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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	60

Chemical Equilibria - 1

1. Which change leads to a higher concentration of SO_3 in this equilibrium mixture?

$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3(g)$ $\Delta H = -188\ kJ\ mol^{-1}$

A. higher concentration of O_2
B. higher temperature
C. lower pressure
D. use of a catalyst

(Total 1 mark)

2. The forward reaction in this equilibrium is endothermic.

$COCl_2\ (g) \rightleftharpoons CO(g) + Cl_2\ (g)$

Which statement is correct?

A. If the total pressure is increased at constant temperature, the proportion of $COCl_2$ in the equilibrium mixture will decrease
B. Use of a catalyst will increase the proportion of $COCl_2$ in the equilibrium mixture at constant temperature and pressure
C. Reducing the equilibrium concentration of CO will increase the value of the equilibrium constant
D. Raising the temperature from 373 K to 473 K will increase the value of the equilibrium constant

(Total 1 mark)

3. In the chemical industry methanol, CH_3OH, is synthesised by reacting together carbon monoxide and hydrogen in the presence of copper, zinc oxide and alumina which act as a catalyst.

This is a reversible reaction.

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

(a) High pressures and low temperatures would give the maximum equilibrium yield of methanol. Explain why.

(2)

(b) Explain why the actual conditions used in the chemical industry might be different from those in (a) above.

(2)

4. Ethanoic acid and ethane-1,2-diol react together to form the diester ($C_6H_{10}O_4$) as shown.

$2CH_3COOH(l) + HOCH_2CH_2OH(l) \rightleftharpoons C_6H_{10}O_4(l) + 2H_2O(l)$

(a) Draw a structural formula for the diester $C_6H_{10}O_4$

(1)

(b) A small amount of catalyst was added to a mixture of 0.470 mol of ethanoic acid and 0.205 mol of ethane-1,2-diol.

The mixture was left to reach equilibrium at a constant temperature. Complete Table 1. Table 1

Amount in the mixture / mol				
	CH_3COOH	$HOCH_2CH_2OH$	$C_6H_{10}O_4$	H_2O
At the start	0.470	0.205	0	0
At equilibrium	0.180			

(3)

(c) Write an expression for the equilibrium constant, Kc, for the reaction.

The total volume of the mixture does not need to be measured to allow a correct value for Kc to be calculated.

Justify this statement.

(2)

(d) A different mixture of ethanoic acid, ethane-1,2-diol and water was prepared and left to reach equilibrium at a different temperature from the experiment in part (b)

The amounts present in the new equilibrium mixture are shown in Table 2.

Amount in the mixture / mol				
	CH_3COOH	$HOCH_2CH_2OH$	$C_6H_{10}O_4$	H_2O
At new equilibrium	To be calculated	0.264	0.802	1.15

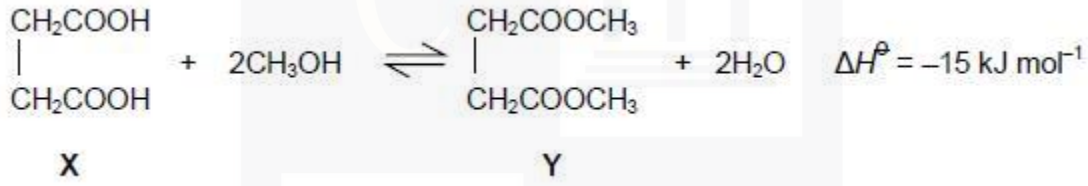
The value of Kc was 6.45 at this different temperature.

Use this value and the data in Table 2 to calculate the amount, in mol, of ethanoic acid present in the new equilibrium mixture.

Give your answer to the appropriate number of significant figures.

(3)

5. Acid X reacts with methanol to form an ester Y.



(a) Write an expression for the equilibrium constant, Kc, for this reaction. Use X and Y in your expression.

(1)

(b) A mixture of 0.32 mol of acid X and 0.84 mol of CH_3OH was allowed to reach equilibrium in the presence of a small amount of catalyst.

The equilibrium mixture formed contained 0.26 mol of ester Y.
Calculate the amounts, in moles, of X, CH_3OH and H_2O in this equilibrium mixture.

(3)

(c) Calculate the value of Kc and state the units.

(3)

(d) Predict the effect on Kc if the reaction is carried out at a lower temperature.

(1)

6. Hydrogen gas can be made by reacting ethanol with steam in the presence of a catalyst.

$C_2H_5OH(g) + H_2O(g) \rightleftharpoons 2CO(g) + 4H_2(g)$

(a) Give an expression for Kc for this equilibrium. State its units.

(2)

(b) The table shows the amount of each substance in an equilibrium mixture in a container of volume 750 cm^3

Substance	$C_2H_5OH(g)$	$H_2O(g)$	$CO(g)$	$H_2(g)$
Amount of substance / mol	0.0750	0.156	0.110	0.220

Calculate Kc

(3)

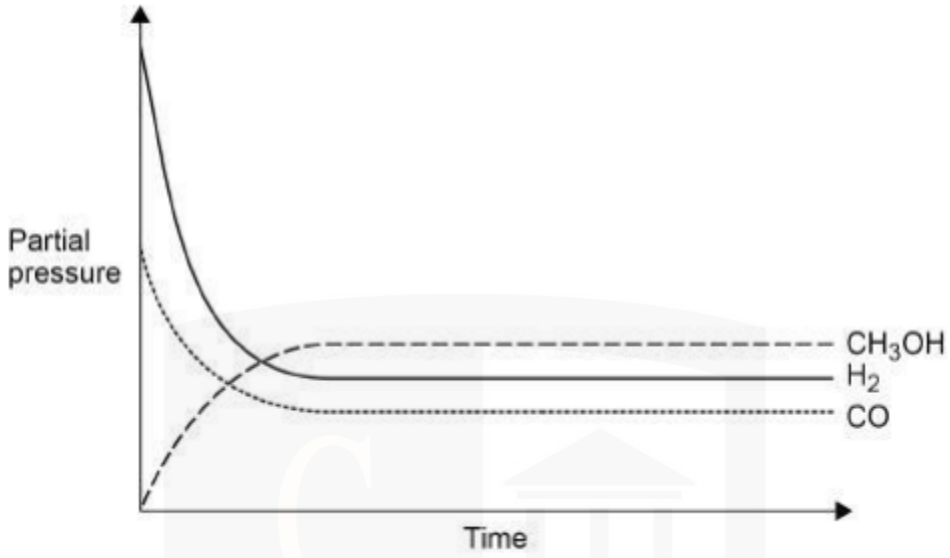
(c) The pressure of the equilibrium mixture was increased by reducing the volume of the container at constant temperature.
Predict the effect of increasing the pressure on the equilibrium yield of hydrogen.
Explain your answer.
Predict the effect of increasing the pressure on the value of K_c

(4)

7. Methanol can be manufactured in a reversible reaction as shown.

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

The graph below shows how the partial pressures change with time at a constant temperature.



(a) Draw a cross (x) on the appropriate axis of the graph when the mixture reaches equilibrium.

(1)

(b) A 0.230 mol sample of carbon monoxide is mixed with hydrogen in a 1:2 mol ratio and allowed to reach equilibrium in a sealed flask at temperature T.

At equilibrium the mixture contains 0.120 mol of carbon monoxide. The total pressure of this mixture is 1.04×10^4 kPa

Calculate the partial pressure, in kPa, of hydrogen in the equilibrium mixture.

(4)

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

(2)

(d) Some more carbon monoxide is added to the mixture in part (b).

The new mixture is allowed to reach equilibrium at temperature T.

State the effect, if any, on the partial pressure of methanol and on the value of Kp.

(2)

(e) State the effect, if any, of the addition of a catalyst on the value of Kp for this equilibrium.
Explain your answer.

(2)

8. Nitrogen monoxide reacts with chlorine to form nitrosyl chloride (NOCl).

$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$

(a) 1.50 mol of NO are mixed with 1.00 mol of Cl_2 and the mixture is left to reach equilibrium at a given temperature.

The equilibrium mixture contains 0.350 mol of NOCl
Calculate the amount, in moles, of NO and of Cl_2 in the equilibrium mixture.

(2)

(b) Give the expression for the equilibrium constant, Kc, for the reaction between nitrogen monoxide and chlorine to form nitrosyl chloride.

(1)

(c) A different equilibrium mixture is prepared in a flask of volume 800 cm^3 at a different temperature.

At equilibrium this mixture contains 0.850 mol of NO and 0.458 mol of Cl_2
For the reaction at this temperature
$Kc = 1.32 \times 10^{-2}\ mol^{-1}\ dm^3$

Determine the amount, in moles, of NOCl in this equilibrium mixture.

(4)

9. When one mole of ammonia is heated to a given temperature, 50 % of it dissociates and the following equilibrium is established.

$NH_3 \rightleftharpoons 1/2\ N_2 + 3/2 H_2$

What is the total amount, in moles, of gas in this equilibrium mixture?

A. 1.5
B. 2.0
C. 2.5
D. 3.0

(Total 1 mark)

10. Colourless solutions of X(aq) and Y(aq) react to form an orange solution of Z(aq) according to the following equation.

$X(aq) + 2Y(aq) \rightleftharpoons Z(aq) \qquad \Delta H = -20\ kJ\ mol^{-1}$

A student added a solution containing 0.50 mol of X(aq) to a solution containing 0.50 mol of Y(aq) and shook the mixture.

After 30 seconds, there was no further change in colour.

The amount of Z(aq) at equilibrium was 0.20 mol.

(a) Deduce the amounts of X(aq) and Y(aq) at equilibrium.

(2)

(b) The student prepared another equilibrium mixture in which the equilibrium concentrations of X and Z were:

$X(aq) = 0.40\ mol\ dm^{-3}$ and $Z(aq) = 0.35\ mol\ dm^{-3}$.

For this reaction, the equilibrium constant Kc = 2.9 mol^{-2} dm^6.

Calculate a value for the concentration of Y at equilibrium.

Give your answer to the appropriate number of significant figures.

(3)

(c) The student added a few drops of Y(aq) to the equilibrium mixture of X(aq), Y(aq) and Z(aq) in part (c).

Suggest how the colour of the mixture changed. Give a reason for your answer

(3)

(d) The student warmed the equilibrium mixture from part (c).
Predict the colour change, if any, when the equilibrium mixture was warmed.

I am Sorry !!!!!

(1)