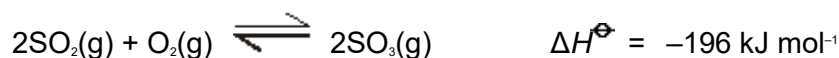


- Q1.** Sulphur dioxide and oxygen were mixed in a 2:1 mol ratio and sealed in a flask with a catalyst.
The following equilibrium was established at temperature T_1



The partial pressure of sulphur dioxide in the equilibrium mixture was 24 kPa and the total pressure in the flask was 104 kPa.

- (a) Deduce the partial pressure of oxygen and hence calculate the mole fraction of oxygen in the equilibrium mixture.

Partial pressure of oxygen

Mole fraction of oxygen

.....
.....

(3)

- (b) Calculate the partial pressure of sulphur trioxide in the equilibrium mixture.

.....

(1)

- (c) Write an expression for the equilibrium constant, K_p , for this reaction. Use this expression to calculate the value of K_p at temperature T_1 and state its units.

Expression for K_p

.....

Calculation

.....

.....

Units

(4)

- (d) When equilibrium was established at a different temperature, T_2 , the value of K_p was found to have increased. State which of T_1 and T_2 is the lower temperature and explain your answer.

Lower temperature.....

Explanation

.....

(3)

- (e) In a further experiment, the amounts of sulphur dioxide and oxygen used, the catalyst and the temperature, T_1 , were all unchanged, but a flask of smaller volume was used.

Deduce the effect of this change on the yield of sulphur trioxide and on the value of K_p .

Effect on yield of SO_3

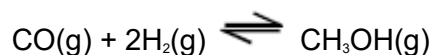
Effect on K_p

.....

(2)

(Total 13 marks)

Q2. 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_2 and CH_3OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

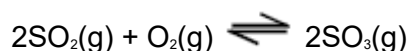
Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
CO(g)	-110	198
H_2 (g)	0	131
CH_3OH (g)	-201	240

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)

Q3. 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

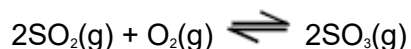
This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm³. At equilibrium, the vessel contains 0.0500 mol of $\text{SO}_2(\text{g})$, 0.0800 mol of $\text{O}_2(\text{g})$ and 0.0700 mol of $\text{SO}_3(\text{g})$.

At equilibrium in the same vessel of volume 1.80 dm³ 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)

Q4. This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:



Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
SO ₃ (g)	-396	+257
SO ₂ (g)	-297	+248
O ₂ (g)	0	+204

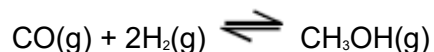
This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm³. At equilibrium, the vessel contains 0.0500 mol of SO₂(g), 0.0800 mol of O₂(g) and 0.0700 mol of SO₃(g).

Possible units for the equilibrium constant K_p include

- A no units
- B kPa
- C Mpa⁻¹
- D kPa⁻²

(Total 1 mark)

Q5. 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, H₂ and CH₃OH 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 ₂ (g)	0	131
CH ₃ OH(g)	-201	240

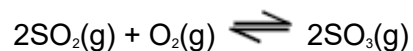
Possible units for the equilibrium constant, K_p , for this reaction are

- A no units

- B** kPa
- C** MPa⁻¹
- D** kPa⁻²

(Total 1 mark)

Q6. This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:



Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
SO ₃ (g)	-396	+257
SO ₂ (g)	-297	+248
O ₂ (g)	0	+204

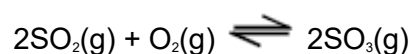
This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm³. At equilibrium, the vessel contains 0.0500 mol of SO₂(g), 0.0800 mol of O₂(g) and 0.0700 mol of SO₃(g).

The mole fraction of SO₃ in the equilibrium mixture is

- A** 0.250
- B** 0.350
- C** 0.440
- D** 0.700

(Total 1 mark)

Q7. This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:



Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$
SO ₃ (g)	-396	+257
SO ₂ (g)	-297	+248
O ₂ (g)	0	+204

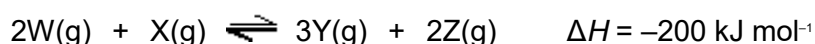
This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm³. At equilibrium, the vessel contains 0.0500 mol of SO₂(g), 0.0800 mol of O₂(g) and 0.0700 mol of SO₃(g).

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)

- Q8. (a) The gaseous reactants **W** and **X** were sealed in a flask and the mixture left until the following equilibrium had been established.



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

State one change in the conditions which would both increase the rate of reaction and decrease the value of K_p . Explain your answers.

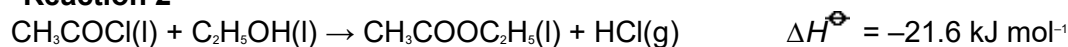
(7)

- (b) Ethyl ethanoate can be prepared by the reactions shown below.

Reaction 1



Reaction 2



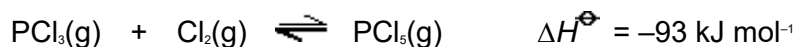
- (i) Give one advantage and one disadvantage of preparing ethyl ethanoate by **Reaction 1** rather than by **Reaction 2**.

- (ii) Use the information given above and the data below to calculate values for the standard entropy change, ΔS^\ominus , and the standard free-energy change, ΔG^\ominus , for **Reaction 2** at 298 K.

	CH ₃ COCl(l)	C ₂ H ₅ OH(l)	CH ₃ COOC ₂ H ₅ (l)	HCl(g)
$S^\ominus/\text{JK}^{-1}\text{mol}^{-1}$	201	161	259	187

(8)
(Total 15 marks)

- Q9.** When a mixture of 0.345 mol of PCl₃ and 0.268 mol of Cl₂ was heated in a vessel of fixed volume to a constant temperature, the following reaction reached equilibrium.



At equilibrium, 0.166 mol of PCl₅ had been formed and the total pressure was 225 kPa.

- (a) (i) Calculate the number of moles of PCl₃ and of Cl₂ in the equilibrium mixture.

Moles of PCl₃

Moles of Cl₂

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

.....

(3)

- (b) Calculate the mole fraction and the partial pressure of PCl₃ in the equilibrium mixture.

Mole fraction of PCl₃

.....
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,

.....

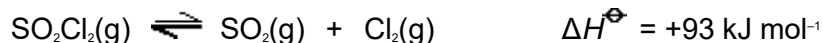
(ii) the temperature were to be increased at constant volume.

.....

(2)

(Total 12 marks)

Q10. At high temperatures, SO_2Cl_2 dissociates according to the following equation.



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)