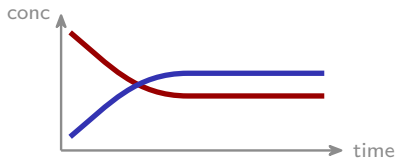


Equilibrium

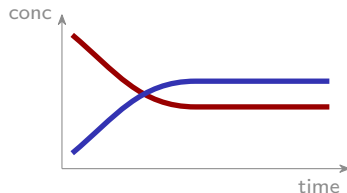
AP Chemistry ■ Unit 7

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



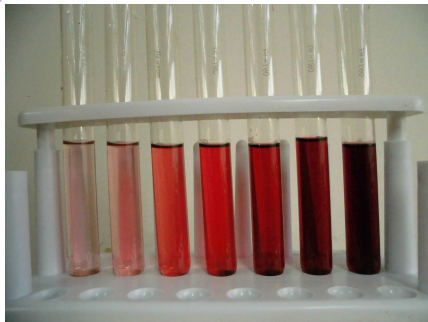
1

Dynamic

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

2

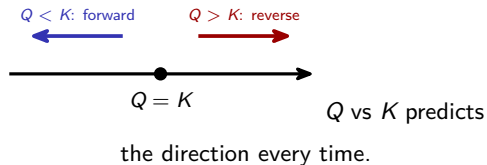
Q and K

The reaction quotient and K

Equilibrium constant

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

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



3

ICE

ICE tables

Organise the work in an **ICE table** ICE 表:
Initial, **C**hange ($\pm x$ by coefficient),
Equilibrium.

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

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

Worked example – an ICE table

For $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$ with $K_c = 50$, starting from 0.100 M of each reactant, find the equilibrium concentrations.

■ I: 0.100, 0.100, 0. C: $-x$, $-x$, $+2x$.

E: $0.100 - x$, $0.100 - x$, $2x$

■ $K_c = \frac{(2x)^2}{(0.100 - x)^2} = 50$

■ take the square root of both sides:

$$\frac{2x}{0.100 - x} = \sqrt{50} = 7.07$$

■ $x = 0.0779$, so $[\text{HI}] = 0.156 \text{ M}$ and each reactant is 0.022 M

The perfect square lets you take a root instead of solving a quadratic. Always check whether the expression is one before reaching for the formula.

4

Magnitude

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

Writing K , and manipulating it

writing K	from the balanced equation – and pure solids and liquids are left out
K_c and K_p	from equilibrium concentrations, or from partial pressures
$K \gg 1$	products strongly favoured – the reaction is nearly complete
$K \ll 1$	reactants favoured – very little product forms
reversing the reaction	inverts K , giving $1/K$
multiplying coefficients by n	raises K to the n th power; adding two reactions multiplies their K s

Leaving out solids and liquids is not a simplification – their concentration does not change, so it is already absorbed into K .

5

Le Chatelier

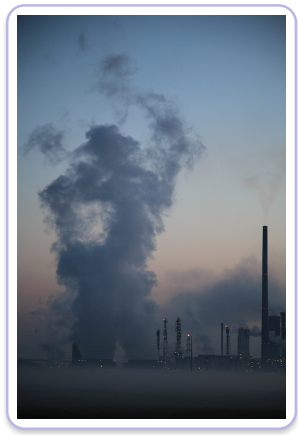
Le Chatelier's principle

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

add a substance $\Rightarrow$ shift *away* from it

raise pressure $\Rightarrow$ toward fewer gas moles

add heat $\Rightarrow$ shift as if heat were added



Industry shifts equilibrium with Le Chatelier

Justifying every Le Chatelier shift with Q

Q	the reaction quotient – the same expression as K , evaluated at any moment
$Q < K$	too few products, so the reaction shifts right
$Q > K$	too many products, so it shifts left
$Q = K$	at equilibrium; no net change
the method	a disturbance changes Q , and the system reacts to bring Q back to K
why it is better	this makes the reasoning quantitative rather than a memorised rule about stress

Only **temperature** changes K itself. Everything else changes Q , which is why every other disturbance can be reasoned about this way.

6

Solubility

Solubility equilibria

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



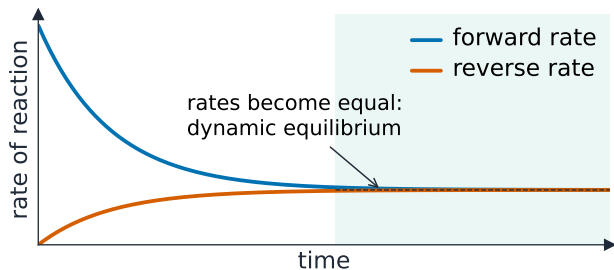
$$K_{sp} = [\text{Ag}^+][\text{Cl}^-] = s^2$$

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

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

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

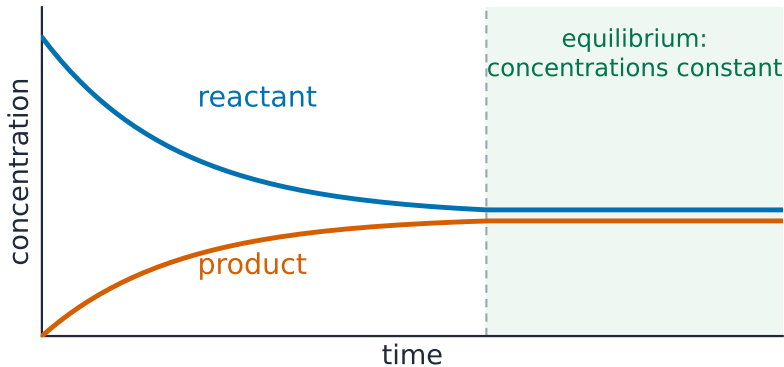
Introduction to Equilibrium



$$\text{at equilibrium: } \text{rate}_f = \text{rate}_r \cdot K_c = \frac{[\text{products}]}{[\text{reactants}]}$$

Dynamic equilibrium: the forward and reverse rates become equal

Reactant and product concentrations change



$$\text{at equilibrium: } r_f = r_r \cdot K_c = \frac{[\text{products}]}{[\text{reactants}]}$$

Reactant and product concentrations change, then hold constant once equilibrium is reached

Direction of Reversible Reactions

At equilibrium the amounts of reactants and products are fixed but usually **not** equal.

Whether the mixture favors products or reactants depends on the reaction; you compare the current state to the equilibrium condition to predict which way it shifts.

Introduction to 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: the equilibrium shifts to oppose the change made

Exam tips

- At equilibrium the forward and reverse **rates** are equal, but the **amounts** are usually not.
- Leave pure solids and liquids out of the K expression; a large K favours products, a small K favours reactants.
- Apply **Le Chatelier**: add reactant $\rightarrow$ shift forward; raise pressure $\rightarrow$ shift toward fewer gas moles; raise temperature $\rightarrow$ shift in the **endothermic** direction.
- A **catalyst does not shift** the position of equilibrium – it only speeds the approach.
- Use an **ICE table** for equilibrium concentrations, and the small- x approximation when K is small.

7

Recap

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

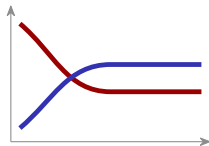
4

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