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CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	AQA (A-LEVEL)
TOPIC:	CHEMICAL EQUILIBRIA
PAPER TYPE:	QUESTION PAPER -1
TOTAL QUESTIONS	10
TOTAL MARKS	61

Chemical Equilibria - 2

1. When substances P and Q react together to form substance R an equilibrium is established according to the equation

$P(g) + Q(g) \rightleftharpoons 2R(g)$

The equilibrium constant expression is $K_c = \frac{[R]^2}{[P][Q]}$

1.0 mol of P and 1.0 mol of Q were mixed in a container with volume 1.0 dm^3 At equilibrium, x mol of P had reacted.

(a) The amount, in moles, of each of P and Q at equilibrium is (1− x).

Deduce in terms of x the amount, in moles, of R in the equilibrium mixture.

(1)

(b) At 298 K the value of the equilibrium constant $K_c = 3.6$

Calculate a value for the equilibrium concentration, in mol dm^{-3}, of R.

(3)

2. Hydrogen can be prepared on an industrial scale using the reversible reaction between methane and steam.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206$ kJ mol^{-1}

The reaction is done at a temperature of 800 °C and a low pressure of 300 kPa in the presence of a nickel catalyst.

Explain, in terms of equilibrium yield and cost, why these conditions are used.

(Total 6 marks)

3. Which statement about the use of a catalyst in a reversible reaction is correct?

A. The activation energy for the reverse reaction is increased.
B. The equilibrium constant increases.
C. The rate of the reverse reaction increases.
D. The enthalpy change for the forward reaction decreases.

(Total 1 mark)

4. This question is about the equilibrium.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

(a) State and explain the effect, if any, of a decrease in overall pressure on the equilibrium yield of SO_3

(3)

(b) A 0.460 mol sample of SO_2 is mixed with a 0.250 mol sample of O_2 in a sealed container at a constant temperature.

When equilibrium is reached at a pressure of 215 kPa, the mixture contains 0.180 mol of SO_3

Calculate the partial pressure, in kPa, of SO_2 in this equilibrium mixture.

(4)

(c) A different mixture of SO_2 and O_2 reaches equilibrium at a different temperature.

Give an expression for the equilibrium constant (Kp) for this reaction.

(1)

(d) What is the effect on the value of Kp if the pressure of this equilibrium mixture is increased at a constant temperature?

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Tick (✓) one box.

A. The value of Kp increases.
B. stays the same.
C. decreases.

(1)

5. For this reaction at equilibrium, which combination of temperature and pressure would give the greatest equilibrium yield of products?

$W(g) + X(g) \rightleftharpoons 2Y(g) + Z(g)$ $\Delta H = +47 \text{ kJ mol}^{-1}$

A. High pressure and high temperature
B. High pressure and low temperature
C. Low pressure and high temperature
D. Low pressure and low temperature

(Total 1 mark)

6. This question is about equilibrium.

(a) 1 mol of a diester with molecular formula $C_7H_{12}O_4$ is added to 1 mol of water in the presence of a small amount of catalyst.

The mixture is left to reach equilibrium at a constant temperature.

$C_7H_{12}O_4(l) + 2H_2O(l) \rightleftharpoons 2CH_3COOH(l) + HO(CH_2)_3OH(l)$

At equilibrium, x mol of ethanoic acid are present in the mixture.

Complete Table 1 by deducing the amounts, in terms of x, of the diester, water and diol present in the equilibrium mixture.

Amount in the mixture / mol				
	Diester	Water	Acid	Diol
At the start	1	1	0	0
At equilibrium			x	

The value of the equilibrium constant, Kc is 0.161 at this temperature. Calculate the amount of water, in mol, in this new equilibrium mixture. Show your working

(3)

(b) Deduce the structure of the diester in part (a)

(1)

(c) A new equilibrium mixture of the substances from part (a) is prepared at a different temperature.

$C_7H_{12}O_4(l) + 2H_2O(l) \rightleftharpoons 2CH_3COOH(l) + HO(CH_2)_3OH(l)$

Table 2 shows the amount of each substance in this new equilibrium mixture.

Table 2

Amount in the mixture / mol				
	Diester	Water	Acid	Diol
At equilibrium	0.971	To be calculated	0.452	0.273

7. Which statement is not always correct for a reaction at equilibrium?

reactants ⇌ products

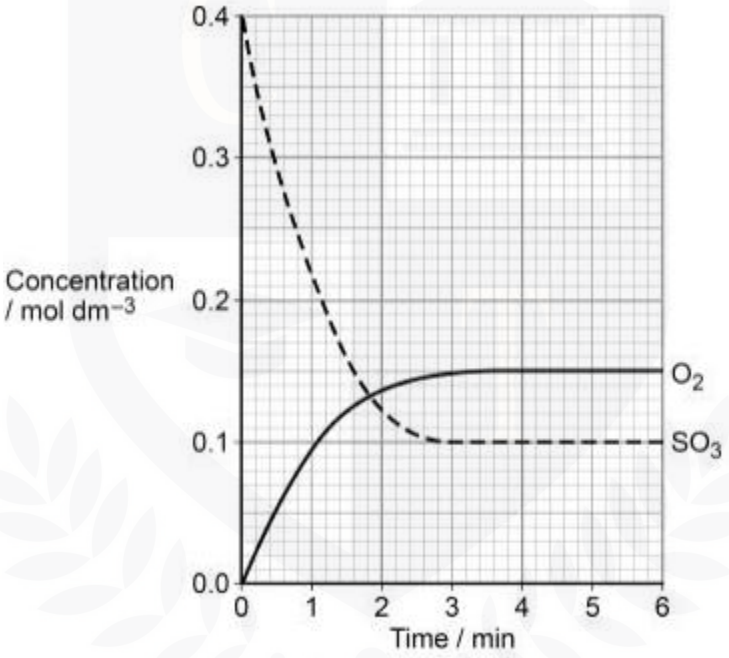
A. The concentrations of the reactants and products are equal.
B. The equilibrium can be achieved starting from the reactants.
C. The equilibrium can be achieved starting from the products.
D. The rate of the forward reaction is equal to the rate of the reverse reaction.

(Total 1 mark)

8. This question is about equilibrium.
Sulfur trioxide decomposes to form sulfur dioxide and oxygen at temperature T_1 according to the equilibrium shown.

$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ $\Delta H = +196 \text{ kJ mol}^{-1}$

The graph shows the concentrations of sulfur trioxide and of oxygen over a period of 6 minutes at temperature T_1



(a) State the time, to the nearest minute, when equilibrium is first established.
Explain your answer.

(2)

(b) The temperature of the mixture was changed to T_2 and the mixture left to establish a new equilibrium.

In the new equilibrium mixture the concentration of sulfur trioxide was found to be 0.07 mol dm^{-3}

Deduce which of T_1 and T_2 is the higher temperature.
Explain your deduction.

(2)

9. Methanol can be manufactured in a reversible reaction as shown by the equation.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

(a) State and explain the effect of using a catalyst on the yield of methanol in this equilibrium.

(2)

(b) Give an expression for the equilibrium constant (Kc) for this reaction.

(1)

(c) A mixture of carbon monoxide and hydrogen was allowed to reach equilibrium in a container of volume 250 cm^3 at temperature T.

At equilibrium, the mixture contained 0.340 mol of carbon monoxide, 0.190 mol of hydrogen and 0.0610 mol of methanol.

Calculate the value of the equilibrium constant (Kc) for this reaction at temperature T.

(3)

(d) Methanol decomposes on heating in a reaction that is the reverse of that used in its manufacture.

$CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g)$

Use your answer from part (c) to determine the value of Kc for this equilibrium at temperature T.
State the units for this value of Kc (If you were unable to complete the calculation in part (c), assume a value of Kc = 0.825 mol^{-2} dm^6.
(This is not the correct value.)

(2)

10. Compounds A and B react together to form an equilibrium mixture containing compounds C and D according to the equation

$2A + B \rightleftharpoons 3C + D$

(a) A beaker contained 40 cm^3 of a 0.16 mol dm^{-3} aqueous solution of A. 9.5×10^{-3} mol of B and 2.8×10^{-2} mol of C were added to the beaker and the mixture was left to reach equilibrium.

The equilibrium mixture formed contained 3.9×10^{-3} mol of A.

Calculate the amounts, in moles, of B, C and D in the equilibrium mixture.

I am Sorry !!!!!

(5)

(b) Give the expression for the equilibrium constant (Kc) for this equilibrium and its units.

(2)

(c) A different equilibrium mixture of these four compounds, at a different temperature, contained 0.21 mol of B, 1.05 mol of C and 0.076 mol of D in a total volume of 5.00×10^2 cm^3 of solution.

At this temperature the numerical value of Kc was 116
Calculate the concentration of A, in mol dm^{-3} , in this equilibrium mixture. Give your answer to the appropriate number of significant figures.

(3)

(d) Justify the statement that adding more water to the equilibrium mixture in part (c) will lower the amount of A in the mixture.

(3)

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