Equilibrium Constant Kc for Homogeneous Systems

Question Paper 4

Level	A Level
Subject	Chemistry
Exam Board	AQA
Module	3.1 Physical Chemistry
Topic	3.1.6 Chemical Equilibria + Le Chatelier +Kc
Sub-Topic	3.1.6.2 Equilibrium Constant Kc for Homogeneous Systems
Booklet	Question Paper 4

Time Allowed: **56 minutes**

Score: **/56**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

Q1. Methanol is synthesised from carbon monoxide and hydrogen according to the equation below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -91 \text{ kJ mol}^{-1}$$

Which one of the following changes would **not** affect the value of the equilibrium constant and would **not** increase the yield of methanol?

A increase in temperature

B decrease in temperature

C increase in pressure

D decrease in pressure

(Total 1 mark)

Q2. The equilibrium constant, K_c, for a reaction which leads to ozone (O_3) formation is

$$K_c = \frac{[N_2][O_3]^2}{[NO]^2[O_2]^2}$$

More ozone is formed as the temperature rises. Which one of the following is true at equilibrium?

A When ozone molecules collide with nitrogen they may form nitrogen monoxide.

B The enthalpy change for the reaction has a negative sign.

C Less ozone is formed at high pressure.

D At a fixed temperature, the magnitude of K_c increases as the concentration of NO decreases.

(Total 1 mark)

Q3. The data below refer to the industrial production of nitric acid from ammonia.

Reaction 1 $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^{\ominus} = -909 \text{ kJ mol}^{-1}$

Reaction 2 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H^{\ominus} = -115 \text{ kJ mol}^{-1}$

Reaction 3 $3NO_2(g) + H_2O(l) \rightleftharpoons 2HNO_3(aq) + NO(g) \qquad \Delta H^{\ominus} = -117 \text{ kJ mol}^{-1}$

Possible units for the equilibrium constant, K_c, for *reaction 2* are

A $mol^{-2}\ m^{6}$

B $mol^{-1}\ dm^{3}$

C no units

D $mol\ dm^{-3}$

(Total 1 mark)

Q4. Nitrogen dioxide dissociates according to the following equation.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 21.3 g of nitrogen dioxide were heated to a constant temperature, *T*, in a flask of volume 11.5 dm^3, an equilibrium mixture was formed which contained 7.04 g of oxygen.

(a) (i) Calculate the number of moles of oxygen present in this equilibrium mixture and deduce the number of moles of nitrogen monoxide also present in this equilibrium mixture.

Number of moles Of O_2 at equilibrium .....

.....

Number of moles of NO at equilibrium .....

(ii) Calculate the number of moles in the original 21.3 g of nitrogen dioxide and hence calculate the number of moles of nitrogen dioxide present in this equilibrium mixture.

Original number of moles of NO_2 .....

.....

Number of moles of NO_2 at equilibrium .....

.....

(4)

(b) Write an expression for the equilibrium constant, K_c, for this reaction. Calculate the value of this constant at temperature T and give its units.

Expression for K_c .....

.....

Calculation .....

.....

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.....

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(4)

(c) The total number of moles of gas in the flask is 0.683. Use the ideal gas equation to determine the temperature *T* at which the total pressure in the flask is 3.30×10^5 Pa. (The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

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(3)

(d) State the effect on the equilibrium yield of oxygen and on the value of K_c when the same mass of nitrogen dioxide is heated to the same temperature *T*, but in a different flask of greater volume.

Yield of oxygen .....

Value of K_c .....

(2)
(Total 13 marks)

Q5. The ester methyl ethanoate is hydrolysed as shown in the following equation.

$$CH_3COOCH_3(l) + H_2O(l) \rightleftharpoons CH_3COOH(l) + CH_3OH(l) \qquad \Delta H^{\ominus} = +3 \text{ kJ mol}^{-1}$$

A 3 mol sample of methyl ethanoate was mixed with 3 mol of water and left to reach equilibrium at 298 K. The equilibrium yield of ethanoic acid was 2 mol. The value of K_c for this reaction at 298 K is

A $\frac{2}{3}$

B $\frac{4}{9}$

C 2

D 4

(Total 1 mark)

Q6. Use the information below to answer this question.

A saturated solution of magnesium hydroxide, $Mg(OH)_2$, contains 0.1166 g of $Mg(OH)_2$ in 10.00 dm^3 of solution. In this solution the magnesium hydroxide is fully dissociated into ions.

The equilibrium constant expression for the dissolving of magnesium hydroxide is $K = [Mg^{2+}][OH^-]^2$. In a saturated solution of $Mg(OH)_2$ at a different temperature, the concentration of hydroxide ions is 1.0×10^{-3} mol dm^{-3}.

Which one of the following has the correct value and units for K under these conditions?

A 1.0×10^{-6} mol^2 dm^{-6}

B 5.0×10^{-7} mol^2 dm^{-6}

C 1.0×10^{-9} mol^3 dm^{-9}

D 5.0×10^{-10} mol^3 dm^{-9}

(Total 1 mark)

Q7. (a) A flask containing a mixture of 0.200 mol of ethanoic acid and 0.110 mol of ethanol was maintained at 25 °C until the following equilibrium had been established.

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

The ethanoic acid present at equilibrium required 72.5 cm^3 of a 1.50 mol dm^{-3} solution of sodium hydroxide for complete reaction.

(i) Calculate the value of the equilibrium constant, K_c, for this reaction at 25 °C.

(ii) The enthalpy change for this reaction is quite small. By reference to the number and type of bonds broken and made, explain how this might have been predicted.

(9)

(b) Aspirin can be prepared by acylation using either ethanoyl chloride or ethanoic anhydride, as represented by the equations shown below.

$CH_3COCl + HOC_6H_4COOH \rightarrow CH_3COOC_6H_4COOH + HCl$

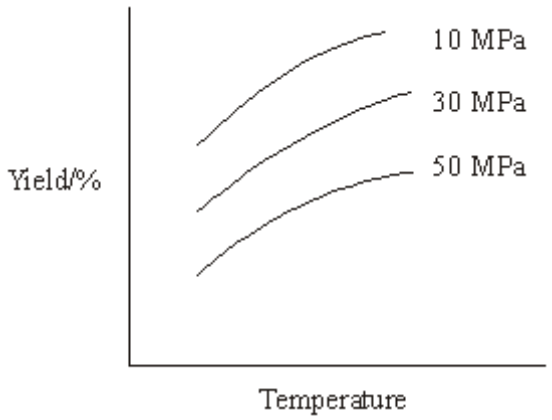
$(CH_3CO)_2O + HOC_6H_4COOH \rightarrow CH_3COOC_6H_4COOH + CH_3COOH$

(i) By a consideration of the intermolecular forces involved, explain why the product HCl is a gas but the product CH_3COOH is a liquid at room temperature.

(ii) Give **two** industrial advantages of using ethanoic anhydride rather than ethanoyl chloride in the manufacture of aspirin.

(4)
(Total 13 marks)

Q8. (a) The diagram below shows the effect of temperature and pressure on the equilibrium yield of the product in a gaseous equilibrium.



(i) Use the diagram to deduce whether the forward reaction involves an increase or a decrease in the number of moles of gas. Explain your answer.

Change in number of moles .....

Explanation .....

.....

.....

(ii) Use the diagram to deduce whether the forward reaction is exothermic or endothermic.
Explain your answer.

The forward reaction is .....

Explanation .....

.....

.....

(6)

(b) When a 0.218 mol sample of hydrogen iodide was heated in a flask of volume V dm^3, the following equilibrium was established at 700 K.

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

The equilibrium mixture was found to contain 0.023 mol of hydrogen.

(i) Calculate the number of moles of iodine and the number of moles of hydrogen iodide in the equilibrium mixture.

Number of moles of iodine.....

Number of moles of hydrogen iodide.....

.....

(ii) Write an expression for K_c for the equilibrium.

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.....

(iii) State why the volume of the flask need not be known when calculating a value for K_c.

.....

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(iv) Calculate the value of K_c at 700 K.

.....

.....

.....

(v) Calculate the value of K_c at 700 K for the equilibrium

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

.....

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(7)
(Total 13 marks)

Q9. Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

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

The percentage of ethanoic acid converted into the ester $CH_3COOC_2H_5$ in this reaction is

A 22.5%

B 30%

C 43%

C 90%

(Total 1 mark)

Q10. Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation below.
In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

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

The equilibrium constant for the reaction under these conditions is

A 0.20

B 0.23

C 3.9

C 4.3

(Total 1 mark)

Q11. Use the information about the following solutions to answer the question below.

Solution F: This is a mixture of 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water.

Solution G: This was originally the same mixture as solution **F** but it has been left to reach equilibrium.

Solution **G** was found to contain 0.5 mol of propanoic acid. Which one of the following is

the value of the equilibrium constant (K_c) for the following equilibrium?

propanoic acid + methanol $\rightleftharpoons$ methyl propanoate + water

A 0.2

B 1

C 5

D 10

(Total 1 mark)

Q12. Tetrafluoroethene, C_2F_4, is obtained from chlorodifluoromethane, $CHClF_2$, according to the equation:

$$2CHClF_2(g) \rightleftharpoons C_2F_4(g) + 2HCl(g) \qquad \Delta H^{\ominus} = +128 kJ\ mol^{-1}$$

(a) A 1.0 mol sample of $CHClF_2$ is placed in a container of volume 18.5 dm^3 and heated.

When equilibrium is reached, the mixture contains 0.20 mol of $CHClF_2$

(i) Calculate the number of moles of C_2F_4 and the number of moles of HCl present at equilibrium.

Number of moles of C_2F_4 .....

Number of moles of HCl .....

(ii) Write an expression for K_c for the equilibrium.

.....

(iii) Calculate a value for K_c and give its units.

Calculation .....

.....

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.....

Units .....

(6)

(b) (i) State how the temperature should be changed at constant pressure to increase the equilibrium yield of C_2F_4

.....

(ii) State how the total pressure should be changed at constant temperature to increase the equilibrium yield of C_2F_4

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(2)

(c) C_2F_4 is used to manufacture the polymer polytetrafluoroethene, PTFE. Name the type of polymerisation involved in the formation of PTFE.

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(1)
(Total 9 marks)