Equilibria

A-Level Chemistry ▪ Topic 25

A-Level Chemistry

What we will cover

1. Conjugate acids & bases
2. pH & the constants
3. Calculating pH
4. Buffer solutions
5. Solubility & partition

pH paper estimates acidity

1 Acids and pH

Conjugate acids and bases

An acid loses H^+ to give its **conjugate base** 共轭碱; a base gains H^+ to give its **conjugate acid** 共轭酸.

> A **conjugate pair** 共轭酸碱对 differs by just one H^+ – e.g. CH_3COOH and CH_3COO^-.

conjugate pair: differ by one H^+

$$\underset{\text{acid}}{CH_3COOH} \rightleftharpoons \underset{\text{conjugate base}}{CH_3COO^-} + H^+$$

pH and the constants

$$\mathrm{pH} = -\log[\mathrm{H}^+]$$

$$K_a = \frac{[\mathrm{H}^+][\mathrm{A}^-]}{[\mathrm{HA}]}$$

$$K_w = [\mathrm{H}^+][\mathrm{OH}^-]$$

A larger K_a 酸解离常数 (smaller pK_a) is a stronger acid; $K_w = 1.0 \times 10^{-14}$ at 298 K.

Calculating pH

strong acid – $[H^+]$ = conc. ; HCl $0.050 \Rightarrow$ pH $= 1.30$

strong base – $[H^+] = K_w/[OH^-]$; NaOH $0.10 \Rightarrow$ pH $= 13.0$

weak acid – $[H^+] = \sqrt{K_a[HA]}$; ethanoic $0.10 \Rightarrow$ pH $= 2.87$

The four pH calculations

strong acid	fully ionised, so $[H^+]$ is the acid's concentration; pH $= -\log[H^+]$
weak acid	only partly ionised, so $[H^+] = \sqrt{K_a \times [HA]}$, where K_a is the **acid dissociation constant** 酸解离常数
strong alkali 强碱	find $[OH^-]$, then use the **ionic product of water** 水的离子积 $K_w = [H^+][OH^-] = 10^{-14}$
a buffer	$[H^+] = K_a \dfrac{[HA]}{[A^-]}$
a conjugate pair 共轭酸碱对	an acid and the base left after it donates its proton – the two components of every buffer

A buffer works because the mixture holds a store of both partners: the acid mops up added alkali, and the conjugate base mops up added acid.

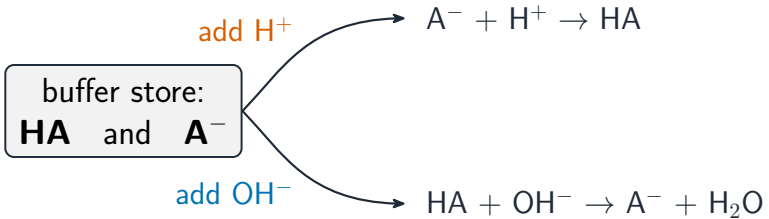
2 Buffers and solubility

Buffer solutions

A **buffer** 缓冲溶液 (a weak acid + its conjugate base) resists pH change:

- added H^+ removed by A^-
- added OH^- removed by HA

HCO_3^- keeps blood near pH 7.4.



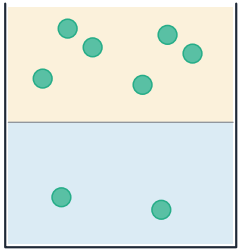
either way, the pH barely changes

Solubility product

The **solubility product** 溶度积 $K_{sp} = [Ag^+][Cl^-]$ (each ion to the power of its number).

> The **common ion effect** 同离子效应: a salt is less soluble in a solution already containing one of its ions (Le Chatelier).

Partition coefficients



solvent 1 (non-polar)

$$K_{\text{pc}} = \frac{[\text{solute in 1}]}{[\text{solute in 2}]}$$

solvent 2 (water)

The **partition coefficient** 分配系数 is the ratio of a solute's concentrations in two immiscible solvents.

$$K_{\text{pc}} = \frac{[\text{solute in 1}]}{[\text{solute in 2}]}$$

It depends on the **polarity** 极性 of the solute & solvents.

When a partition coefficient applies

what it is	the ratio of a **solute** 溶质's concentrations in two immiscible solvents at equilibrium
the condition	it holds only when the solute is in the same physical state in both solvents – no dimerising or dissociating
what it depends on	the **polarity** 极性 of the solute and of the two solvents
the rule	"like dissolves like" – a polar solute favours the polar solvent
where it is used	solvent extraction, and chromatography, where the same partition runs continuously along the plate

Repeated extraction with small portions removes more solute than one extraction with the same total volume. That is the calculation the exam sets.

pH and the equilibrium constants

$$\text{pH} = -\log[\text{H}^+]$$

0 7 14

acidic neutral alkaline

The pH scale: pH = -log of the hydrogen-ion concentration

Exam tips

- $\mathrm{pH} = -\log[\mathrm{H}^+]$; for a **strong acid** $[\mathrm{H}^+]$ = concentration, for a **weak acid** use $[\mathrm{H}^+] = \sqrt{K_a[\mathrm{HA}]}$.
- For a base, get $[\mathrm{H}^+]$ from $K_w = [\mathrm{H}^+][\mathrm{OH}^-] = 1.0 \times 10^{-14}$.
- For a **buffer** use $[\mathrm{H}^+] = K_a \times [\mathrm{acid}]/[\mathrm{salt}]$ and explain how it removes added $\mathrm{H}^+/\mathrm{OH}^-$.
- Write the K_{sp} expression with the correct powers; the number of decimal places in a pH equals the significant figures of $[\mathrm{H}^+]$.

3 Recap

Worked example – pH of a strong acid

Find the pH of $0.050\,\mathrm{mol\,dm^{-3}}$ hydrochloric acid.

- HCl is a strong acid: it dissociates completely.
- So $[\mathrm{H^+}] = 0.050\,\mathrm{mol\,dm^{-3}}$ – the concentration itself.
- $\mathrm{pH} = -\log_{10}[\mathrm{H^+}] = -\log_{10}(0.050)$
- $= 1.30$.

Strong acid: $[\mathrm{H^+}]$ *is* the concentration.
Weak acid: you must go through K_a – never assume full dissociation.

Topic 25 – key takeaways

1 Conjugate pairs

differ by one H^+

2 pH

$-\log[H^+]$; K_a, K_w for weak/strong

3 Buffers

weak acid + its salt resist pH change

4 Solubility

K_{sp}; the common ion effect

Check yourself

1. Write the pH formula.
2. What does a buffer resist?
3. What two things make a buffer?
4. What does the common ion effect do to solubility?

Answers **1.** $\text{pH} = -\log[\text{H}^+]$ **2.** a change in pH **3.** a weak acid & its conjugate base **4.** lowers it