3. Rate of chemical reactions and chemical equilibrium

Let us Assess

1. Question

a) In which of the following reversible reactions does the change in pressure not influence equilibrium? What is the reason?

i) $H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$

ii) $N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$

b) What is the use of applying high pressure during formation of ammonia from nitrogen and hydrogen?

Answer

a) (i) $H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$

Change in pressure means change in the number of molecules. If we increase the pressure then number of molecules per unit volume increases and the number of effective collisions also increases. So, to decrease this pressure, the reaction will proceed in that direction to attain equilibrium where the number of molecules are less. But in this reaction the number of reactant and product molecules are same so there will no change in equilibrium state. So, the change in pressure will not influence equilibrium.

b) In gaseous system, decrease in the number of molecules helps to decrease the pressure. According to Le Chatelier principle, If we increase the pressure then the number of molecules per unit volume increases which results increment in the number of effective collisions. So, to decrease the pressure, reaction will decrease reactant molecules and the reaction will proceed in that direction to attain equilibrium where the number of molecules is less. So, the above reaction will proceed in forward direction. So, in the above reaction, the reactant molecules will react and form product very easily because there are less molecules at product side. Hence the formation of ammonia will increase.

2. Question

$$C(s) + H_2O(g) \underset{\leftarrow}{\overset{\text{heat}}{\rightleftharpoons}} CO(g) + H_2(g)$$

a) Identify the reactants and products.

b) Products are frequently removed from the system. Explain the reason.

Answer

a) Reactants = C(s) and $H_2O(g)$

Products = CO(g) and $H_2(g)$

The substances which reacts are called reactants and the substances which formed during reaction are called products.

b) We know that According to Le Chatelier principle if we change the concentration of a system at equilibrium then the system will try to cancel the effect of that change and it will attain a new state of equilibrium. So when we remove the products then product molecules will decrease so the reaction will proceed in a forward direction to attain the equilibrium. And so the products will increase.

Note- Equilibrium is that state when the rate of forward reaction becomes equal to the rate of backward reaction.

3. Question

$$N_2O_4(g) \underset{\text{Exothermic}}{\overset{\text{Endothermic}}{\rightleftharpoons}} 2NO_2(g)$$

a) Which gas is brown in colour?

b) How does an increase in temperature influence the state of equilibrium?

c) How can the yield of the product NO_2 be increased?

Answer

a) NO_2 (Nitrogen dioxide).

b) By collision theory on increasing the temperature, the energy, as well as speed of molecules increases and the number of effective collisions, also increases. Due to these effective collisions, the molecules react and form product more easily. So, when we will increase the temperature then the molecules will react more easily and will attain equilibrium state more easily. So, increase in temperature influence the state of equilibrium.

c) The yield of the product NO_2 can be increased

(i) By increase the temperature- By collision theory On increasing the temperature, the energy as well as the speed of molecules increases and the number of effective collisions also increases. Due to these effective collisions, the molecules react and form product more easily. So when we increase the temperature then reactant molecules will react more easily and the formation of NO_2 will increase.

(ii) By increasing the concentration of N_2O_4- According to collision theory on increasing the concentration, the number of reactant molecules per unit volume increases and so the number of effective collisions also increases. And the reactant molecules react more easily. So on increasing the concentration, the reactant molecules will react more easily and the rate of reaction will increase.

4. Question

The chemical equation for the reaction between marble and dilute HCl is given.

$CaCO_3$ (s) + 2HCl (aq) → $CaCl_2$ (aq) + CO_2 (g) + H_2O (l)

a) Which is the gas formed here?

b) Suggest two methods for increasing the rate of reaction. Explain the reason for your suggestions.

Answer

a) CO_2 gas is formed here.

Carbonates on reaction with dilute HCl produces metal chloride, water, and CO2 gas.

b) (i) By increase the concentration- According to collision theory on increasing the concentration, the number of reactant molecules per unit volume increases and the number of molecules undergoing effective collisions also increases. So the reactant molecules will react and form product easily. Hence the rate of reaction will increase.

(ii) By increase the surface area- If solids are made into small pieces or powder then their surface area increases and the number of molecules undergoing effective collisions also increases. So reactant molecules will react and form product easily. So the rate of reaction will increase.

5. Question

$2NO(g) + O_2(g) \leftrightharpoons 2NO_2(g)$ + heat

In this reaction how do the following changes influence the amount of the product?

a) Decrease in temperature

b) Increase in pressure

c) Increase in the concentration of oxygen

Answer

a) In the above reaction, on decreasing the temperature the system tries to increase the temperature by evolving heat. So the rate of exothermic reaction will increase. So, the above reaction will proceed in the forward reaction for increasing the temperature. Hence the formation of NO_2 will increase.

Note- Exothermic reactions are those reactions which evolve heat.

b) In the gaseous system, a decrease in the number of molecules helps to decrease the pressure. According to Le Chatelier principle, If we increase the pressure then the number of molecules per unit volume increases which results in increment in the number of effective collisions. So, to decrease the pressure, the reaction will decrease reactant molecules and the reaction will proceed in that direction to attain equilibrium where the number of molecules is less. So the above reaction will proceed in forwarding direction. So in the above reaction, the reactant molecules will react and form product very easily because there are fewer molecules

at product side. Hence the formation of NO_2 will increase.

c) On increase in the concentration of oxygen, the reaction will proceed in a forward direction to attain equilibrium by decreasing concentration of reactants. So, the amount of NO_2 will increase.

6. Question

$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g) + heat$

a) In this reaction what happens to the volume when the reactants change to the products?

b) What change in pressure is required for the maximum yield of the product?

c) What is the change in the concentration required for increasing the rate of the forward reaction?

d) What is the catalyst used in this reaction? What is its effect?

Answer

a) When reactants change to the products then the volume decreases because 4-mole reactant molecules are converted into 2-mole product molecules.

b) Increase the pressure for maximum yield of the product. According to Le Chatelier principle, On increasing the pressure the reaction will proceed in a forward direction to attain equilibrium by reducing pressure. To reduce the pressure, reaction decreases reactant molecules. So the reactant molecules will react and form product very easily. Hence product formation will increase.

c) Increase the reactant concentration for increasing the rate of the forward reaction because on increase the reactant concentration the reaction will proceed in a forward direction to attain equilibrium by decreasing reactant molecules.

d) Iron is used as a catalyst in this reaction. A catalyst increases the rate of reaction.

Extended Activities

1. Question

Some apparatus and chemicals are given.

Zn, Mg, dilute HCl, $CaCO_3$, test tube, water

a) Design an experiment to prove that the nature of reactants can influence the rate of reaction.

b) Write the equations for the chemical reactions.

c) Write the expression for the rate of the reaction.

Answer

a) Experiment-1- When Mg react with dilute HCl in test tube then hydrogen gas will evolve.

Experiment-2- When Zn react with dilute HCl in a test tube then hydrogen gas will evolve.

The reaction of Mg with dilute HCl will occur faster than the reaction of Zn with dilute HCl. The Mg is more reactive than Zn because Mg is above to Zn in reactivity series. So, the nature of reactants can influence the rate of reaction.

b) $Mg + 2HCl \rightarrow MgCl_2 + H_2$

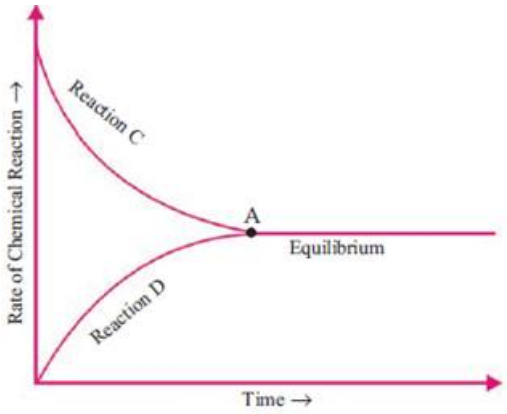
$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

c) Rate of reaction = $\frac{\text{Amount of reactants used}}{\text{Time is taken for consumption of the reactant}}$

Rate of reaction = $\frac{\text{Amount of product formed}}{\text{Time is taken for the formation of the product}}$

2. Question

The graph for the reaction N_2 (g) + $3H_2$ (g) $\leftrightharpoons$ $2NH_3$ (g) + heat is given below.



a. Identify and write the reactions C and D.

b. What happens to the position of point A in the graph when a catalyst is used? Redraw the graph accordingly.

Answer

a) Reaction C is Forward reaction

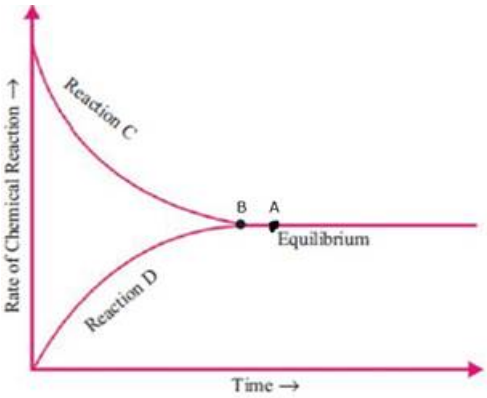
N_2 (g) + $3H_2$ (g) $\rightarrow 2NH_3$ (g)

Reaction D is Backward reaction

$2NH_3$ (g) $\rightarrow N_2$ (g) + $3H_2$ (g)

The rate of forward reaction decreases with time and the rate of backward reaction increases with time to attain the state of equilibrium.

b) When the catalyst is used then the rate of reaction will be increased and the reaction will attain equilibrium more easily. So the point A will shift towards the left side. And the new equilibrium point is B.



3. Question

The experiments conducted by two students are given below.

Experiment - 1

2 mL of sodium thiosulphate solution is taken in a test tube, heated and to it, 2 mL of HCl solution is added.

Experiment - 2

2 mL of sodium thiosulphate solution is taken in a test tube and to it, 2 mL of HCl solution is added.

a) In which experiment is the precipitate formed first? Justify your answer.

b) Write the balanced equation for the reaction.

Answer

a) The precipitate will form first in experiment-1 because of increasing the temperature the energy as well as the speed of molecules increases. As a result of the number of molecules undergoing effective collisions increases. So the reactant molecules will react more easily. Hence the rate of reaction will increase.

b) $Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + SO_2(g) + S(s)$

Note- In balanced equation, the number of atoms of an element will be same on both side of reaction.

4. Question

Some materials available in the laboratory are given below. Magnesium ribbon, marble powder, marble pieces, dilute HCl, concentrated HCl.

a) Which are the materials required for the preparation of more CO_2 in less time?

b) Write the balanced chemical equation for the reaction.

Answer

a) The materials are required for the preparation of more CO_2 in less time are Marble powder and concentrated HCl because if we take marble powder then the surface area increases and the number of molecules undergoing effective collisions also increases. So, the rate of reaction will increase. And if we take concentrated HCl then the number of molecules per unit volume increases and the number of effective collisions also increases. So, the rate of reaction will increase.

b) $CaCO_3 (s) + 2HCl (aq) \rightarrow CaCl_2 (aq) + H_2O (l) + CO_2 (g)$

Note- Carbonates on reaction with dilute HCl produces metal chloride, water and CO2 gas.