Unit 06

Equilibria

Descriptive Questions

Q.1. (Ex. Q.4 (i)) How can you derive the reversible reaction at equilibrium?
(a) in the forward direction (b) in the backward direction 09206001

Ans.

(a) In the forward Direction:

To derive the reversible reaction in the forward direction at equilibrium, following step should be taken:

1. **Concentration of reactants:** Adding one or more reacting species will push the reaction towards forward direction producing more products.
2. **Concentration of products:** With drawing one or more product species will shift the equilibrium position to the right, favoring the formation of more products.
3. **Temperature:**
   - If the reaction is exothermic, decreasing the temperature shift the equilibrium to forward direction producing more products.
   - If the reaction is endothermic, increase the temperature shifts the equilibrium to forward direction producing more products.
4. **Effect of Pressure & Volume:**
   - In gas phase reaction, if reaction proceeds with decrease in volume at equilibrium stage. Then further decrease in volume or increase in pressure at equilibrium will shift the equilibrium position in forward direction.
   - In gas phase reaction if reaction proceeds with increase in volume at equilibrium stage. Then further increase in volume or decrease in pressure at equilibrium, will shift the equilibrium position in forward direction.

(b) In the backward Direction:

To derive the reversible reaction in the backward direction at equilibrium the following steps should be taken:

1. **Concentration of reactants:** By decreasing the concentration of reactants, it will shift the equilibrium towards backward direction producing more reactants.
2. **Concentration of products:** By increasing the concentration of products will push the reaction to backward direction producing more reactants.
3. **Temperature:**
   - If the reaction is exothermic, increasing the temperature at equilibrium will shift the equilibrium position in the backward direction.
   - If the reaction is endothermic, decreasing the temperature at equilibrium will shift the equilibrium position in the backward direction.
4. **Effect of Pressure & Volume:**
   - In gas phase reaction if reaction proceeds with decrease in volume at equilibrium stage. Then further increase in volume or decrease in pressure at equilibrium will shift the equilibrium position in backward direction.

- In gas phase reaction if reaction proceeds with increase in volume at equilibrium stage. Then further decrease in volume or increase in pressure at equilibrium will shift the equilibrium position in backward direction.

Q.2. (Ex. Q.4 (ii)) Explain how the forward and backward reactions change when the system approaches equilibrium. 09206002

Ans. When a system approaches equilibrium, the forward and backward reactions change in their rates until they become equal.

Forward Reaction:
If a reversible reaction is started by mixing the reactants, the reaction moves in the forward direction only.

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Backward Reaction:

After some time when enough concentrations of the products are built up, they react to give back the reactants in the reverse reaction.

$$2NH_3 \longrightarrow N_2 + 3H_2$$

Equilibrium State:

The reaction will keep on going in both the directions until the rate of forward reaction becomes equal to the rate of backward reaction. The number of reactant molecules which will disappear as a result of forward reaction becomes equal to the number of reactant molecules which will form as a result of the reverse reaction. The same will be true for the product molecules. At this stage, the reaction is said to be in a state of **chemical equilibrium.** It appears as if nothing is going on in the reaction vessel as the concentrations of both reactant and product molecules do not undergo any change at this stage. Since the reaction did not cease at this state of equilibrium, rather it keeps on going in both the directions, this state is called **dynamic equilibrium.** The concentrations of reacting species (reactants and products) remain constant at equilibrium.

$$N_{2(g)} + 3H_{2(g)} \underset{\text{Fe}}{\overset{\text{400°C, 200 atm}}{\rightleftharpoons}} 2NH_{3(g)}$$

Q.3. (Ex. Q.4 (iii)) Describe the effect of a catalyst on the reversible reaction. 09206003

Ans. At the stage of dynamic equilibrium, the rates of both forward and backward reactions are equal.
A catalyst increases both the rates of forward and backward reactions of a reversible reaction. So if a reversible reaction is carried out in the presence of a catalyst it will decrease the time taken by the reaction to attain the state of equilibrium.

Example:
Consider the following Haber's process at equilibrium.

$$N_{2(g)} + 3H_{2(g)} \underset{\text{Fe}}{\overset{\text{400°C, 200 atm}}{\rightleftharpoons}} 2NH_{3(g)}$$

The Haber's process is commonly used for ammonia synthesis in which iron catalyst is used to enhance the reaction rates. The catalyst helps increase the yield of ammonia without being consumed in the process. In this way, the yield of ammonia gas for production of urea fertilizer can be maximized.

Role of Catalyst in Haber's Process

For a dynamic equilibrium to be setup the rate of the forward reaction must be equal to the rate of backward reaction. This does not happen instantly and for very slow reaction, it may take years. Both the rates of formation and the decomposition of ammonia are reasonably fast at around 400°C in the presence of a catalyst. This reaction will reach the equilibrium state within minutes of the start of reaction.

Q.4. (Ex. Q.4 (iv)) How can a reversible reaction be forced to go to completion? 09206004

Ans. A reversible chemical can be forced to go to completion by disturbing in the following possible ways.

- **i.** Adding one or more of the reacting species
- **ii.** Withdrawing one or more of the product species
- **iii.** Changing the temperature of the reaction
- **iv.** Changing the pressure or volume of the reaction if it involves reactants and products in the gaseous state

Example:

Consider the following reversible reaction at equilibrium.

$$N_{2(g)} + 3H_{2(g)} \underset{\text{Fe}}{\overset{\text{400°C, 200 atm}}{\rightleftharpoons}} 2NH_{3(g)}$$

- **(i)** Adding N_2 or H_2 continuously in reaction mixture force this reversible reaction to completion.
- **(ii)** Withdrawing of NH_3 force this reversible reaction to completion.
- **(iii)** Decreasing temperature (up to 400°C) will force the reaction to completion.
- **(iv)** Decreasing volume or increasing pressure at equilibrium will force the above reaction to completion.

Q.5. (Ex. Q.4 (v)) How does change in temperature affect the reaction at equilibrium?

Ans. Effect of changing the temperature on the state of equilibrium: 09206005

The formation of ammonia is exothermic in the forward direction and hence this reaction will be endothermic in the reverse direction.

$$N_{2(g)} + 3H_{2(g)} \overset{\text{Heat}}{\rightleftharpoons} 2\,NH_{3(g)} \quad \Delta H = -92.4\ \text{KJ/mole}$$

If this reaction is at equilibrium and its temperature is increased, the state of the equilibrium will be disturbed again. The ΔH of this reaction is negative. This means the total energy of the system containing N_2 and H_2 is higher than that of ammonia. The increase in temperature of this reaction at equilibrium will push the reaction in the backward direction i.e. the reactants side. Decreasing the temperature will derive the equilibrium to the forward direction.

If the reaction is exothermic, decreasing the temperature shift the equilibrium to forward direction producing more products. If the reaction is exothermic, increasing the temperature at equilibrium will shift the equilibrium position in the backward direction.

If the reaction is endothermic increase the temperature shifts the equilibrium to forward direction producing more products can also help to derive the reaction forward. In gas phase reaction if reaction proceeds with increase in volume at equilibrium stage. Then Decrease in volume or increase in pressure at equilibrium, will shift the equilibrium position in Backward direction.

Investigative Questions

Q.1. (Ex. Q.5 (i)) Study the effect of heat on hydrated $CuSO_4$. Why does this salt look coloured and why does it lose colour upon heating? 09206006

Ans. Copper sulphate pentahydrate ($CuSO_4.5\ H_2O$) is an important salt which is blue in colour. When this salt is heated strongly, its colour changes to white. This physical change involves the following equilibrium.

$$\underset{\text{Hydrated Copper Sulphate}}{CuSO_4 \cdot 5\ H_2O} \xrightleftharpoons{\text{Heat}} \underset{\text{Anhydrous Copper Sulphate}}{CuSO_4} + 5\ H_2O$$

When white anhydrous copper sulphate absorbs moisture from the atmosphere, it will turn blue again.

Presence of Blue Color: The blue color of $CuSO_4.5H_2O$ comes from the water molecules present in its structure. These water molecules interact with the copper ions in the compound, causing it to appear blue.

Absence of Blue Color: The blue color of $CuSO_4.5H_2O$ is lost upon heating because the water molecules within its structure are removed through dehydration. This removal of water causes the crystals to lose their color and appear white.

Q.2. (Ex. Q.5 (ii)) Synthesis of ammonia gas is very important industrially because it is used in the preparation of urea fertilizer. Explain the conditions you will use to get the maximum yield of ammonia. 09206007

Ans. Industrial production of ammonia in Haber Process is a very useful application of the phenomenon of chemical equilibrium. Ammonia gas leads to the formation of an important fertilizer urea. The ability of ammonia gas to be converted into its liquid form easily is used to drive the reaction to completion. In this way, practically 100% conversion of N_2 and H_2 to NH_3 is achieved.

$$N_{2(g)} + 3H_{2(g)} \xrightleftharpoons[\text{Fe}]{\text{400°C, 200 atm}} 2NH_{3(g)}$$

To achieve the maximum field of ammonia gas in the industrial synthesis process, the following condition are typically used:

i. **High Pressure:** Increasing the pressure shifts the equilibrium towards the formation of more ammonia molecules typically, pressures of around 200-300 atm are used to maximize the yield of ammonia.

ii. **Low Temperature:** Lower temperatures favor the exothermic reaction that produce ammonia. However, the reaction is faster at higher temperatures. Temperature of around 400-500^{O}C is often used to balance the yield and reaction rate.

iii. **Catalyst:** The Haber's process is commonly used for ammonia synthesis in which iron catalyst is used to enhance the reaction rate. The catalyst increase the yield of ammonia

without being consumed in the process. In this way, the yield of ammonia gas for production of urea fertilizer can be maximized.

Exercise Short Question

Q.1 How is dynamic equilibrium different from the static equilibrium? 09206008

Ans. Dynamic equilibrium and static equilibrium are different in how they function.

Dynamic Equilibrium

Dynamic equilibrium happens when reactions are still occurring but the rate of the forward reaction equals to the rate of the reverse reaction. This means that the concentrations of reactants and products remain constant, but they are constantly changing and interconverting. Dynamic equilibrium is all about ongoing reactions maintaining balance.
processes.

Static Equilibrium

Static equilibrium, happens when all the forces are balanced, when everything is at rest. There is no movement or change happening in the system. The static equilibrium is a state of complete stillness with no changes taking place and are not interacting or converting into one another. It occurs in physical processes.

Q.2 How the following reversible reaction will be affected if its temperature is increased? 09206009

$$2H_2O_{(l)} \underset{}{\overset{\text{Electricity}}{\rightleftharpoons}} 2H_{2(g)} + O_{2(g)}$$

Ans. If the temperature is increased in the reversible reaction, it will favor the endothermic process. In this case, the reaction is breaking down water into hydrogen and oxygen gas, which requires energy.

By raising the temperature, the system will shift to absorb that extra heat, promoting the formation of more hydrogen and oxygen gases. This means that the concentrations of H_2 and O_2 will increase, while the concentration of H_2O will decrease.

Q.3 How can you get the maximum yield in a reversible reaction? 09206010

Ans. We can get the maximum yield in a reversible reaction, by following factors:

1. **Adding the Reactant**: Increasing the concentration of the reactants will shift the reaction in forward direction, lead to more products.
2. **Temperature**: If the reaction is exothermic (releases heat), lowering the temperature at equilibrium can increase the yield of products. Conversely, if the reaction is endothermic (absorbs heat), increasing the temperature will favor the formation of products.
3. **Pressure**: For reactions involving gases, increasing the pressure will favor the side with fewer moles of gas. This can lead to a higher yield of products if they are on that side.
4. **Removal of Products:** Continuously removing products as they are formed can drive the reaction forward, increasing the yield of products.

Q.4 How can you decrease the time to attain the position of equilibrium in a reversible reaction? 09206011

Ans. Use a Catalyst: Adding the catalyst can decrease the time to attain the position of equilibrium in a reversible reaction, Adding a catalyst provides an alternative pathway for the reaction with a lower activation energy, which speeds up both the forward and reverse reactions without being consumed in the process.

Q.5 What is the effect of increasing pressure on the following reaction? 09206012

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$$

Ans. Increasing the pressure on the reaction $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$ will have an effect based on the number of moles of gas on each side of the equation.

In this reaction, there are 2 moles of gas on the reactant side (1 mole of N_2 and 1 mole of O_2) and 2 moles of gas on the product side (2 moles of NO). Since the number of moles of gas is the same on both sides of the reaction, increasing the pressure will not favor either the forward or reverse reaction.

Therefore, there will be no significant shift in the position of equilibrium due to a change in pressure in this specific reaction.

Practice Exercise Solution

Q.6 Elaborate an example of dynamic equilibrium which exists in this world between the three physical states of water. 09206013

Ans. A simple example of dynamic equilibrium is the balance between ice, water, and water vapor.

In a closed container, ice can melt into water and water can evaporate intovapouron heating. At the same time, water vapour can condense back into liquid water and liquid water can freeze into ice.

When the rates of these processes are equal, the amounts of ice, liquid water, and water vapor remain constant, even though they are constantly changing states.

Q.7 Dinitrogen tetra oxide (N_2O_4) is a colourless gas. It slowly changes to brown coloured nitrogen dioxide (NO_2) at 100°C. Predict how the colour of the mixture will change if N_2O_4 is kept in a sealed flask at 100°C. 09206014

$$\underset{\text{Colourless}}{N_2O_4} \overset{100\,^{\circ}C}{\rightleftharpoons} \underset{\text{Brown}}{2NO_{2(g)}}$$

Ans. When dinitrogen tetra oxide (N_2O_4) is kept in a sealed flask at 100°C, it will start to convert into nitrogen dioxide (NO_2). The reaction is represented as follows:

$$N_2O_{4\,(g)} \overset{100\,^{\circ}C}{\rightleftharpoons} 2NO_{2\,(g)}$$

At this temperature, the equilibrium will shift towards the production of more NO_2 which is brown in color. As a result, the color of the mixture will gradually change from colorless (due to N_2O_4) to a brown due to NO_2 is formed.

If the system reaches equilibrium, the mixture will have a brown color due to the presence of nitrogen dioxide, although the exact shade will depend on the concentrations of both gases.

Q.8 The preparation of ethyl acetate is commercially very important because it is used as thinner in paint industry. 09206015

$$\underset{\text{Ethyl alcohol}}{C_2H_5OH_{(l)}} + \underset{\text{Acetic acid}}{CH_3COOH_{(l)}} \overset{\text{dil.}H_2SO_4}{\rightleftharpoons} \underset{\text{Ethyl acetate}}{CH_3COOC_2H_{5(l)}} + H_2O_{(l)}$$

One way to get the better yield of the product ethyl acetate is to remove water from the reaction mixture as soon as it is formed. Suggest a suitable method to withdraw water from the reaction mixture.

Ans. One effective method to withdraw water from the reaction mixture of ethyl acetate production is by using a drying agent or a dehydrating agent. Common drying agents include substances like magnesium sulphate ($MgSO_4$) or sodium sulphate (Na_2SO_4).

You can add the drying agent to the reaction mixture and it will absorb the water that forms. Once the water is absorbed, you can then filter out the drying agent leaving behind a mixture with a higher concentration of ethyl acetate.

SLO Based Additional Short Questions

Introduction

Q.9 What are irreversible reactions? Give a few characteristics of them. 09206016

Ans. The reactions in which products do not recombine to form reactants are called irreversible reactions.

- They are supposed to be completed.
- They are represented by single arrow (→) between reactants and products.
- It proceeds in only one direction.

$$NaCl_{(aq)} + AgNO_{3(aq)} \longrightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

Q.10 Define reversible reactions. Write their two characteristics. 09206017

Ans. "The reactions in which products react to produce reactants are called reversible reactions."

- These reactions never go to completion.
- They are represented by a double arrow (⇌) between reactants and products.
- Reversible reaction moves in both the forward and backward reaction under the same conditions.

Example:

$$N_{2(g)} + 3H_{2(g)} \underset{Fe}{\overset{400°C,\ 200\ atm}{\rightleftharpoons}} 2NH_{3(g)}$$

Q.11 How reversible reaction goes to completion? 09206018

Ans. A reversible reaction, goes to completion if either one of the products is withdrawn from the reaction mixture or being a gas, it escapes into the atmosphere. **For example,** calcium carbonate is decomposed by heating at a particular temperature.

$$CaCO_{3(S)} \overset{Heat}{\rightleftharpoons} CaO_{(S)} + CO_{2(g)}$$

If the above reaction is carried out in an open container, the carbon dioxide gas will escape into the atmosphere as soon as it is formed and the reaction is forced to go to completion.

Q.12 Give example of reversible reaction. 09206019

Ans.

$$N_{2(g)} + 3H_{2(g)} \underset{Fe}{\overset{400^{o}C,\ 200atm}{\rightleftharpoons}} 2NH_{3(g)}$$

In this reaction, one mole of nitrogen gas reacts with three moles of hydrogen gas under the conditions of reaction in a closed container to give two moles of ammonia gas. After its formation, the ammonia gas decomposes to give the reactants back. The reaction never goes to completion. At any time, all the three species are simultaneously present in the reaction mixture.

Q.13 How does the moisture affect the colouring in cabalt chloride? 09206020

Ans. When cobalt chloride hexahydrate ($CoCl_2.6H_2O$) which is pink in colour is heated, it is converted to anhydrous $CoCl_2$ which is blue in color.

When anhydrous cobalt chloride absorbs less moisture, it is first converted into a dihydrate which is purple in colour.

$$CoCl_2 \cdot 6H_2O \underset{}{\overset{Heat}{\rightleftharpoons}} CoCl_2 + 6H_2O$$

Hydrated Cobalt chloride (Pink) — *Anhydrous Cobalt chloride (Blue)*

Dynamic Equilibrium

Q.14 What is chemical equilibrium? 09206021

Ans. When the rate of the forward reaction takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant; it is called a chemical equilibrium state.

Q.15 What is dynamic equilibrium? 09206022

Ans. At the stage of dynamic equilibrium, the rates of both forward and backward reactions are equal but takes place in opposite direction.

Q.16 Define catalytic methanation. 09206023

Ans. Vast deposits of coal are available in Thar, Sindh. This coal can be used to generate electricity. When coal is made to react with steam then CO and H_2 are produced. These products then react by a reversible reaction called catalytic methanation to yield methane.

$$C_{(s)} + H_2O_{(g)} \longrightarrow CO_{(g)} + H_{2(g)}$$

water gas

$$CO_{(g)} + 3H_{2(g)} \overset{\text{Catalyst}}{\rightleftharpoons} CH_{4(g)} + H_2O_{(g)}$$

Q.17 Write down the conditions for equilibrium. 09206024

Ans. The following physical conditions for equilibrium is:

i. The concentration of reactant or product remains unchanged.
ii. The temperature of the system remains constant.
iii. The pressure or volume of the system remains constant.
iv. Reaction must happen in closed system.

Changing the physical Conditions of a Chemical Reaction

Q.18 Give the example of equilibrium from daily life. 09206025

Ans. When fizzy drinks are made, CO_2 is dissolved in the liquid drink under pressure and sealed. When you remove lid of the bottle, bubbles of CO_2 of suddenly appear. When you put the lid back on the bottle, the bubbles stop. This is due to the following equilibrium.

$$CO_{2(g)} \rightleftharpoons CO_{2(aq)}$$

The forward reaction happens during manufacturing and the reverse reaction happens on opening of bottle.

Q.19 What will be the effect of catalyst on equilibrium state? 09206026

Ans. A catalyst increases both the rates of forward and back reactions of a reversible reaction. So if a reversible reaction is carried out in the presence of a catalyst it will decrease the time taken by the reaction to attain the state of equilibrium.

Q.20 How a reversible chemical system can be disturbed? 09206027

Ans. A reversible chemical system may be distributed in the following possible ways.

1. Adding or withdrawing one or more of the reacting species
2. Adding or withdrawing one or more of the product species
3. Changing the temperature of the reaction
4. Effect of the presence of a catalyst on a reversible reaction
5. Changing the pressure of the reaction if it involves reactants or the products in the gaseous state.

Effect of Changing the Temperature on the State of Equilibrium

Q.21 What will be the effect on equilibrium state if we change the physical conditions? 09206028

Ans. Consider the following reversible reaction at equilibrium.

$$N_{2(g)} + 3H_{2(g)} \underset{\text{Fe}}{\overset{\text{400°C, 200 atm}}{\rightleftharpoons}} 2NH_{3(g)}$$

The concentrations of all the participating chemicals will be constant at the state of equilibrium. At this stage if we add more N_2 gas in the mixture, its concentration will increase and the reaction will no longer maintain its state of equilibrium. To restore the equilibrium state again, nitrogen will

react with hydrogen to produce more ammonia. This change will go on until a new state of equilibrium is reached at which the concentration of all the species will again become constant. These new concentrations will, however, be different from the concentrations of the earlier equilibrium state.

Now let us disturb the equilibrium again by withdrawing some of the ammonia gas formed. As a result, its concentration will decrease. To restore the equilibrium state, more nitrogen and hydrogen will react to produce ammonia. When the state of equilibrium is reached again, the concentrations of all the species shall again become constant.

Q.22 What is the effect of temperature on the state of equilibrium? 09206029

Ans. The formation of ammonia is exothermic in the forward direction and hence this reaction will be endothermic in the reverse direction.

$$N_{2(g)} + 3H_{2(g)} \xrightleftharpoons[Fe]{400°C,\ 200\ atm} 2NH_{3(g)}$$

$$\Delta H = -92.4 kJ/mole$$

If this reaction is at equilibrium and its temperature is increased, the state of the equilibrium will be disturbed again. The ΔH of this reaction is negative. This means the total energy of the system containing N_2 and H_2 is higher than that of ammonia. The increase in temperature of this reaction at equilibrium will push the reaction in the backward direction i.e. the reactants side. Decreasing the temperature will drive the equilibrium to the forward direction.

Q.23 What will be the effect of pressure on equilibrium state? 09206030

Ans. Change of pressure will disturb the equilibrium state of only those gaseous reactions in which the number of moles of the reacting gases will be different from the number of moles of the gases being produced. Since the formation of ammonia gas meets such a condition, the state of its equilibrium will be disturbed by changing the pressure exerted on the reaction mixture.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

1 mole + 3 moles = 4 moles ⟶ 2 moles

In this reaction, 4 moles of reacting gases are producing two moles of product gas. 4 moles of gases at say S.T.P will occupy 4 x 22.414 = 89.656 dm^3 of volume. 2 moles of NH_3 will occupy 2 x 22.414 = 44.828 dm^3 of volume. If this reaction is at equilibrium and the pressure is increased, the equilibrium will be disturbed. To restore this, the reaction will move to that side in which the number of moles are less i.e. forward direction. The formation of ammonia gas is thus favoured at high pressure.

Constructed Response Question

Q.1. (Ex. Q. 3 (i)) Why are some reactions irreversible while others are reversible? 09206031

Ans. Some reactions are irreversible while others are reversible due to following reasons:

- In many irreversible reactions, the products formed are more stable than the reactants. For example, combustion reactions often produce gases and heat, making it energetically unfavorable for the products to return to the original reactants.
- Certain conditions, such as temperature and pressure, can influence whether a reaction is reversible. For instance,

reactions that occur at high temperatures or pressures may favor the formation of products, making them less likely to return back to reactants.

- If a reaction produces a gas or a precipitate, this can drive the reaction to completion. For example, if a gas is produced, it can escape from the reaction mixture, preventing the reverse reaction from occurring.
- In reversible reactions, the equilibrium can be established where both reactants and products coexist. In contrast, irreversible reactions tend to proceed to completion.
- The speed of the forward and reverse reactions can also play a role. If the reverse reaction has very high activation energy, it may not occur under normal conditions, making the process effectively irreversible.

Q.2. (Ex. Q. 3 (ii)) Why are combustion reactions generally irreversible?
09206032

Ans. Combustion reactions are generally irreversible for several reasons:

- Combustion reactions release a significant amount of energy in the form of heat and light. This energy release indicates that the products formed (like carbon dioxide and water) are more stable than the reactants (like hydrocarbons and oxygen).
- Many combustion reactions produce gaseous products. For example, burning hydrocarbons typically produces carbon dioxide and water vapor. These gases can escape into the atmosphere, which prevents the reverse reaction from occurring since the products are no longer available in the reaction mixture.

Combustion reactions usually proceed to completion, meaning that all the reactants are converted into products.

Overall, the formation of gaseous products and the tendency to go to completion makes combustion reactions effectively irreversible.

Q.3. (Ex. Q. 3 (iii)) Can you make an irreversible reaction reversible and vice versa?
09206033

Ans. You can alter the conditions of a reaction to make a reversible reaction irreversible or an irreversible reaction reversible, but this often involves significant changes to the system.

- **Making a Reversible Reaction Irreversible:** You can achieve this by removing one of the products from the reaction mixture which drives the reaction to completion. For example, in the synthesis of ammonia.

$$N_{2(g)} + 3H_{2(g)} \underset{\text{Fe}}{\overset{400°C,\ 200\ atm}{\rightleftharpoons}} 2NH_{3(g)}$$

If you continuously remove ammonia as it forms, the reaction will shift to the right to produce more ammonia, making it effectively irreversible under those conditions.

- **Making an Irreversible Reaction Reversible:** This is more challenging but can be done under specific conditions. For example, in the combustion of hydrocarbons, if you were to introduce a process that captures carbon dioxide and water vapor and converts them back to hydrocarbons (like using a chemical reaction in a closed system), you could theoretically create a reversible cycle. However, this typically requires significant energy and specific catalysts.

Q.4. (Ex. Q. 3 (iv)) How do you know if a reaction is reversible or irreversible? 09206034

Ans. To determine if a reaction is reversible or irreversible, you can consider several factors:

- Many reactions are inherently reversible, such as those involving weak acids and bases or equilibrium reactions. In contrast, reactions like combustion or certain oxidation-reduction processes are typically irreversible.
- If a reaction releases a significant amount of energy (exothermic), it is more likely to be irreversible. Reactions that absorb energy (endothermic) may be reversible, especially if they can reach an equilibrium state.
- If a reaction produces gases or involves a change in the number of moles of gas, it may favor reversibility. For example, if a gas is produced and escapes, the reaction may not easily reverse.
- The conditions under which a reaction occurs (temperature, pressure, concentration) can influence its reversibility. Changing these conditions can shift the equilibrium and affect whether the reaction can be reversed.

Q.5. (Ex. Q. 3 (v)) Do the phase changes in water (solid to liquid, liquid to vapour) reversible or irreversible? 09206035

Ans. The phase changes in water, such as solid to liquid (melting) and liquid to vapor (evaporation), are reversible processes.

- **Melting (Solid to Liquid):** When ice is heated, it absorbs energy and melts into liquid water. This process can be reversed by cooling the liquid water, which will freeze back into ice.
- **Evaporation (Liquid to Vapor):** When liquid water is heated, it turns into water vapor (gas). This process is also reversible; when the vapor cools, it can condense back into liquid water.

Both of these phase changes can occur in a closed system, where the water can transition between solid, liquid, and gas states without any loss of mass.

Multiple Choice Questions (Exercise)

1. **What will happen if the rates of forward and reverse reactions are very high?** 09206036
   (a) The equilibrium point will reach very soon.
   (b) The equilibrium point will reach very late.
   (c) The reaction will not attain the state of dynamic equilibrium.
   (d) The reaction will be practically irreversible.
2. **Predict which components of the atmosphere react in the presence of lightening.** 09206037
   (a) N_2 and H_2O
   (b) O_2 and H_2O
   (c) CO_2 and O_2
   (d) N_2 and O_2
3. **An inorganic chemist places one mole of PCl_5 in a container A and one mole of each Cl_2 and PCl_3 in container B. Both the containers were sealed and heated to the same temperature to reach the state of equilibrium. Guess about the composition of mixtures in both the containers.** 09206038
   (a) Both the containers will have the same composition of mixtures.
   (b) Container A will have more concentration of PCl_3 than B.
   (c) Container A will have less concentration of PCl_3 than B.
   (d) Both the containers will have zero concentration of its reactants.

4. **CaO or lime is used extensively in steel, glass and paper industries. It is produced in an exothermic reversible reaction by the decomposition of lime ($CaCO_3$). Choose the conditions to produce maximum amount of lime.** 09206039
(a) Heating at high temperature in a closed vessel
(b) Heating at high temperature in an open vessel
(c) Cooling it in a closed vessel
(d) Cooling it in an open vessel

5. **What condition should be met for the reversible reaction to achieve the state of equilibrium?** 09206040
(a) All the reactants should be converted into the products.
(b) 50% of the reactants should be converted into products.
(c) The concentration of all the reactants and the product should become constant.
(d) One of the products should be removed from the reaction mixture.

6. **Why the gas starts coming out when you open a can of fizzy drink?** 09206041
(a) Because the solubility of the gas increases
(b) Because the gas is insoluble in water
(c) Because the gas is dissolved under pressure hence it comes out when pressure is decreased
(d) Because the solubility of the gas decreases at high pressure

7. **The following reaction is performed in an open vessel.** 09206042

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

How the equilibrium will be affected if you increase the pressure?
(a) The forward reaction will be favoured
(b) The backward reaction will be favoured
(c) No effect on backward reaction
(d) No effect on forward or backward reaction

8. **When a reaction will become a reversible one?** 09206043
(a) If the activation energy of the forward reaction is comparable to that of backward reaction
(b) If the activation energy of the forward reaction is higher than that of backward reaction
(c) If the activation energy of the forward reaction is lower than that of backward reaction
(d) If the enthalpy change of both the reactions is zero.

9. **Is reversible reaction useful for preparing compounds on large scale?** 09206044
(a) No
(b) Yes
(c) They are useful only when equilibrium lies far to the right side
(d) They are useful only when equilibrium lies far to the left side

10. **What will happen to the concentrations of the products if a reversible reaction at equilibrium is not disturbed?** 09206045
(a) They will remain constant
(b) They will keep on increasing
(c) They will keep on decreasing
(d) They will remain constant for some time and then start decreasing

SLO Based Additional MCQ's

Introduction

11. **In an irreversible reaction equilibrium is:** 09206046
(a) established quickly
(b) established slowly
(c) never established
(d) established when reaction stops.

12. **The characteristics of reversible reactions are the following except:** 09206047
(a) products never recombine to form reactants
(b) they never complete
(c) they proceed in both ways
(d) they have a double arrow between reactants and products

13. **A reverse reaction is one that:** 09206048
(a) proceeds from left to right
(b) in which reactants react to form products
(c) slows down gradually
(d) speeds up gradually

14. **The reactions in which the products do not recombine to form reactants are called:** 09206049
(a) irreversible reactions
(b) reversible reactions
(c) decomposition reactions
(d) addition reactions

15. **The reactions in which the products can recombine to form reactants are called:** 09206050
(a) irreversible reactions
(b) reversible reactions
(c) decomposition reactions
(d) addition reactions

16. **Which type of reactions speed up gradually?** 09206051
(a) irreversible reactions
(b) reverse reactions
(c) forward reactions
(d) decomposition reactions

17. **Such reactions which continue in both directions are called:** 09206055
(a) Irreversible
(b) Reversible
(c) Non-reactive
(d) Dynamic

18. **In a chemical reaction, the substances that combine are called:** 09206053
(a) reactants (b) products
(c) masses (d) materials

19. **The forward reaction takes place from:** 09206054
(a) right to left
(b)left to right
(c) Both a & b
(d) None of the above

20. **Equilibrium state is achievable in:** 09206055
(a) Closed system
(b) Open system
(c) Both a & b
(d) None of these

21. **A complete reaction is in which:** 09206056
(a) All the reactants convert into products
(b) All the reactants do not convert into products
(c) Half reactants convert into products
(d) Only 10% reactatns convert into products

22. **In the beginning the rate of reverse reaction is:** 09206057
(a) moderate
(b) Negligible
(c) slow
(d) very fast

23. **The new substance formed in a chemical reaction is:** 09206058
(a) reactant (b) product
(c) forward (d) reverse

24. **The colour of anhydrous copper (II) sulphate solid is:** 09206059
(a) blue (b) pink
(c) black (d) white

25. **The colour of hydrated copper (II) sulphate solid is:** 09206060
(a) blue (b) pink
(c) black (d) white

26. **The colour of anhydrous cobalt (II) chloride solid is:** 09206061
(a) blue (b) pink
(c) black (d) white

27. **The colour of hydrated cobalt (II) chloride solid is:** 09206062
(a) blue (b) pink
(c) black (d) white

Dynamic Equilibrium

28. **Which of the following does not happen, when a system is at equilibrium state?** 09206063
(a) forward and reverse reactions stop
(b) forward and reverse rates become equal
(c) concentration of reactants and products stop changing
(d) reaction continues to occur in both the directions

29. **Which is true about the equilibrium state?** 09206064
(a) The forward reaction stops
(b) The reverse reaction stops
(c) Both forward and reverse reactions stop
(d) Both forward and reverse reactions continue at the same rate

30. **When a system is at equilibrium state:** 09206065
(a) the concentration of reactants and product becomes equal
(b) the opposing reactions (forward the reverse) stop
(c) the rate of the reverse reaction becomes very low
(d) the rate of the forward and reverse reactions become equal

31. **When the rate of the forward reaction takes place at the rate of reverse reaction the composition of the reaction mixture remains constant, it is called:** 09206066
(a) chemical equilibrium
(b) static equilibrium
(c) both (a) & (b)
(d) none of the above

32. **Which type of reactions do not go to completion?** 09206067
(a) irreversible reactions
(b) reversible reactions
(c) addition reactions
(d) decomposition reactions

33. **For the following reaction, equilibrium mixture will contain:** 09206068
$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)} \quad K_c = 0.211$
(a) Only N_2O_4
(b) Only NO_2
(c) NO_2 and N_2O_4 in reasonable amount
(d) NO_2 in large amount

Changing the physical Conditions of a Chemical Reaction

34. **Nitrogen and hydrogen were reacted together to make ammonia:** 09206069
$N_2 + 3H_2 \rightleftharpoons 2NH_3 \quad K_c = 2.86 mol^{-2} dm^6$
What will be present in the equilibrium mixture?
(a) NH_3 only
(b) N_2, H_2 and NH_3
(c) N_2 and H_2 only
(d) H_2 only

35. **Concentration of reactants and products at equilibrium remains unchanged if:** 09206070
(a) concentration of any reactant or product is not changed.
(b) temperature of the reaction is not changed
(c) pressure or volume of the system is not changed
(d) all of the above are observed

36. **At what temperature, rate of ammonia formation & decomposition is the highest;** 09206071

(a) 300 °C
(b) 400 °C
(c) 500 °C
(d) 600 °C

37. **Industrially, ammonia is produced by which process?** 09206072

(a) Haber process
(b) Solvay process
(c) hydrogenation
(d) Halogenation

Effect of Changing the Temperature on the State of Equilibrium

38. **Formation of ammonia from Nitrogen and hydrogen is an:** 09206073

(a) Exothermic Reaction
(b) Endothermic Reaction
(c) Both A & B
(d) No heat change

39. **How much heat absorbed when NH_3 decomposed into N_2 and H_2?** 09206074

(a) 90.4 kJ/mol
(b) 94.2 KJ/mol
(c) 92.4 KJ/mol
(d) 95.2 KJ/mol

40. **Which compound is used a thinner in paint industry?** 09206075

(a) C_2H_5OH
(b) CH_3COOH
(c) $CH_3COOC_2H_5$
(d) H_2O

Answer Key

1	a	2	d	3	a	4	b	5	c
6	c	7	d	8	a	9	c	10	a
11	c	12	a	13	d	14	a	15	b
16	b	17	b	18	a	19	b	20	a
21	a	22	b	23	b	24	d	25	a
26	a	27	b	28	a	29	d	30	d
31	a	32	b	33	c	34	b	35	d
36	b	37	a	38	b	39	c	40	c