A-LEVEL CHEMISTRY • EXERCISE SHEET

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 • haber 哈伯法 • partial pressure 分压

Objective

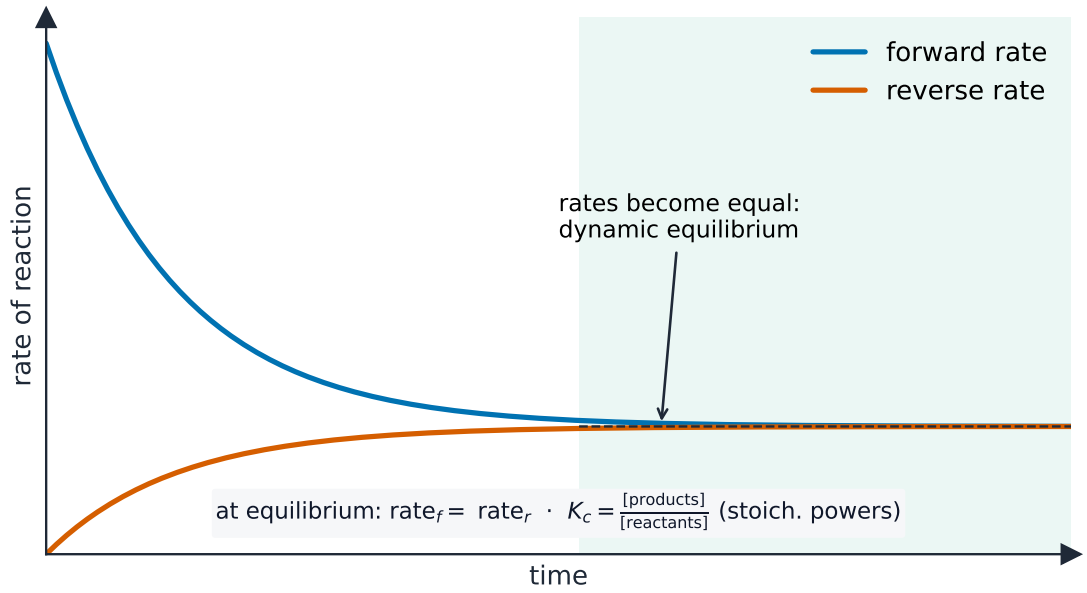
Build the skills to answer exam questions on **chemical equilibria** — **dynamic equilibrium** 动态平衡, **Le Chatelier's principle** 勒夏特列原理, the equilibrium constants K_c and K_p, and the **Haber** 哈伯法 process.

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

increase [reactant]	→ towards the **products**
increase pressure	→ to the **fewer-gas-molecules** side
increase temperature	→ in the **endothermic** direction

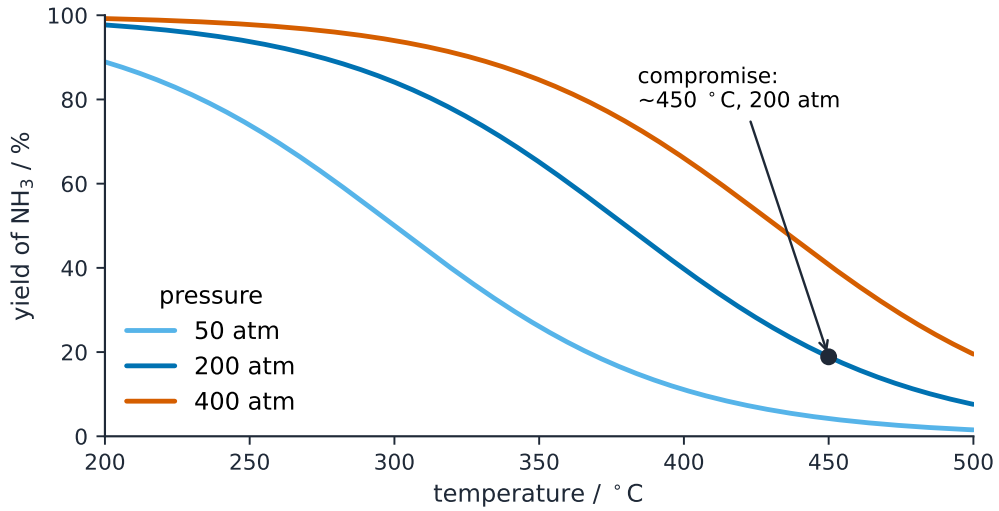
a **catalyst** speeds both directions equally, so it gives *no shift*

Le Chatelier: the equilibrium shifts to oppose a change. ↑[reactant]→products; ↑pressure→fewer gas molecules; ↑temperature→endothermic direction; catalyst→no shift

Equilibrium constants

For $aA + bB \rightleftharpoons cC + dD$: $K_c = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$. **Example.** $H_2 + I_2 \rightleftharpoons 2HI$ with $[H_2]=[I_2]=0.20$, $[HI]=1.6$: $K_c = \dfrac{1.6^2}{0.20 \times 0.20} = 64$ (no units). Partial pressure = mole fraction × total pressure → K_p. **Only temperature changes K.**

The Haber process



exothermic: lower T ↑ yield · higher P ↑ yield

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 $N_2 + 3H_2 \rightleftharpoons 2NH_3$. [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, $N_2O_4 \rightleftharpoons 2NO_2$ has $[N_2O_4] = 0.10$ and $[NO_2] = 0.20$ 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]

Solutions

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

2.2 $K_c = \dfrac{[\mathrm{NH_3}]^2}{[\mathrm{N_2}][\mathrm{H_2}]^3}$.

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) $K_c = \dfrac{[\mathrm{NO_2}]^2}{[\mathrm{N_2O_4}]} = \dfrac{0.20^2}{0.10} = 0.40$ mol dm^{-3}.
(b) no change — only temperature changes K_c.

3.4 total moles = 4.0; mole fraction of $\mathrm{SO_2}$ = 3.0/4.0 = 0.75; $p(\mathrm{SO_2}) = 0.75 \times 400 =$ 300 kPa.