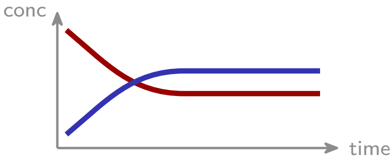
Equilibrium

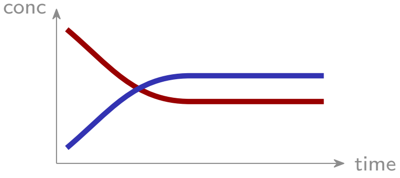
AP Chemistry ▪ Unit 7

AP Chemistry



What we will cover

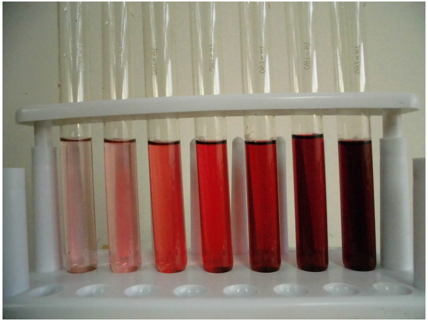
1. Dynamic equilibrium
2. The reaction quotient and K
3. ICE tables
4. Magnitude and properties of K
5. Le Chatelier's principle
6. Solubility equilibria



Dynamic equilibrium

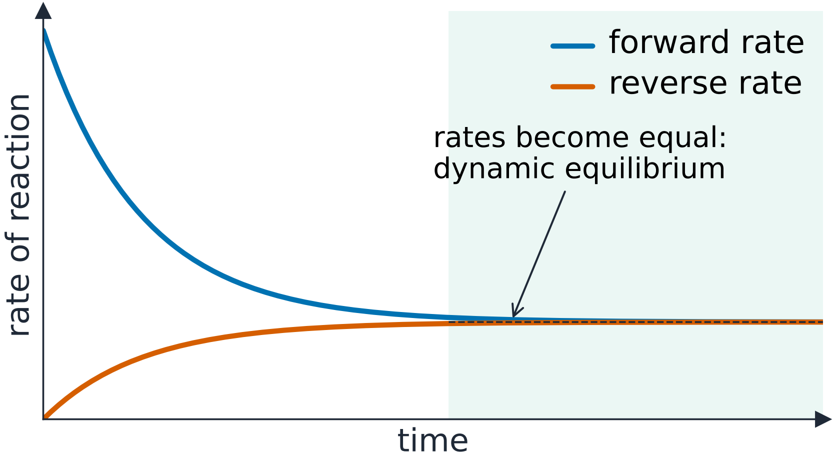
Chemical equilibrium 化学平衡 is **dynamic** 动态的: the forward and reverse reactions run at the same rate, so concentrations stay constant (not zero).

> Reached from either side – all reactant or all product gives the same mixture.



Dynamic equilibrium: forward and reverse still run

Dynamic equilibrium

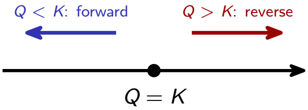


The reaction quotient and K

Equilibrium constant

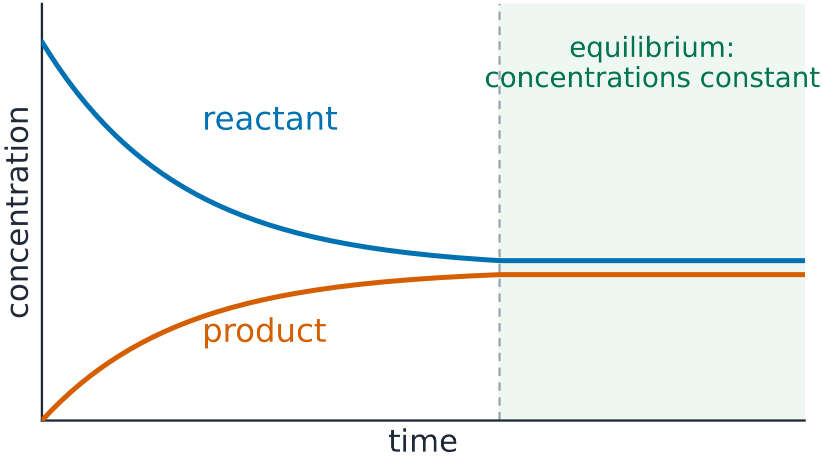
$$K = \frac{[\mathrm{C}]^c[\mathrm{D}]^d}{[\mathrm{A}]^a[\mathrm{B}]^b}$$

Reaction quotient 反应商 Q has the same form at any moment. Leave out pure solids and liquids.



Q vs K predicts the direction every time.

The reaction quotient and K



ICE tables

Organise the work in an **ICE table** ICE 表: **I**nitial, **C**hange ($\pm x$ by coefficient), **E**quilibrium.

Then substitute into K

When K is tiny, assume $x \ll$ initial (avoid the quadratic) – and check.

	HA	H^+	A^-
I	0.10	0	0
C	$-x$	$+x$	$+x$
E	$0.10-x$	x	x

$$K = \frac{x^2}{0.10 - x} \approx \frac{x^2}{0.10}.$$

Magnitude and properties of K

The size of K shows where the balance sits:

- $K \gg 1$ – product-favored
- $K \ll 1$ – reactant-favored
- $K \approx 1$ – comparable amounts

Manipulating K

- reverse: $K \to 1/K$
- scale by n: $K \to K^n$
- add reactions: $K \to K_1 K_2$

Le Chatelier's principle

Le Chatelier 勒夏特列原理: a disturbed system shifts to partly undo the change.

add a substance ⇒ shift *away* from it

raise pressure ⇒ toward fewer gas moles

add heat ⇒ shift as if heat were added

Industry shifts equilibrium with Le Chatelier

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*

Solubility equilibria

A sparingly soluble salt has a **solubility product** 溶度积 K_{sp} (solid left out):

AgCl $\rightleftharpoons \mathrm{Ag^+ + Cl^-}$

$$K_{sp} = [\mathrm{Ag^+}][\mathrm{Cl^-}] = s^2$$

$s = \sqrt{1.8 \times 10^{-10}} = 1.3 \times 10^{-5}\,\mathrm{M}.$

> **Common-ion effect** 同离子效应: adding a shared ion shifts dissolving backward – less dissolves (K_{sp} unchanged).

In $0.10\,\mathrm{M}$ NaCl, AgCl solubility drops to $1.8 \times 10^{-9}\,\mathrm{M}.$

Unit 7 – key takeaways

1 Equilibrium

dynamic; equal forward and reverse rates

2 Q vs K

$Q < K$ forward, $Q > K$ reverse; ICE table for K

3 Le Chatelier

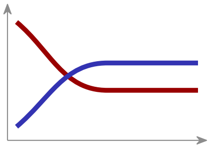
shift to undo a stress; only T changes K

4 Solubility

K_{sp}; common ion suppresses dissolving

Check yourself

1. At equilibrium, how do the forward and reverse rates compare?
2. If $Q < K$, which way does the reaction run?
3. Which stress actually changes the value of K?
4. Does adding a common ion raise or lower solubility?



Answers **1.** they are equal **2.** forward **3.** temperature **4.** lower