
the Contact process	sulfur dioxide to sulfur trioxide over vanadium(V) oxide, about $450\,^{\circ}$C and 2 atm

Both use a compromise temperature: hotter is faster but gives less yield, because both forward reactions are exothermic.

Exam tips

- Explain a faster rate with **collision theory**: successful collisions happen more often. Concentration, pressure and surface area all raise how often particles collide; a higher temperature does that *and* gives more particles enough energy.
- A **catalyst** lowers the activation energy and speeds the reaction up, but is not used up and does *not* change ΔH or the position of equilibrium.
- At **equilibrium** the forward and reverse rates are equal and the concentrations stop changing – it does *not* mean the amounts of reactant and product are equal.
- Use Le Chatelier's principle: raising temperature favours the endothermic direction; raising pressure favours the side with fewer gas molecules; adding a substance shifts the equilibrium away from it.
- **Redox** – OIL RIG: Oxidation Is Loss, Reduction Is Gain of electrons. They always happen together, and an oxidising agent is itself reduced.

4 Recap

Worked example – speeding up a reaction

Powdered marble reacts with acid faster than a single lump. Explain using collision theory.

- A reaction needs particles to collide with at least the **activation energy** 活化能.
- Powder has a much larger surface area exposed to the acid.
- So there are more collisions per second between acid particles and the marble.
- More successful collisions per second $\Rightarrow$ a faster rate.

Surface area, concentration and pressure work by giving more collisions. Temperature also gives more energetic ones; a catalyst lowers E_a.

Topic 6 – key takeaways

1 Rate

more frequent / energetic collisions = faster

2 Catalyst

lowers E_a; not used up; ΔH unchanged

3 Equilibrium

forward = reverse in a closed system

4 Redox

OIL RIG; oxidation & reduction together

Check yourself

1. Why does a powder react faster than a lump?
2. How does a catalyst speed up a reaction?
3. What is equal at equilibrium?
4. In OIL RIG, what is oxidation?

Answers **1.** more surface, so more collisions **2.** it lowers the activation energy **3.** the forward & reverse rates **4.** loss of electrons