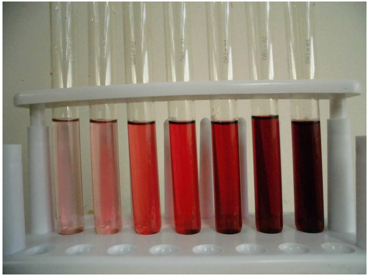
Equilibria

A-Level Chemistry ▪ Topic 7

A-Level Chemistry

What we will cover

1. Dynamic equilibrium
2. Le Chatelier's principle
3. Equilibrium constants
4. Haber & Contact
5. Brønsted–Lowry acids
6. Strong/weak & titrations



a shifting equilibrium

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.

$$\boxed{\text{reactants}} \rightleftharpoons \boxed{\text{products}}$$

> 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

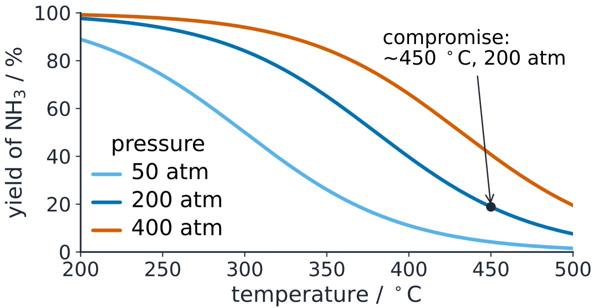
$$K_c = \frac{[\mathsf{C}]^c[\mathsf{D}]^d}{[\mathsf{A}]^a[\mathsf{B}]^b}$$

$H_2 + I_2 \rightleftharpoons 2HI$

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

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

2 Acids and bases

Brønsted–Lowry acids and bases

$$\underset{\text{acid}}{HCl} \xrightarrow{\;H^+\;} + \underset{\text{base}}{H_2O} \longrightarrow H_3O^+ + Cl^-$$

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

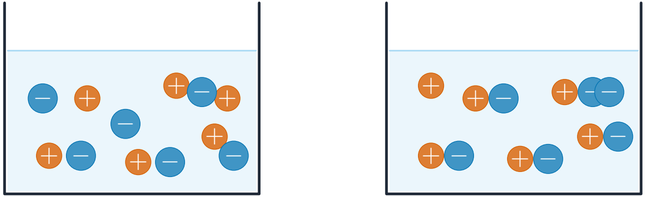
The reaction makes two **conjugate** 共轭 acid–base pairs.

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

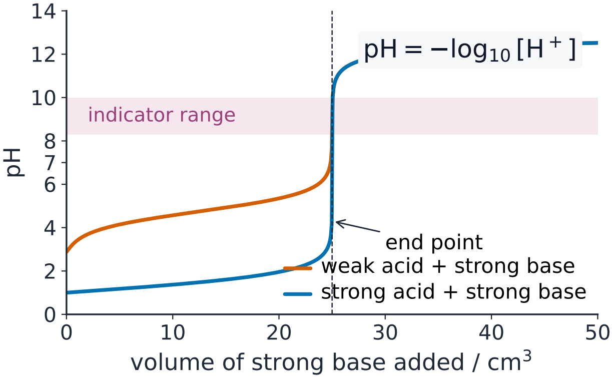
weak acid
mostly molecules: few ions

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

H^+ (proton)

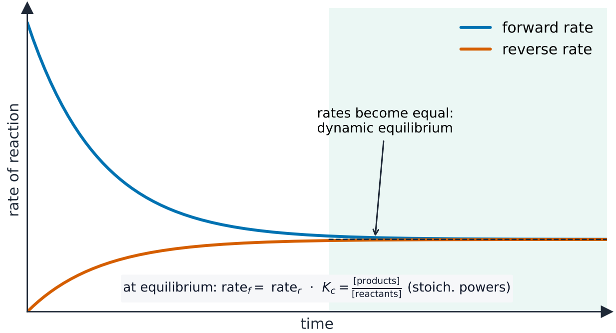
$$\mathrm{HCl} + \mathrm{H_2O} \rightarrow \mathrm{H_3O^+} + \mathrm{Cl^-}$$

acid (proton donor) base (proton acceptor)

conjugate pair: $\mathrm{HCl} / \mathrm{Cl^-}$ and $\mathrm{H_2O} / \mathrm{H_3O^+}$

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

Reversible reactions and dynamic equilibrium



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

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^+.

3 Recap

Topic 7 – key takeaways

1 Equilibrium

equal forward & reverse rates

2 Le Chatelier

the equilibrium opposes any change

3 K_c

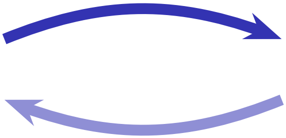
products over reactants; only T changes it

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