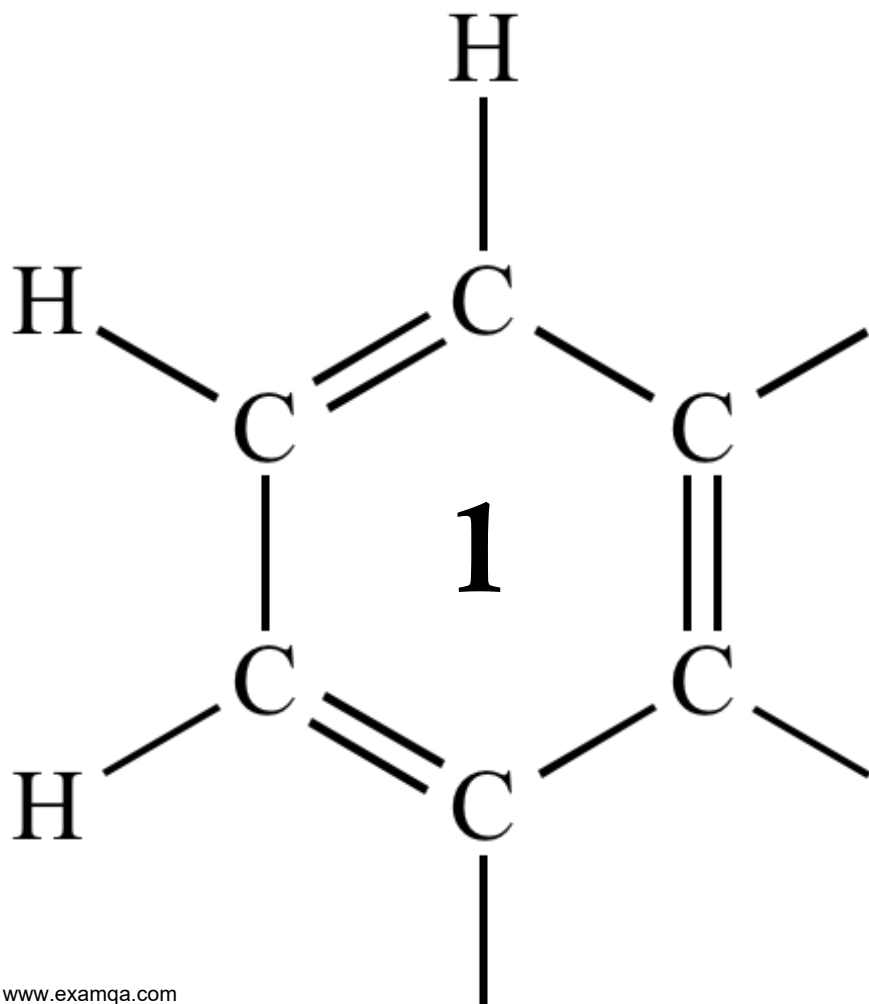


OCR A2 CHEMISTRY

# MODULE 5.2

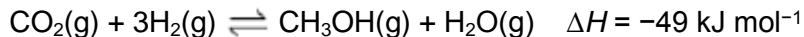
EQUILIBRIUM



1

Many chemical processes release waste products into the atmosphere. Scientists are developing new solid catalysts to convert more efficiently these emissions into useful products, such as fuels. One example is a catalyst to convert these emissions into methanol. The catalyst is thought to work by breaking a H–H bond.

An equation for this formation of methanol is given below.



Some mean bond enthalpies are shown in the following table.

<b>Bond</b>	C=O	C–H	C–O	O–H
<b>Mean bond enthalpy / kJ mol<sup>-1</sup></b>	743	412	360	463

- (a) Use the enthalpy change for the reaction and data from the table to calculate a value for the H–H bond enthalpy.

H–H bond enthalpy = ..... kJ mol<sup>-1</sup>

(3)

- (b) A data book value for the H–H bond enthalpy is 436 kJ mol<sup>-1</sup>.

Suggest **one** reason why this value is different from your answer to part (a).

.....

.....

.....

(1)

- (c) Suggest **one** environmental advantage of manufacturing methanol fuel by this reaction.

.....

.....

.....

(1)

(d) Use Le Chatelier's principle to justify why the reaction is carried out at a high pressure rather than at atmospheric pressure.

.....  
.....  
.....  
.....  
.....  
.....

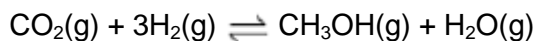
**(3)**

(e) Suggest why the catalyst used in this process may become less efficient if the carbon dioxide and hydrogen contain impurities.

.....  
.....  
.....

**(1)**

- (f) In a laboratory experiment to investigate the reaction shown in the equation below, 1.0 mol of carbon dioxide and 3.0 mol of hydrogen were sealed into a container. After the mixture had reached equilibrium, at a pressure of 500 kPa, the yield of methanol was 0.86 mol.



Calculate a value for  $K_p$

Give your answer to the appropriate number of significant figures.

Give units with your answer.

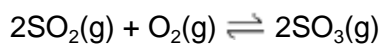
$K_p = \dots\dots\dots$  Units =  $\dots\dots\dots$

(7)

(Total 16 marks)

2

Which change would alter the value of the equilibrium constant ( $K_p$ ) for this reaction?



- A Increasing the total pressure of the system.
- B Increasing the concentration of sulfur trioxide.
- C Increasing the concentration of sulfur dioxide.
- D Increasing the temperature.

(Total 1 mark)

**3**

An experiment was carried out to determine the equilibrium constant,  $K_c$ , for the following reaction.



A student added measured volumes of propan-1-ol and propanoic acid to a conical flask. A measured volume of concentrated hydrochloric acid was added to the flask, which was then sealed.

After 1 week, the contents of the flask were poured into water and the solution was made up to a known volume.

This solution was titrated with standard sodium hydroxide solution.

- (a) Explain how the student could determine the amount, in moles, of propan-1-ol added to the flask.

.....  
.....  
.....  
.....

**(2)**

- (b) The titration described above gives the total amount of acid in the equilibrium mixture. Explain how, by carrying out a further experiment, the student could determine the amount of propanoic acid in the equilibrium mixture.

.....  
.....  
.....  
.....

**(2)**

- (c) In a repeat experiment, the student failed to seal the flask that contained the equilibrium mixture.

Explain why this error would lead to the student obtaining an incorrect value for the equilibrium constant  $K_c$

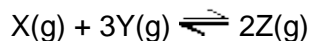
.....  
.....  
.....  
.....

**(2)**

**(Total 6 marks)**

4

A sealed flask containing gases **X** and **Y** in the mole ratio 1:3 was maintained at 600 K until the following equilibrium was established.



The partial pressure of **Z** in the equilibrium mixture was 6.0 MPa when the total pressure was 22.0 MPa.

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

.....  
.....

(ii) Calculate the partial pressure of **X** and the partial pressure of **Y** in the equilibrium mixture.

*Partial pressure of X* .....

.....

*Partial pressure of Y* .....

(iii) Calculate the value of  $K_p$  for this reaction under these conditions and state its units.

*Value of  $K_p$*  .....

.....

.....

*Units of  $K_p$*  .....

(6)

(b) When this reaction is carried out at 300 K and a high pressure of 100 MPa, rather than at 600 K and 22.0 MPa, a higher equilibrium yield of gas **Z** is obtained.

Give two reasons why an industrialist is unlikely to choose these reaction conditions.

*Reason 1* .....

*Reason 2* .....

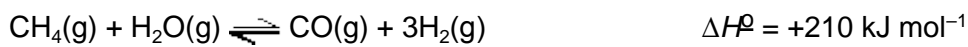
(2)

(Total 8 marks)

**5**

The manufacture of methanol can be achieved in two stages.

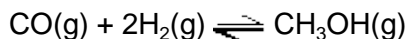
- (a) In the first stage, methane and steam react according to the following equation.



Discuss, with reasons, the effects of increasing separately the temperature and the pressure on the yield of the products and on the rate of this reaction.

**(6)**

- (b) In the second stage, carbon monoxide and hydrogen react according to the following equation.



A 62.8 mol sample of carbon monoxide was added to 146 mol of hydrogen. When equilibrium was reached at a given temperature, the mixture contained 26.2 mol of methanol at a total pressure of 9.50 MPa.

Write an expression for the equilibrium constant,  $K_p$ , for this reaction. Calculate a value for  $K_p$  at this temperature and give its units.

**(8)****(Total 14 marks)****6**

This question is about the reaction given below.



Enthalpy data for the reacting species are given in the table below.

Substance	CO(g)	H <sub>2</sub> O(g)	CO <sub>2</sub> (g)	H <sub>2</sub> (g)
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-110	-242	-394	0

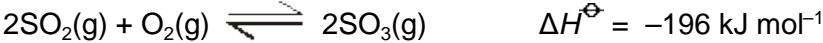
Which one of the following statements is **not** correct?

- A** The value of  $K_p$  changes when the temperature changes.
- B** The activation energy decreases when the temperature is increased.
- C** The entropy change is more positive when the water is liquid rather than gaseous.
- D** The enthalpy change is more positive when the water is liquid rather than gaseous.

**(Total 1 mark)**

7

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)**