

7.1 Chemical equilibria: reversible reactions and dynamic equilibrium

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS equilibrium 平衡 • equilibrium constant 平衡常数 • dynamic equilibrium 动态平衡
• partial pressure 分压 • haber 哈伯法

Objective

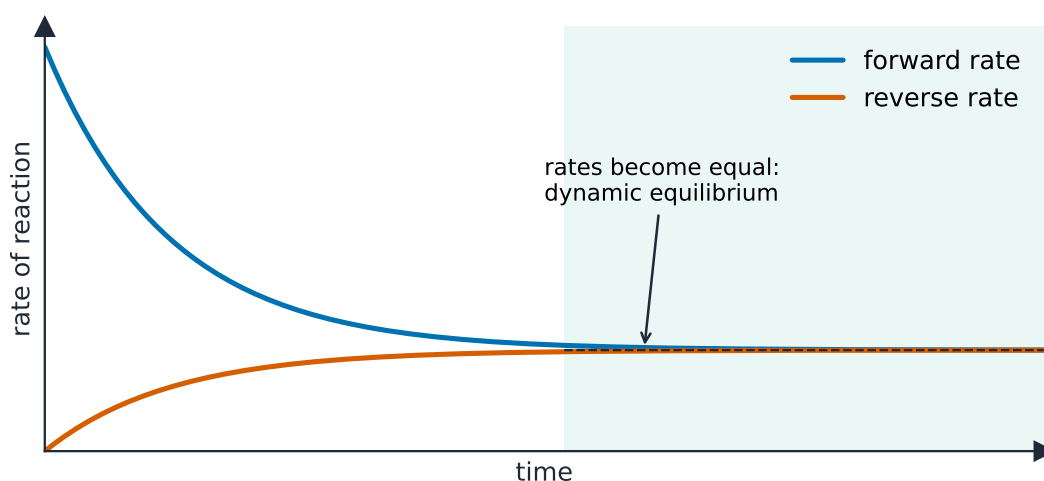
Build the skills to answer exam questions on **chemical equilibria** — **dynamic equilibrium** 动态平衡, **Le Chatelier's principle** 勒夏特列原理, the equilibrium constants K_c and K_p , and the **Haber** 哈伯法 process.

You must be able to:

- explain dynamic equilibrium and use Le Chatelier's principle
- write K_c and K_p expressions and use partial pressures
- carry out equilibrium calculations and explain the Haber/Contact conditions

1 Worked examples

- Dynamic equilibrium and Le Chatelier



at equilibrium: $\text{rate}_f = \text{rate}_r \cdot K_c = \frac{[\text{products}]}{[\text{reactants}]}$ (stoich. powers)

At dynamic equilibrium the forward and reverse rates are equal, so concentrations stay constant (closed system)

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

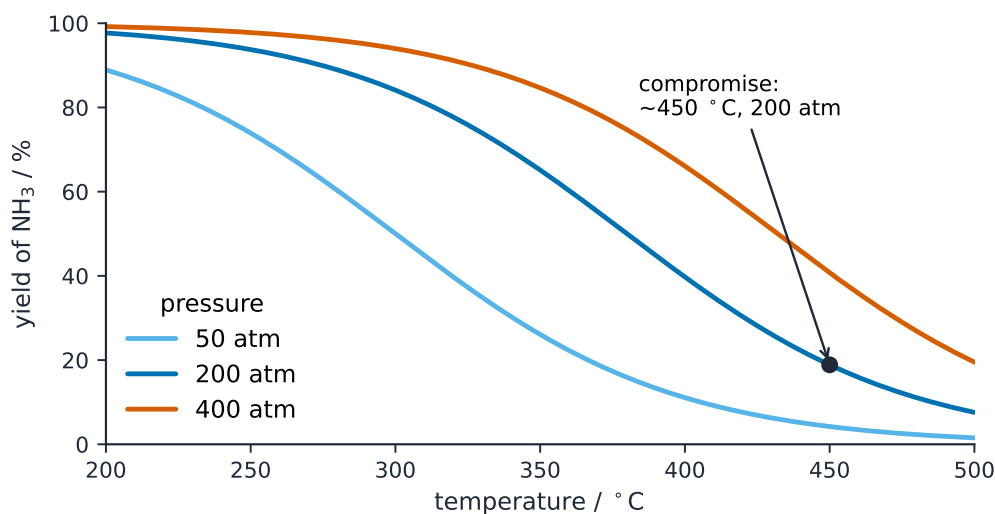
a **catalyst** speeds both directions equally, so it gives *no shift*

Le Chatelier: the equilibrium shifts to oppose a change. $\uparrow[\text{reactant}] \rightarrow \text{products}$; $\uparrow \text{pressure} \rightarrow \text{fewer gas molecules}$; $\uparrow \text{temperature} \rightarrow \text{endothermic direction}$; catalyst $\rightarrow$ no shift

■ Equilibrium constants

For $aA + bB \rightleftharpoons cC + dD$: $K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$. **Example.** $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$ with $[\text{H}_2] = [\text{I}_2] = 0.20$, $[\text{HI}] = 1.6$: $K_c = \frac{1.6^2}{0.20 \times 0.20} = 64$ (no units). Partial pressure = mole fraction $\times$ total pressure $\rightarrow K_p$. **Only temperature changes K .**

■ The Haber process



exothermic: lower $T \uparrow$ yield $\cdot$ higher $P \uparrow$ yield

Haber ($\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$, exothermic): more NH_3 at low T , high p ; $\sim 450^{\circ}\text{C}$, 200 atm, Fe catalyst is the compromise

2 Practice

2.1 State the **two** features of a system at dynamic equilibrium.

[2]

2.2 Write the K_c expression for $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$.

[1]

3 Exam-style questions

3.1 For an **exothermic** equilibrium, increasing the temperature:

[1]

A	B
C	D

A shifts it towards the products

B shifts it towards the reactants (the endothermic direction)

C has no effect

D increases the value of K_c towards products

3.2 Adding a catalyst to a system at equilibrium:

[1]

A	B
C	D

A shifts it towards the products

B shifts it towards the reactants

C does not change the position of equilibrium

D increases K_c

3.3 At equilibrium, $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$ has $[\text{N}_2\text{O}_4] = 0.10$ and $[\text{NO}_2] = 0.20 \text{ mol dm}^{-3}$.

(a) Write the expression for K_c and calculate its value (give units).

[3]

(b) State the effect on the **value** of K_c of increasing the pressure.

[1]

3.4 A gas mixture contains 3.0 mol of SO_2 and 1.0 mol of O_2 at a total pressure of 400 kPa. Calculate the partial pressure of SO_2 .

[2]