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VCE Chemistry ¾
Equilibrium [2.7]
Test Solutions

20 Marks. 1 Minute Reading. 16 Minutes Writing.

Results:

Test Questions	_____ / 15
Extension	_____ / 5

Section A: Test Questions (15 Marks)

Question 1 (4 marks)

Tick whether the following statements are **true** or **false**.

Statement	True	False
a. If a reaction is reversible, this means that both the forward and backward reactions occur at the same time.	✓	
b. In VCE chemistry, we study equilibria occurring in open systems.		✓
c. A dynamic equilibrium is established when the forward and backward reactions occur at the same rate and subsequently stop reacting.		✓
d. The K_c value gives you the ratio of the concentration of reactants to the concentration of products.		✓
e. Equilibria in which solids and liquids are present are assigned a 'concentration' value of 1, and consequently ignored in K_c and Q_c expressions.	✓	
f. If a particular reaction has a large extent of reaction, its Q_c value will be high.		✓
g. If the Q_c value is less than the K_c value, the rate of the forward reaction will be greater than the rate of the reverse reaction until equilibrium is established.	✓	
h. RICE tables are used to find the **moles** of each reactant and product at equilibrium, and then these values are directly plugged into the K_c expression to obtain the equilibrium constant.		✓

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Question 2 (6 marks)

Henry is investigating the reaction between nitrogen and oxygen to produce nitrogen monoxide:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad K_c \text{ at } 25°C = 2.20 \times 10^{-5}$$

a. Explain what can be said about the extent of the reaction above at 25°C. Justify your answer with reference to the position of equilibrium. (2 marks)

$K_c < 10^{-4}$ so, the reaction shown occurs to a small extent (1). This means that at equilibrium, there are much more reactants present than products; the position of equilibrium lies to the left/towards the reactants (2).

b.

i. Calculate the K_c value for the reaction, $NO(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g)$ at 25°C. (1 mark)

$$K_c \text{ (new)} = \frac{1}{\sqrt{K_c \text{ (old)}}} = \frac{1}{\sqrt{2.2 \times 10^{-5}}}$$

$$= 213 \text{ (no unit) (3 sf)}$$

ii. For the reaction provided in **part b. i.** if the reaction takes place in a 2.00 L vessel and $[NO] = 2.30 \times 10^2\ M$ and $[O_2] = 1.80 \times 10^3\ M$ at equilibrium, calculate the amount, in $M\ mol$, of N_2 which must be present in the vessel when the rates of the forward and reverse reactions are equal. (3 marks)

$$K_c = \frac{[N_2]^{\frac{1}{2}}[O_2]^{\frac{1}{2}}}{[NO]}$$

$$213.2 = \frac{[N_2]^{\frac{1}{2}}(1.8 \times 10^3)^{\frac{1}{2}}}{2.3 \times 10^2}$$

$$\Rightarrow [N_2] = \left(\frac{213.2 \times 2.3 \times 10^2}{(1.8 \times 10^3)^{\frac{1}{2}}}\right)^2$$

$$= 1.336 \times 10^6\ M$$

$$n(NO) = cV = 1.336 \times 10^6 \times 2.00 = 2.67 \times 10^6 \text{ mol}$$

$$= 2.67\ M\text{mol}$$

Question 3 (5 marks)

The following reversible reaction is being investigated in a laboratory:

$$2P(g) + 5Cl_2(g) \rightleftharpoons 2PCl_5(g) \qquad K_c = 118.7\ M^{-5} \text{ at } 100°C$$

The reaction was initiated by mixing 2.32 mol of phosphorus with 5.27 mol of chlorine in a sealed, 5.00 L evacuated vessel at 100°C. 10 minutes into the reaction, it is observed that the concentration of PCl_5 is 0.333 M.

a. Calculate the reaction quotient for this reaction once 10 minutes have elapsed. (3 marks)

	$2P(g)$ +	$5Cl_2(g)$ ⇌	$2PCl_5(g)$
n_i (mol)	2.32	5.27	0
n_c (mol)	- 1.665	- 4.1625	+1.665
$n_{10\ mins}$ (mol)	0.655	1.1075	1.665
$C_{10\ mins}$ (M)	0.131	0.2215	0.333

$$Q_c = \frac{[PCl_5]^2}{[P]^2[Cl_2]^5} = \frac{0.333^2}{0.131^2 \cdot 0.2215^5}$$

$$= 1.21 \times 10^4\ M^{-5}$$

b. State whether the system is at equilibrium 10 minutes into the reaction or not. If not, explain how the reactions will progress towards equilibrium. (1 mark)

$Q_c \neq K_c$ → system is not at equilibrium. Since $Q_c > K_c$, the system will favour the backwards reaction in order to establish equilibrium.

c. Had this reaction occurred in a compressed, 1.00 L vessel (still at 100°C), predict the effect this would have had on the equilibrium constant. (1 mark)

No effect → K_c value for a particular reaction is ONLY impacted by a change in temperature.

Section B: Extension (5 Marks)

Question 4 (5 marks)

Anika is investigating the production of hydrogen iodide via the reversible reaction between gaseous iodine and hydrogen in a closed vessel of volume V litres, according to the following equation:

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$$

The K_c value for this reaction is 26.9 at 300°C.

a. Given that Anika placed 3.20 mol of both $H_2(g)$ and $I_2(g)$ into the empty container at 300°C, calculate the amount of HI, in mol, that would have been present at equilibrium. (4 marks)

$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$

n_i (mol)	3.20	3.20	0
n_c (mol)	$-x$	$-x$	$+2x$
n_e (mol)	$3.20-x$	$3.20-x$	$2x$
C_e (M)	$\frac{3.20-x}{V}$ ✓	$\frac{3.20-x}{V}$ ✓	$\frac{2x}{V}$ ✓

$$K_c = \frac{[HI]^2}{[I_2][H_2]} = \frac{\left(\frac{2x}{V}\right)^2}{\left(\frac{3.20-x}{V}\right)^2}$$

$$26.9 = \left(\frac{2x}{3.20-x}\right)^2$$

$$\Rightarrow 5.186(3.20-x) = 2x$$

$$16.6 - 5.186x = 2x$$

$$\Rightarrow 7.186x = 16.6$$

$$\Rightarrow x = 2.31 \text{ mol}$$

$$\therefore n_e(HI) = 2x = 2 \times 2.31 = 4.62 \text{ mol}$$

b. Anika decides to conduct the same experiment at a slightly cooler temperature to ensure her safety and calculates the system's reaction quotient (Q_c) after 5 minutes, obtaining a value of 26.9. Explain what Anika may conclude about the position of equilibrium in this instance. (1 mark)

Cannot conclude anything as we do not know the K_c value at this new temperature. Therefore, we have nothing to compare the calculated Q_c value to, so we are unsure as to where the position of equilibrium lies.

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