Chemical Reactions

IGCSE Chemistry ▪ Topic 6

IGCSE Chemistry

What we will cover

1 Change and rate

Physical vs chemical change

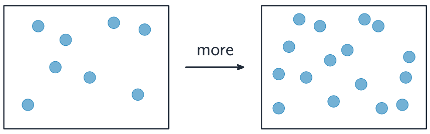
Iron rusting – a new substance forms

- 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

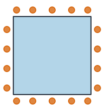


What a collision needs

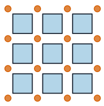
Rate of reaction	The **rate of reaction** 反应速率 is how fast the **reactants** 反应物 are used up, or the **products** 生成物 formed.
Frequency	More collisions per second – higher concentration, higher pressure, larger surface area – means a faster rate.
Energy	A collision only works if the particles have enough **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 ⟶ slower

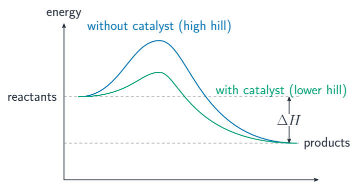


same mass
as powder
large surface
area ⟶ faster

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

> More exposed particles ⇒ more collisions ⇒ a faster rate.

Catalysts

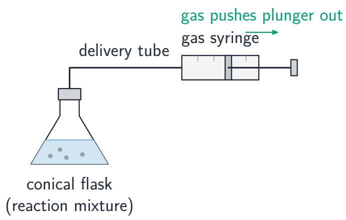


a catalyst lowers the activation energy; ΔH is unchanged

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

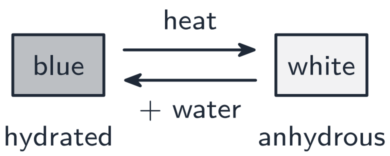
The graph is steepest at the start, then flat.

2 Equilibrium

Reversible reactions

A **reversible reaction** 可逆反应 (⇌) can go both ways.

> Blue **hydrated** 水合 $CuSO_4$ ⇌ 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

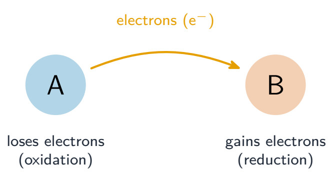
Conditions are a **compromise** 折中: medium pressure (safe), fairly high temperature (good rate).

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.

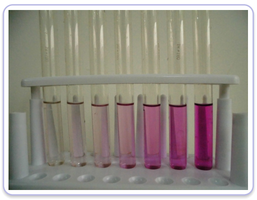
An **oxidising agent** 氧化剂 is itself reduced (purple MnO_4^- fades).

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



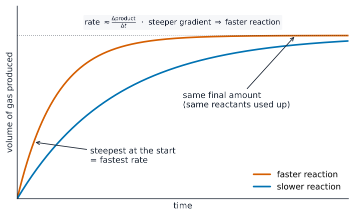
Potassium manganate(VII) is deep purple; as it is reduced (or diluted) the purple fades to colourless

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 °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 °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 ⇒ 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

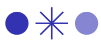
forward = reverse in a closed system

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