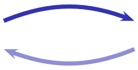
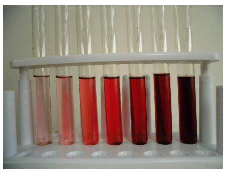
Equilibria

A-Level Chemistry ▪ Topic 7

A-Level Chemistry



What we will cover



a shifting equilibrium

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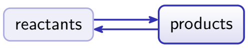
1 Equilibrium

Dynamic equilibrium

A **dynamic equilibrium** 动态平衡 is a closed system where the forward and reverse rates are equal. Concentrations stay constant, but both reactions still run.

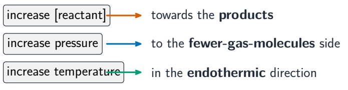


reactants ⇌ products

> It is dynamic: molecules keep reacting. It is equilibrium: nothing measurable changes.

Le Chatelier's principle

the equilibrium shifts to *oppose* the change you make



increase [reactant] → towards the **products**

increase pressure → to the **fewer-gas-molecules** side

increase temperature → in the **endothermic** direction

a **catalyst** speeds both directions equally, so it gives *no shift*

Le Chatelier's principle 勒夏特列原理: the equilibrium shifts to oppose a change.

- more reactant → towards products
- more pressure → fewer-gas side
- more heat → endothermic way
- a **catalyst** 催化剂 → no shift

Equilibrium constants

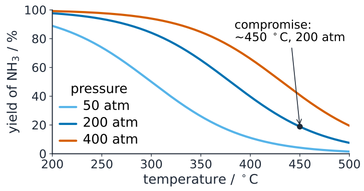
$$K_c = \frac{[\mathrm{C}]^c[\mathrm{D}]^d}{[\mathrm{A}]^a[\mathrm{B}]^b}$$

$H_2 + I_2 \rightleftharpoons 2HI$

$$K_c = \frac{1.6^2}{0.20 \times 0.20} = 64 \text{ (no units here)}$$

Only temperature changes K_c or K_p. For gases use **partial pressure** 分压 = **mole fraction** 摩尔分数 × total pressure.

The Haber and Contact processes



exothermic: lower *T* ↑ yield · higher *P* ↑ yield

Conditions balance yield, rate & cost:

- **Haber** 哈伯法:
  $N_2 + 3H_2 \rightleftharpoons 2NH_3$ –
  $\sim 450\,°C$, 200 atm, Fe
- **Contact** 接触法:
  $2SO_2 + O_2 \rightleftharpoons 2SO_3$ – V_2O_5

Low temperature gives more yield but too slowly.

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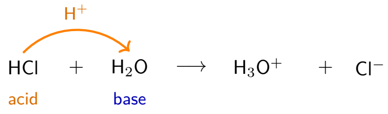
2 Acids and bases

Brønsted–Lowry acids and bases



H^+

$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$

acid base

conjugate acid–base pairs:
$HCl\,/\,Cl^-$ and $H_2O\,/\,H_3O^+$

- an **acid** 酸 is a **proton donor** 质子供体
- a **base** 碱 is a **proton acceptor** 质子受体

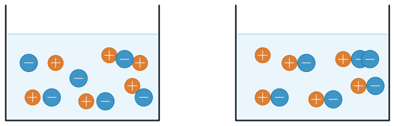
The reaction makes two **conjugate** 共轭 acid–base pairs.

Strong and weak acids

This is about ionisation, not concentration:

- **strong acid** 强酸 – fully **dissociated** 解离
- **weak acid** 弱酸 – only partly dissociated

A strong acid has a lower **pH** pH & conducts better.



strong acid
fully dissociated: many ions

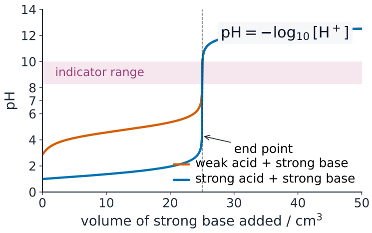
weak acid
mostly molecules: few ions

Bronsted-Lowry, and telling strong from weak

an acid	a proton donor – it gives H^+
a base 碱	a **proton acceptor** 质子受体 – it takes H^+. A base that dissolves in water is an alkali
the acids to know	hydrochloric HCl, sulfuric H_2SO_4, nitric HNO_3, and ethanoic CH_3COOH
a strong base 强碱	fully dissociated – NaOH, KOH; a **weak base** 弱碱 such as ammonia only partly
test 1: reactive metal	a strong acid fizzes faster at the same concentration
test 2: pH	measured with a pH meter or **universal indicator** 通用指示剂 – strong acids give a lower pH at equal concentration

> Strong is about how far it dissociates; concentrated is about how much is dissolved. A concentrated weak acid is entirely possible.

Titration curves



Neutralisation 中和: $H^+ + OH^- \rightarrow H_2O$, forming a **salt** 盐.

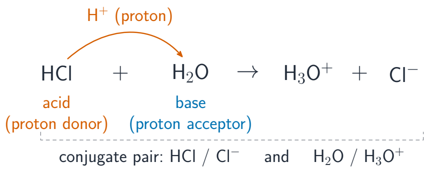
> A **titration curve** 滴定曲线 has a steep pH jump at the end point – pick an **indicator** 指示剂 that changes colour inside it.

Neutralisation and the shape of a titration curve

neutralisation 中和	$H^+ + OH^- \rightarrow H_2O$ – the same ionic equation whichever acid and alkali
a titration 滴定	add one solution to another and follow the pH
the titration curve 滴定曲线	has a steep, almost vertical section at the end point
strong–strong	the vertical section is long, and centred near pH 7
weak acid–strong base	shorter, and centred above 7; the reverse case is centred below it
choosing an indicator	its colour change must fall inside the vertical section

> The indicator is chosen from the *curve*, not from the acid. That is why phenolphthalein suits a weak acid and methyl orange does not.

Acids and bases: the Brønsted–Lowry theory



$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

> Brønsted–Lowry: the acid donates a proton (H^+) to the base, making two conjugate acid–base pairs

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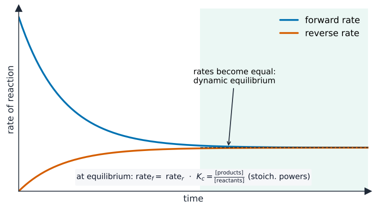
Reversible reactions and dynamic equilibrium



> At dynamic equilibrium the forward and reverse rates have become equal, so the concentrations stay constant

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The Haber and Contact processes, continued

> Ammonia for fertiliser is made by the Haber process in large industrial plants like this one.

Exam tips

- Define **dynamic equilibrium** with all three points: forward and reverse rates equal, concentrations constant, closed system.
- Answer **Le Chatelier** questions by stating the change, the direction of shift, and the reason; a **catalyst does not shift** the position (it speeds both rates).
- Write K_c as **products over reactants**, each raised to its balancing number; include state symbols to decide what appears.
- Justify Haber/Contact conditions as a **compromise** between yield, rate and cost – do not just quote them.
- Brønsted: acid = **proton donor**, base = proton acceptor; conjugate pairs differ by one H^+.

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3 Recap

Topic 7 – key takeaways

① **Equilibrium**

equal forward & reverse rates

② **Le Chatelier**

the equilibrium opposes any change

③ K_c

products over reactants; only T changes it

④ **Acids**

donate protons; strong = fully dissociated

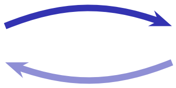
Check yourself

① At equilibrium, how do the forward & reverse rates compare?

② Raising pressure shifts to which side?

③ What only changes the value of K_c?

④ A proton donor is an acid or a base?



Answers **1.** they are equal **2.** the side with fewer gas molecules **3.** temperature **4.** an acid