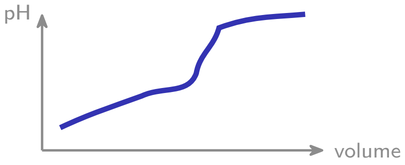
Acids and Bases

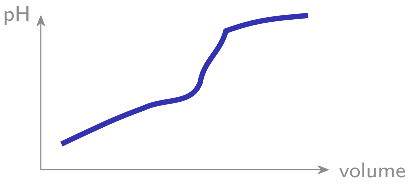
AP Chemistry ▪ Unit 8

AP Chemistry



What we will cover

1. Bronsted-Lowry and pH
2. Strong acids and bases
3. Weak acid and base equilibria
4. Buffers and Henderson-Hasselbalch
5. Acid-base titrations
6. Structure and pKa



Bronsted-Lowry and pH

Bronsted-Lowry 布朗斯特-劳里: an acid donates a proton, a base accepts one – forming **conjugate pairs** 共轭酸碱对.

Water and pH

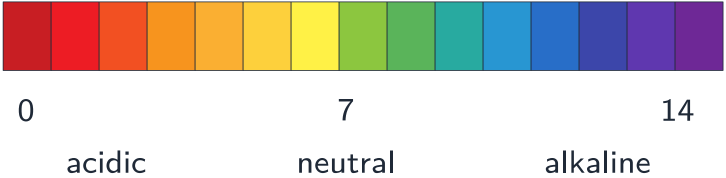
$$K_w = [\mathrm{H}^+][\mathrm{OH}^-] = 10^{-14}$$

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

pH measures acidity of a solution

Bronsted-Lowry and pH

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



Strong acids and bases

A **strong acid** 强酸 ionizes completely, so $[\mathrm{H}^+]$ equals its concentration.

Two logarithms

$$\mathrm{pH} = -\log[\mathrm{H}^+], \; \mathrm{pOH} = -\log[\mathrm{OH}^-]$$

$$\mathrm{pH} + \mathrm{pOH} = 14$$

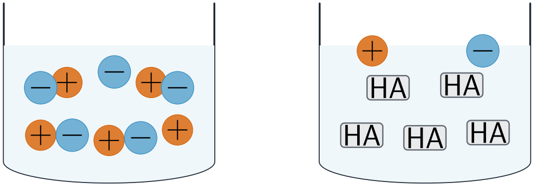
Worked example

$0.010\,\mathrm{M}$ HCl:

$$[\mathrm{H}^+] = 0.010 \Rightarrow \mathrm{pH} = 2$$

$$\mathrm{pOH} = 12, \; [\mathrm{OH}^-] = 10^{-12}$$

Strong acids and bases



strong acid
fully split into ions (e.g. HCl)

weak acid
mostly molecules, few ions (e.g. ethanoic acid)

Weak acid and base equilibria

A **weak acid** 弱酸 only partly ionizes:

Ionization constant

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

Larger K_a = stronger. For a conjugate pair, $K_a K_b = K_w$.

Worked example

$0.10\,\mathrm{M}$, $K_a = 10^{-5}$:

$$K_a \approx \frac{x^2}{0.10} \Rightarrow x = 10^{-3}$$

$$\mathrm{pH} = 3$$

A strong acid at $0.10\,\mathrm{M}$ would give pH 1.

Buffers and Henderson-Hasselbalch

A **buffer** 缓冲溶液 holds pH steady with both a weak acid and its conjugate base:

- added acid $\Rightarrow$ conjugate base soaks up H^+
- added base $\Rightarrow$ weak acid soaks up OH^-

Henderson-Hasselbalch

$$\mathrm{pH} = \mathrm{p}K_a + \log \frac{[\mathrm{A}^-]}{[\mathrm{HA}]}$$

Equal amounts $\Rightarrow$ $\mathrm{pH} = \mathrm{p}K_a$. **Capacity** 缓冲容量 grows with total concentration.

Buffers and Henderson-Hasselbalch

buffer store:
HA and $\mathbf{A^-}$

add H^+: $A^- + H^+ \rightarrow HA$

add OH^-: $HA + OH^- \rightarrow A^- + H_2O$

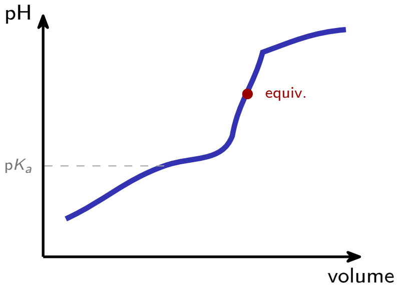
either way, the pH barely changes

Acid-base titrations

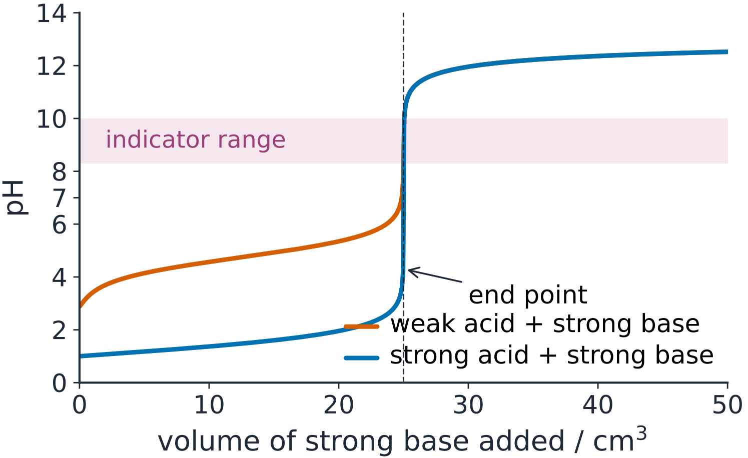
A **titration curve** 滴定曲线 plots pH against titrant volume:

- the **equivalence point** 等当点 is the steep jump
- at the **half-equivalence point** 半等当点, $\mathrm{pH} = \mathrm{p}K_a$

> Strong-strong: equivalence at pH 7.
> Weak acid-strong base: above 7.



Acid-base titrations



Structure and pKa

Acid strength comes down to how easily the acidic H leaves, and how stable the **conjugate base** 共轭碱 is:

- **binary acids** 无氧酸: stronger *down* a group (weaker bond)
- **oxyacids** 含氧酸: more oxygens $\Rightarrow$ stronger

$\mathbf{p}K_a = -\log K_a$

Smaller $\mathrm{p}K_a$ = stronger acid.

$\mathrm{pH} < \mathrm{p}K_a$: the acid form dominates; $\mathrm{pH} > \mathrm{p}K_a$: the conjugate base dominates.

Unit 8 – key takeaways

1 pH

$\mathrm{pH} = -\log[\mathrm{H}^+]$; $\mathrm{pH} + \mathrm{pOH} = 14$

2 Weak acids

K_a equilibrium; $K_a K_b = K_w$

3 Buffers

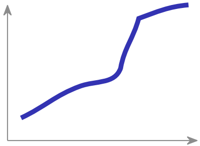
weak acid + conjugate base;
$\mathrm{pH} = \mathrm{p}K_a + \log \frac{[\mathrm{A}^-]}{[\mathrm{HA}]}$

4 Titration

equivalence jump; half-equivalence $\mathrm{pH} = \mathrm{p}K_a$

Check yourself

1. What is the pH of $0.001\,\mathrm{M}$ HCl?
2. In Bronsted-Lowry terms, what does a base do?
3. A buffer needs which two species present?
4. At the half-equivalence point, pH equals what?



Answers **1.** 3 **2.** accepts a proton **3.** a weak acid and its conjugate base **4.** pK_a