Equilibria — free sample worksheet — answers

Chemistry 9701 · Topic 7 · 20 marks · Mark scheme and how not to lose marks

Question 1

EASY [2 marks]

State and explain the effect of adding a catalyst on the position of an equilibrium.

Answer

The position of equilibrium does not change. A catalyst increases the rates of the forward and reverse reactions equally, so equilibrium is reached faster but the composition of the equilibrium mixture is the same.

Mark scheme

B1 no effect on the position of equilibrium
B1 forward and reverse rates increased equally / by the same factor

> **How not to lose marks**
> "State and explain" needs two parts: the effect (no change) *and* the reason (both rates increase equally). Stating the effect alone earns half the marks.

Question 2

EASY [2 marks]

State two features of a system that is in dynamic equilibrium.

Answer

The rate of the forward reaction equals the rate of the reverse reaction. The concentrations of reactants and products remain constant (in a closed system).

Mark scheme

B1 rate of forward reaction = rate of reverse reaction
B1 concentrations (of reactants and products) remain constant / do not change

> **How not to lose marks**
> Never write that the concentrations are *equal* — they are *constant*. "Equal" is one of the most common lost marks on this topic.

Question 3

MEDIUM [2 marks]

For the equilibrium $N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$, write the expression for K_c and deduce its units.

Answer

$K_c = \dfrac{[NO_2]^2}{[N_2O_4]}$. Units: $\dfrac{(\text{mol dm}^{-3})^2}{\text{mol dm}^{-3}} = \text{mol dm}^{-3}$.

Mark scheme

B1 expression
B1 units mol dm^{-3}

> **How not to lose marks**
> Work the units out by substituting mol dm^{-3} for every concentration and cancelling — write the working, don't guess.

Question 4

MEDIUM [5 marks]

Ammonia is made in the Haber process.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) \qquad \Delta H = -92\,\text{kJ mol}^{-1}$$

(a) Write an expression for K_c for this equilibrium. [1]

(b) Explain the effect of increasing the pressure on the equilibrium yield of ammonia. [2]

(c) State and explain the effect of increasing the temperature on the value of K_c. [2]

Answer

(a) $K_c = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$

(b) There are 4 moles of gas on the left and 2 on the right. Increasing the pressure moves the position of equilibrium to the right, the side with fewer moles of gas, to reduce the pressure. The yield of ammonia increases.

(c) K_c decreases. The forward reaction is exothermic, so increasing the temperature moves the position of equilibrium in the endothermic direction (to the left).

Mark scheme

(a) B1 correct expression: square brackets, powers from the equation
(b) B1 fewer moles/molecules of gas on the right (2 vs 4)
(b) B1 equilibrium shifts right, so yield increases
(c) B1 K_c decreases
(c) B1 forward reaction exothermic / reverse endothermic, so equilibrium shifts left

> **How not to lose marks**
> Name the side and count the gas moles ("4 mol of gas on the left, 2 on the right"). "It shifts to the side with fewer moles" without saying which side, or why, loses the mark. Remember: only temperature changes the value of K_c.

Question 5

HARD [5 marks]

2.00 mol of ethanoic acid and 2.00 mol of ethanol were mixed with a little acid catalyst and left to reach equilibrium. The equilibrium mixture contained 1.33 mol of ethyl ethanoate.

(a) Write the equation for this equilibrium. [1]

(b) Calculate K_c, giving your answer to three significant figures. Explain why the volume of the mixture is not needed. [4]

Answer

(a) $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

(b) At equilibrium: ethyl ethanoate 1.33 mol, water 1.33 mol, ethanoic acid $2.00 - 1.33 = 0.67$ mol, ethanol 0.67 mol.

$$K_c = \frac{[CH_3COOC_2H_5][H_2O]}{[CH_3COOH][C_2H_5OH]} = \frac{(1.33/V)(1.33/V)}{(0.67/V)(0.67/V)} = \frac{1.33^2}{0.67^2} = 3.94$$

The volume V cancels because there are the same number of moles of substance on each side of the equation, so K_c has no units.

Mark scheme

(a) B1 balanced equation with equilibrium arrows
(b) M1 equilibrium moles: 1.33, 1.33, 0.67, 0.67
(b) M1 substitution into a correct K_c expression
(b) A1 $K_c = 3.94$ (no units)
(b) B1 V cancels: equal numbers of moles on each side

> **How not to lose marks**
> Write an "initial / change / equilibrium" line for every species before substituting — the method marks are for those moles. Give exactly the 3 s.f. asked for, and state "no units".

Question 6

HARD [4 marks]

Ethanol is manufactured from ethene and steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46\,\text{kJ mol}^{-1}$$

The process is run at about 300 °C. Explain why this temperature is a compromise.

Answer

The forward reaction is exothermic, so a lower temperature would move the position of equilibrium to the right and give a higher equilibrium yield of ethanol. However, at a lower temperature the rate of reaction is too slow. 300 °C gives an acceptable yield at an acceptable rate.

Mark scheme

B1 forward reaction exothermic
B1 so lower temperature gives a higher (equilibrium) yield
B1 but lower temperature gives a slower rate
B1 300 °C balances yield against rate

> **How not to lose marks**
> A "compromise" answer needs *both* sides: what a lower temperature does to yield and what it does to rate. Answers that only discuss yield cap at two marks.