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CHEMICAL EQUILIBRIUM

Learner Note: Please understand and learn the factors affecting the rate of a reaction very well before attempting this section on chemical equilibrium. The only factors affecting chemical equilibrium are temperature, concentration and pressure.

SECTION A: TYPICAL EXAM QUESTIONS

Question 1: 12 minutes

When ethane and oxygen are mixed in a closed container, the following equilibrium is established at a constant temperature of 183°C:



1.1 The open spaces in the table below are numbered from 1.1.1 to 1.1.7.

Change	Mol of CO ₂	Value of K _c	Value of ΔH
Pressure is decreased by increasing the volume at constant temperature	1.1.1	1.1.2	
Temperature is increased at constant volume.	1.1.3	1.1.4	1.1.5
A catalyst is added.	1.1.6		
Pressure is changed at constant temperature by adding helium.	1.1.7		

Write down only the numbers 1.1.1 to 1.1.7 below each other, and opposite each, one selection from increases / remains constant / decreases to indicate the effect upon the specific quantity if the conditions are changed as indicated. (7)

1.2 Give a suitable reason for your choice in question 1.1.2 above. (2)
[9]

Question 2: 5 minutes

Consider the following equilibrium reaction:



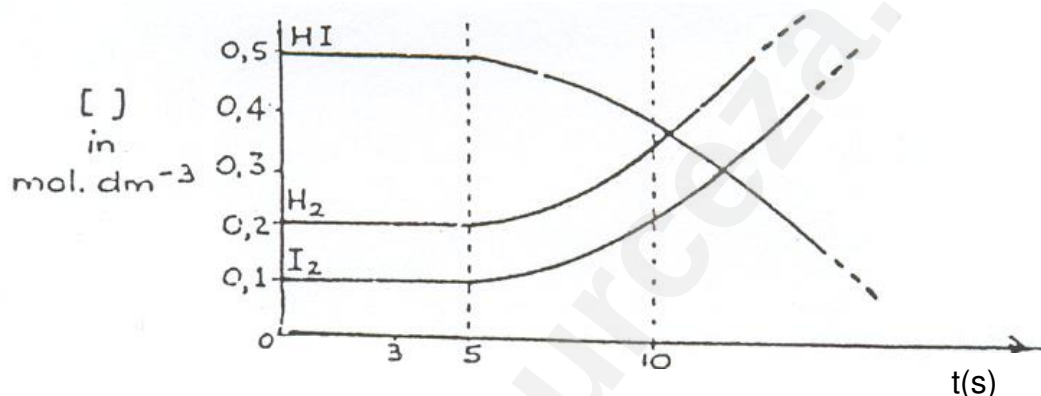
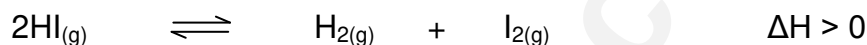
The equilibrium constant for this reaction at two different temperatures is given in the table below:

TEMPERATURE	EQUILIBRIUM CONSTANT
297 K	$2,5 \times 10^{-2}$
594 K	5×10^{-5}

- 2.1 Is ΔH (heat of reaction) positive or negative for the above reaction? Explain your reasoning. (3)
- 2.2. What effect does an increase in pressure (at constant temperature) have on:
- 2.2.1 the equilibrium constant? (1)
- 2.2.2 the equilibrium position? (1)

[5]**Question 3: 5 minutes**

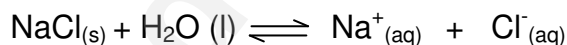
The following diagram shows the concentration of products and reactants, initially in equilibrium, against time. The reaction is:



- 3.1 Is the system in equilibrium at $t = 10\text{s}$? Give a reason for your answer. (2)
- 3.2. Which external factor was applied to the system to bring about a change in the shape of the graph at $t = 5\text{s}$? Explain how this factor caused the change. (3)

[5]**Question 4: 3 minutes**

When a saturated solution of sodium chloride is prepared, the following equilibrium exists:



The saturated solution is decanted and concentrated hydrochloric acid is added to the decanted solution.

- 4.1 What will be observed? (1)
- 4.2 Explain your observation. (2)

[3]

SECTION B: SOLUTIONS AND HINTS**Question 1:**

- 1.1.1. increases ✓
- 1.1.2. remains constant ✓
- 1.1.3. increases ✓
- 1.1.4. increases ✓
- 1.1.5. remains constant ✓
- 1.1.6. remains constant ✓
- 1.1.7. decreases ✓

1.2. Only temperature changes K_c ✓✓

Question 2:

2.1. ΔH is negative ✓. High temp gives a small K_c , therefore, reverse is favoured with high temp. High temp favours endo ✓. Reverse endo. ✓ Forward exo.

2.2.1. none ✓

2.2.2. none ✓

Question 3:

3.1. No ✓. $[HI]$, $[H_2]$ and $[I_2]$ are all changing at 10s. ✓ At equilibrium they would be constant.

3.2. increase temperature. ✓ Endothermic reaction is favoured. ✓ Forward reaction is endothermic since there is more I_2 and H_2 and less HI . ✓

Question 4:

4.1. White ppt ($NaCl$) ✓

4.2. By adding more HCl , there are now more Cl^- ions. ✓ Common ion effect - the equilibrium now shifts to reduce this increase in Cl^- concentration and so the reverse reaction is favoured. ✓

SECTION C: ADDITIONAL CONTENT NOTES**EQUILIBRIUM****EFFECTIVENESS OF REACTIONS**What is equilibrium?

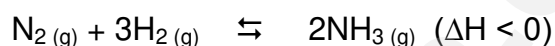
- ⇌ Reactions that take place in both the forward and reverse directions simultaneously, are called reversible reactions.
- ⇌ Observable macroscopic changes stop, while microscopic changes continue as reactants change to products, and products change back into reactants.
- ⇌ When the rate of the forward reaction equals the rate of the reverse reaction, we say a state of dynamic equilibrium has been reached.

Le Chatelier's Principle

If the conditions of an equilibrium system are changed, by changing temperature, pressure or concentration, a process takes place which tends to oppose the effect of the change.

⇌ An equilibrium may be disturbed by changing any one (or more) of the factors for the equilibrium.

- Temperature
- Concentration (gases and solutions)
- Pressure (gases only)

Changing Equilibrium Conditions*Concentration*

An increase in concentration of any reactant will cause an increase in the reaction rate of the forward reaction.



Increasing the concentration of the N_2 or H_2 would, therefore, increase the rate of the forward reaction, hence favouring the shift of the equilibrium towards the forward reaction.

Temperature

An increase in temperature causes an increase in the rate of both reactions.



ΔH refers to the forward reaction. If it is negative, the reaction is exothermic (energy is liberated).



Increasing the temperature will favour the endothermic (reverse) reaction.

Pressure

Pressure can be increased by decreasing the volume of the container.



When the volume of the container decreases, the total concentration of all gases increases.



According to Le Chatelier, the reaction that will decrease the total number of gas moles in the space will be favoured. (favour side with lowest number of gas moles)

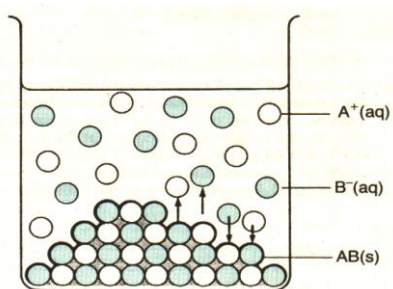
So to ensure maximum yield of ammonia:

Use catalyst to reach equilibrium quickly.



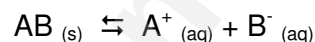
Once equilibrium is reached:

- Drop temperature to 450°C
- Increase conc. of N_2 & H_2 & decrease conc. of NH_3
- Increase pressure in container by reducing volume.

Equilibrium in solutions

$$K_{sp} = [A^+][B^-]$$

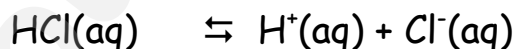
The equation for the equilibrium reaction of a saturated salt solution can be represented as follows:



- * Adding HCl (H^+ and Cl^- ions) to the above solution in equilibrium, causes the equilibrium to favour the reverse reaction to compensate for the additional Cl^- ions that were added to the product side.
- * NaCl is, therefore, precipitated until the equilibrium is restored. More white solid is formed
- * Shifting the equilibrium of a salt in a solution by increasing the concentration of one kind of ion is called the *common ion effect*.

Equilibrium in acids

- ☺ When the acid is strong, the equilibrium lies far to the product side (lots of ions form).



- ☺ When the acid is weak, the equilibrium lies far to the reactant side (few ions form).



SECTION D: HOMEWORK**Question 1 – 5 minutes** *(Taken from DoE Physical Sciences Paper 2 Additional Exemplar 2008)*

Atmospheric pressure reduces at high altitudes and, consequently, the amount of oxygen in the atmosphere is less than at sea level. Mountain climbers can experience hypoxia – a deficiency in oxygen. Symptoms of hypoxia include headache and nausea, and one may even slip into a coma.

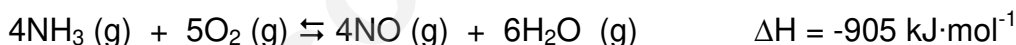
The haemoglobin molecule (Hb) carries oxygen to the blood. In the process the oxygen bonds to the haemoglobin to form oxyhaemoglobin (HbO₂). A simplified equilibrium expression for the reaction is shown below:



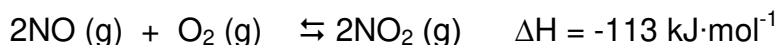
- 1.1 What precaution must a mountain climber take in order to minimise the risk of hypoxia? (2)
 - 1.2 Refer to the above equilibrium reaction and explain why the precaution stated in QUESTION 1.1, is necessary. (3)
- [5]**

Question 2 – 15 minutes*(Taken from DoE Physical Science Paper 2 November 2003)*

The first stage in the Ostwald process for the manufacturing of nitric acid, is the catalytic oxidation of ammonia. A platinum gauze is used as a catalyst. The equation for the reaction is:



- 2.1 Why must the platinum alloy gauze be heated at the beginning of the process? (2)
- 2.2 Why does the platinum alloy gauze remain hot during the process? (2)
- 2.3 The second stage of the Ostwald process takes place slowly in a closed container and is shown by the equation below:



- 2.3.1 What change in temperature must be made to obtain more NO₂? (2)
 - 2.3.2 Using Le Chatelier's principle, give an explanation for the answer to Question 2.3.1. (3)
 - 2.3.3 Use Le Chatelier's principle to explain what the effect of an increase in pressure will have on the amount of NO₂ formed. (3)
- [12]**

SECTION E: SOLUTIONS TO SESSION 22 HOMEWORK**Question 1:**

- 1.1 A larger mass of metal will produce more gas etc ✓✓ (2)

Learner Note: You must give the relationship between the dependent and independent variables.

- 1.2 Temperature ✓✓ and concentration ✓✓ (4)

- 1.3 Any mass bigger than 1,6 g will not influence the volume of the gas produced. ✓✓ (2)

- 1.4 160 cm^3 ✓✓ (2)
[10]

Question 2:

As the temperature increases✓, the number of molecules with the minimum kinetic energy required for a reaction to occur, increases✓. The molecules will be moving faster✓, the number of effective collisions will increase, ✓and thus the rate of the reaction will increase✓. Thus, the sugar dissolves faster in hot water. [5]

Question 3:

- 3.1 It will be easier to form products from the reactants ✓ because the activation energy is less ✓ than the activation energy required to form the reactants from the products. (2)
- 3.2 Carbon monoxide is toxic and can lead to atmospheric pollution and global warming. ✓✓ (2)
- 3.3 It will lower the amount of CO produced and this will lead to less CO poisoning. ✓✓ (2)
[6]

