

7.1 Chemical equilibria: reversible reactions and dynamic equilibrium

Name: _____ Class: _____ Date: _____

Total: 11 marks

Objective

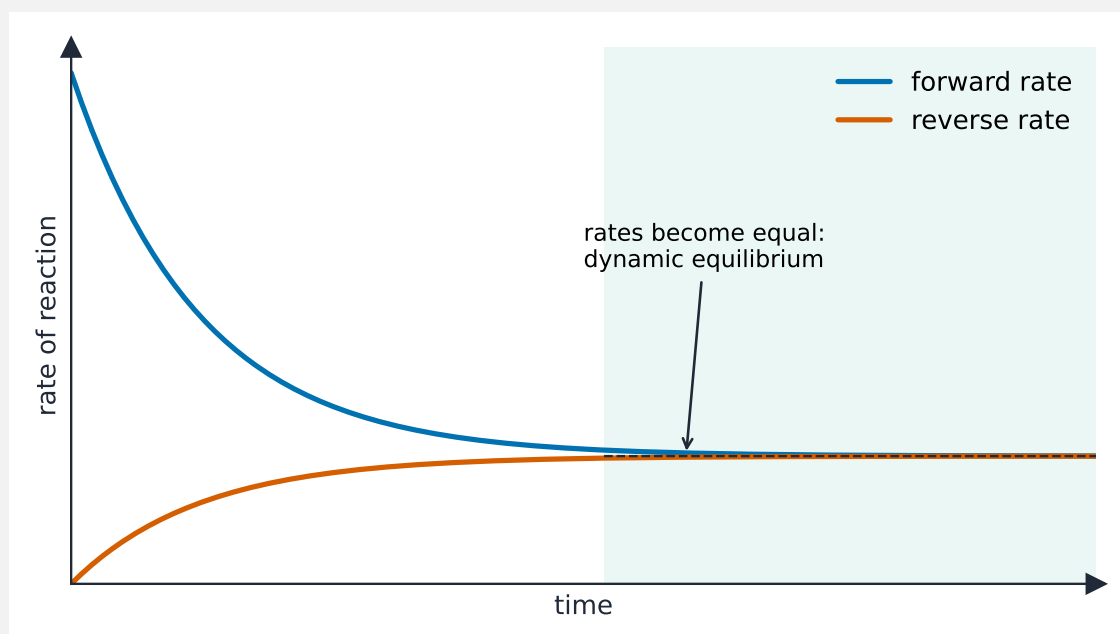
Build the skills to answer exam questions on **chemical equilibria** — **dynamic equilibrium** 动态平衡, **Le Chatelier's principle** 勒夏特列原理, the equilibrium constants K_c and K_p , and the **Haber** 哈伯法 process.

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

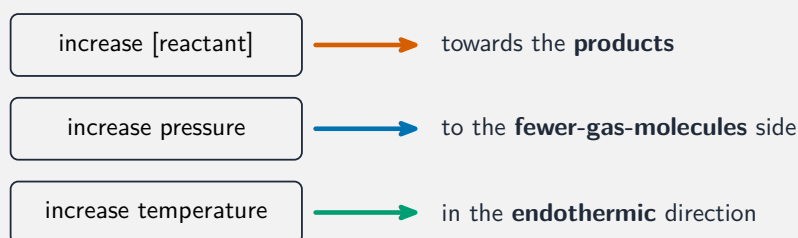
1 Worked examples

■ Dynamic equilibrium and Le Chatelier



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

the equilibrium shifts to *oppose* the change you make



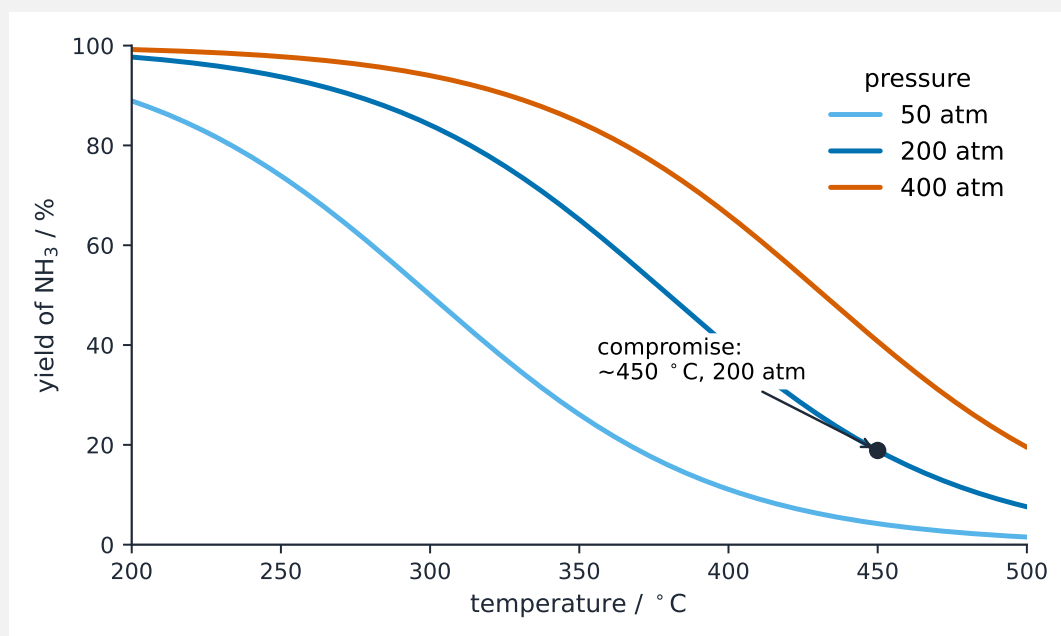
a **catalyst** speeds both directions equally, so it gives *no shift*

Le Chatelier: the equilibrium shifts to oppose a change. $\uparrow$ [reactant] $\rightarrow$ products; $\uparrow$ pressure $\rightarrow$ fewer gas molecules; $\uparrow$ temperature $\rightarrow$ 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.** $H_2 + I_2 \rightleftharpoons 2HI$ with $[H] = [I] = 0.20$, $[HI] = 1.6$: $K_c = \frac{1.6^2}{0.20 \times 0.20} = 64$ (no units). Partial pressure = mole fraction $\times$ total pressure $\rightarrow K_p$. **Only temperature changes K .**

■ The Haber process



Haber ($N_2 + 3H_2 \rightleftharpoons 2NH_3$, exothermic): more NH_3 at low T , high p ; ~450 °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** 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** 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]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **7.1 Chemical equilibria** past-paper sheet in the Library, or try these in **Practice mode**:

- 9701/11 N25 —Q12 (equilibrium)
- 9701/14 N25 —Q13 (Le Chatelier)
- 9701/52 N25 —Q1 (equilibrium, planning/calculation)

Solutions

2.1 the forward and reverse rates are equal; the concentrations of reactants and products stay constant.

2.2 $K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$.

3.1 B. Raising T shifts an exothermic equilibrium towards the reactants (endothermic direction).

3.2 C. A catalyst speeds both directions equally —no shift.

3.3 (a) $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{0.20^2}{0.10} = 0.40 \text{ mol dm}^{-3}$.

(b) no change —only temperature changes K_c .

3.4 total moles = 4.0; mole fraction of SO = $3.0/4.0 = 0.75$; $p(\text{SO}_2) = 0.75 \times 400 = 300 \text{ kPa}$.