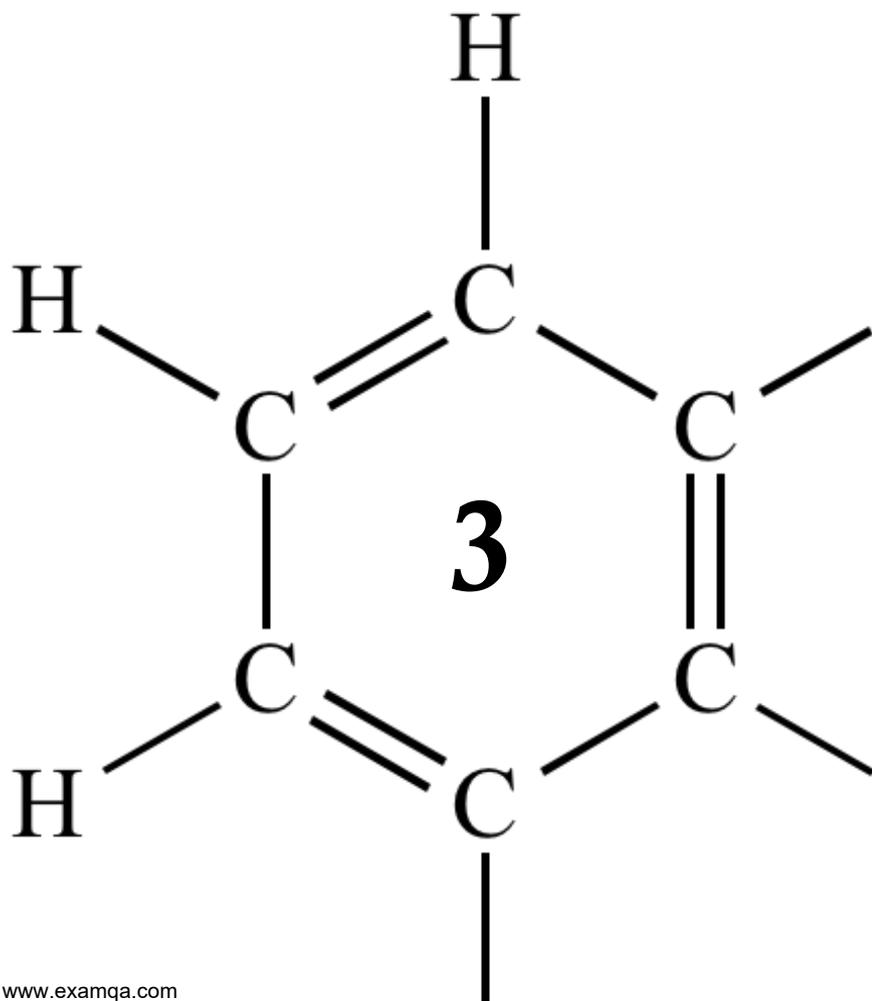


OCR A2 CHEMISTRY

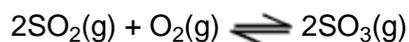
# MODULE 5.2

EQUILIBRIUM



**1**

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



Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
$\text{SO}_3(\text{g})$	-396	+257
$\text{SO}_2(\text{g})$	-297	+248
$\text{O}_2(\text{g})$	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<sup>3</sup>. At equilibrium, the vessel contains 0.0500 mol of  $\text{SO}_2(\text{g})$ , 0.0800 mol of  $\text{O}_2(\text{g})$  and 0.0700 mol of  $\text{SO}_3(\text{g})$ .

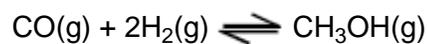
At equilibrium in the same vessel of volume 1.80 dm<sup>3</sup> under altered conditions, the reaction mixture contains 0.0700 mol of  $\text{SO}_3(\text{g})$ , 0.0500 mol of  $\text{SO}_2(\text{g})$  and 0.0900 mol of  $\text{O}_2(\text{g})$  at a total pressure of 623 kPa. The temperature in the equilibrium vessel is

- A 307 °C
- B 596 K
- C 337 °C
- D 642 K

**(Total 1 mark)**

**2**

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



At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.

The number of moles of CO, H<sub>2</sub> and CH<sub>3</sub>OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
CO(g)	-110	198
H <sub>2</sub> (g)	0	131
CH <sub>3</sub> OH(g)	-201	240

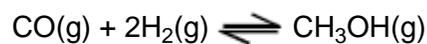
Possible units for the equilibrium constant,  $K_p$ , for this reaction are

- A no units
- B kPa
- C MPa<sup>-1</sup>
- D kPa<sup>-2</sup>

(Total 1 mark)

**3**

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



At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.

The number of moles of CO, H<sub>2</sub> and CH<sub>3</sub>OH present are 0.160, 0.320 and 0.180, respectively.

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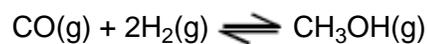
The mole fraction of hydrogen in the equilibrium mixture is

- A 0.242
- B 0.485
- C 0.653
- D 0.970

(Total 1 mark)

**4**

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



At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.

The number of moles of CO, H<sub>2</sub> and CH<sub>3</sub>OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

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H <sub>2</sub> (g)	0	131
CH <sub>3</sub> OH(g)	-201	240

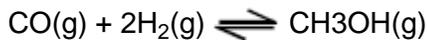
With pressures expressed in MPa units, the value of the equilibrium constant,  $K_p$ , under these conditions is

- A 1.37
- B 1.66
- C 2.82
- D 4.80

**(Total 1 mark)**

5

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



At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa. The number of moles of CO, H<sub>2</sub> and CH<sub>3</sub>OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
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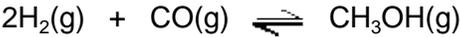
Which one of the following statements applies to this equilibrium?

- 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)

6

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  $1.75 \times 10^4$  kPa.



- (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.

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

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.....  
.....

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

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(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)

**7**

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

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

- (i) It speeds up the forward reaction and slows down the reverse action.
- (ii) 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)**