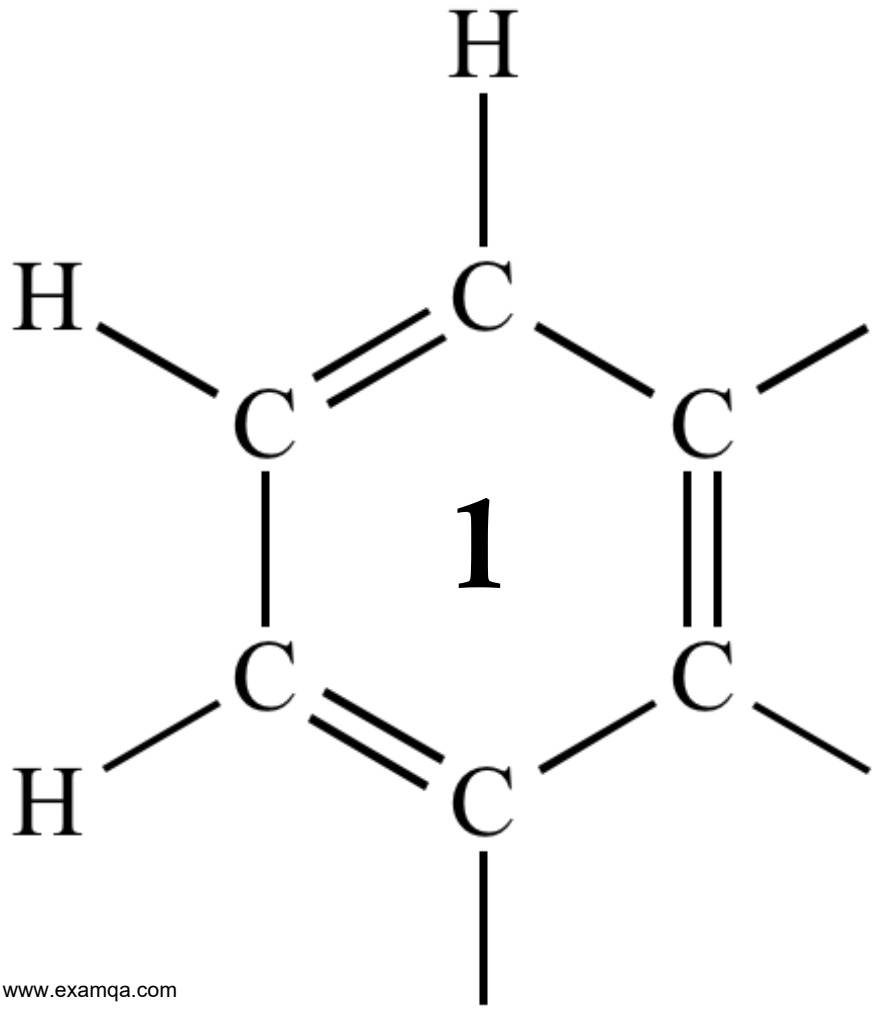
LONDON SCIENCE COLLEGE

AQA A2 CHEMISTRY

EQUILIBRIA

EQUILIBRIUM CONSTANT



1 The equation for the combustion of butane in oxygen is

$$C_4H_{10} + 6\ \tfrac{1}{2}O_2 \rightarrow 4CO_2 + 5H_2O$$

The mole fraction of butane in a mixture of butane and oxygen with the minimum amount of oxygen required for complete combustion is

A 0.133

B 0.153

C 0.167

C 0.200

(Total 1 mark)

2 At high temperatures, SO_2Cl_2 dissociates according to the following equation.

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g) \qquad \Delta H^{\ominus} = +93\ kJ\ mol^{-1}$$

When 1.00 mol of SO_2Cl_2 dissociates, the equilibrium mixture contains 0.75 mol of Cl_2 at 673 K and a total pressure of 125 kPa.

(a) Write an expression for the equilibrium constant, K_p, for this reaction.

.....

.....

(1)

(b) Calculate the total number of moles of gas present in the equilibrium mixture.

.....

(2)

(c) (i) Write a general expression for the partial pressure of a gas in a mixture of gases in terms of the total pressure.

.....

.....

(ii) Calculate the partial pressure of SO_2Cl_2 and the partial pressure of Cl_2 in the equilibrium mixture.

Partial pressure of SO_2Cl_2 .....

.....

Partial pressure of Cl_2 .....

.....

(5)

(d) Calculate a value for the equilibrium constant, K_p, for this reaction and give its units.

.....

.....

.....

(3)

(e) State the effect, if any, of an increase in temperature on the value of K_p for this reaction. Explain your answer.

Effect on K_p .....

Explanation .....

.....

(2)

(f) State the effect, if any, of an increase in the total pressure on the value of K_p for this reaction.

.....

(1)

(Total 14 marks)

3 When a mixture of 0.345 mol of PCl_3 and 0.268 mol of Cl_2 was heated in a vessel of fixed volume to a constant temperature, the following reaction reached equilibrium.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H^{\ominus} = -93 \text{ kJ mol}^{-1}$$

At equilibrium, 0.166 mol of PCl_5 had been formed and the total pressure was 225 kPa.

(a) (i) Calculate the number of moles of PCl_3 and of Cl_2 in the equilibrium mixture.

Moles of PCl_3 .....

Moles of Cl_2 .....

(ii) Calculate the total number of moles of gas in the equilibrium mixture.

.....

(3)

(b) Calculate the mole fraction and the partial pressure of PCl_3 in the equilibrium mixture.

Mole fraction of PCl_3 .....

.....

Partial pressure of PCl_3 .....

.....

(3)

(c) (i) Write an expression for the equilibrium constant, K_p, for this equilibrium.

.....

.....

(ii) The partial pressures of Cl_2 and PCl_5 in the equilibrium mixture were 51.3 kPa and 83.6 kPa, respectively, and the total pressure remained at 225 kPa. Calculate the value of K_p at this temperature and state its units.

.....

.....

.....

(4)

(d) State the effect on the mole fraction of PCl_3 in the equilibrium mixture if

(i) the volume of the vessel were to be increased at a constant temperature,

.....

(ii) the temperature were to be increased at constant volume.

.....

(2)
(Total 12 marks)

4 This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

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

Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
$SO_3(g)$	−396	+257
$SO_2(g)$	–297	+248
$O_2(g)$	0	+204

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

The mole fraction of SO_3 in the equilibrium mixture is

A 0.250

B 0.350

C 0.440

D 0.700

(Total 1 mark)

5 This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

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Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
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With pressures expressed in MPa units, the value of the equilibrium constant, K_p, is

A 4.90

B 6.48

C 9.07

D 16.8

(Total 1 mark)

6 This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

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Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
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Possible units for the equilibrium constant K_p include

A no units

B kPa

C Mpa^{-1}

D kPa^{-2}

(Total 1 mark)

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Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
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This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

At equilibrium in the same vessel of volume 1.80 dm^3 under altered conditions, the reaction mixture contains 0.0700 mol of $SO_3(g)$, 0.0500 mol of $SO_2(g)$ and 0.0900 mol of $O_2(g)$ at a total pressure of 623 kPa. The temperature in the equilibrium vessel is

A 307 °C

B 596 K

C 337 °C

D 642 K

(Total 1 mark)

8 The following information concerns the equilibrium gas-phase synthesis of methanol.

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

At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.
The number of moles of CO, H_2 and CH_3OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
CO(g)	−110	198
H_2(g)	0	131
CH_3OH(g)	−201	240

Possible units for the equilibrium constant, K_p, for this reaction are

A no units

B kPa

C MPa^{-1}

D kPa^{-2}

(Total 1 mark)

9 The following information concerns the equilibrium gas-phase synthesis of methanol.

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At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.
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Thermodynamic data are given below.

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CO(g)	−110	198
H_2(g)	0	131
CH_3OH(g)	−201	240

The mole fraction of hydrogen in the equilibrium mixture is

A 0.242

B 0.485

C 0.653

D 0.970

(Total 1 mark)

10 The following information concerns the equilibrium gas-phase synthesis of methanol.

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

At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.
The number of moles of CO, H_2 and CH_3OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

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CO(g)	−110	198
H_2(g)	0	131
CH_3OH(g)	−201	240

With pressures expressed in MPa units, the value of the equilibrium constant, K_p, under these conditions is

A 1.37

B 1.66

C 2.82

D 4.80

(Total 1 mark)

11 The following information concerns the equilibrium gas-phase synthesis of methanol.

$$CO(g) + 2H_2(g) \rightleftharpoons CH3OH(g)$$

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CO(g)	−110	198
H_2(g)	0	131
CH_3OH(g)	−201	240

Which one of the following statements applies to this equilibrium?

A The value of K_p increases if the temperature is raised.

B The value of K_p increases if the pressure is raised.

C The yield of methanol decreases if the temperature is lowered.

D The yield of methanol decreases if the pressure is lowered.

(Total 1 mark)

12 Hydrogen and carbon monoxide were mixed in a 2:1 mole ratio. The mixture was allowed to reach equilibrium according to the following equation at a fixed temperature and a total pressure of 1.75×10^4 kPa.

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

(a) The equilibrium mixture contained 0.430 mol of carbon monoxide and 0.0850 mol of methanol.

(i) Calculate the number of moles of hydrogen present in the equilibrium mixture.

.....

(ii) Hence calculate the mole fraction of hydrogen in the equilibrium mixture.

.....

.....

.....

(iii) Calculate the partial pressure of hydrogen in the equilibrium mixture.

.....

.....

.....

(5)

(b) In a different mixture of the three gases at equilibrium, the partial pressure of carbon monoxide was 7550 kPa, the partial pressure of hydrogen was 12300 kPa and the partial pressure of methanol was 2710 kPa.

(i) Write an expression for the equilibrium constant, K_p, for this reaction.

.....

(ii) Calculate the value of the equilibrium constant, K_p, for the reaction under these conditions and state its units.

K_p .....

.....

Units .....

(3)

(c) Two isomeric esters **E** and **F** formed from methanol have the molecular formula $C_6H_{12}O_2$

Isomer **E** has only 2 singlet peaks in its proton n.m.r. spectrum.

Isomer **F** is optically active.

Draw the structures of these two isomers.

*Isomer **E***

*Isomer **F***

(2)
(Total 10 marks)

13

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

Which of the following statements about a catalyst is / are true?

(i) It speeds up the forward reaction and slows down the reversere action.

(iii) It increases the proportion of molecules with higher energies.

(iii) A homogeneous catalyst usually acts in the solid state.

(iv) It does not alter the value of the equilibrium constant.

(Total 1 mark)