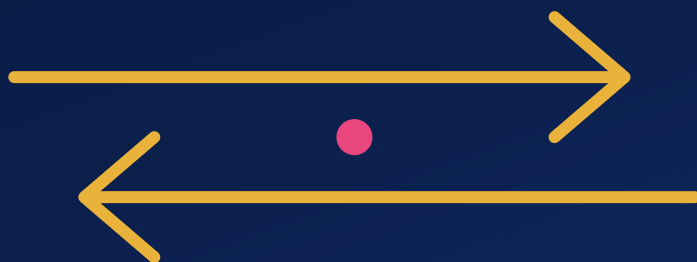


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CLASS 9 • CHEMISTRY

CHAPTER 6

Equilibria



Exercise Solutions

Complete step-by-step answers with explanations

10 MCQs

5 Short Answers

5 Constructed

5 Descriptive

2 Investigate

Tick ✓ • Learn • Excel

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How to use this guide: Read each question, think of your own answer first, then check it here. In every MCQ the correct option is

highlighted & ticked ✓

and the reason is explained right below it.

1

Multiple Choice Questions

Tick (✓) the correct answer

i What will happen if the rates of forward and reverse reactions are very high?

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.

Explanation — Correct Answer: (a)

The rate of a reaction determines how fast it proceeds. If both the forward and reverse reactions are naturally very fast, they will rapidly consume reactants and form products. Equilibrium is achieved when the rate of the forward reaction equals the rate of the reverse reaction. Because both rates are high, this balance will be struck very quickly, meaning the system reaches equilibrium sooner rather than later.

Question 1 · Multiple Choice Questions (continued)

ii Predict which components of the atmosphere react in the presence of lightning.

a N_2 and H_2O

b O_2 and H_2O

c CO_2 and O_2

d N_2 and O_2



Explanation — Correct Answer: (d)

Lightning provides a massive amount of electrical energy. This energy is enough to break the very strong triple covalent bond in nitrogen (N_2) and the double bond in oxygen (O_2). Once broken, these highly reactive atoms combine to form nitrogen oxides (NO and NO_2). These oxides then dissolve in atmospheric moisture to form nitric acid, which falls to earth as a natural fertilizer.

Question 1 · Multiple Choice Questions (continued)

iii 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.

a Both the containers will have the same composition of mixtures. ✓

b Container A will have more concentration of PCl_5 than B.

c Container A will have less concentration of PCl_5 than B.

d Both the containers will have zero concentration of its reactants.

Explanation — Correct Answer: (a)

The reaction is $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$. Equilibrium is a dynamic state that depends only on the final temperature, not on the starting amounts (as long as the system is closed). At the same temperature, the equilibrium constant (K_c) is the same for both containers. Starting with 1 mole of PCl_5 (Container A) or 1 mole each of PCl_3 and Cl_2 (Container B) will result in the exact same equilibrium concentrations of all three gases.

Question 1 · Multiple Choice Questions (continued)

iv 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.

- ☐ 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

Explanation — Correct Answer: (b)

The decomposition of limestone is: $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$. This is an endothermic reaction (requires heat) and produces a gas.

According to Le Chatelier's principle, increasing temperature drives the reaction in the endothermic (forward) direction. Furthermore, removing the CO_2 gas as it forms (by using an open vessel) constantly disturbs the equilibrium, forcing the reaction to continuously shift right to replace the lost CO_2 , thus maximizing the yield of lime (CaO).

Note: the word "exothermic" in the question stem is a printing slip — this decomposition is endothermic, as explained above.

Question 1 · Multiple Choice Questions (continued)

v

What condition should be met for the reversible reaction to achieve the state of equilibrium?

- a All the reactants should be converted into the products.
- b 50% of the reactants should be converted into products.
- c The concentrations of all the reactants and the products should become constant.** ✓
- d One of the products should be removed from the reaction mixture.

Explanation — Correct Answer: (c)

Dynamic equilibrium is reached when the rate of the forward reaction equals the rate of the reverse reaction. At this point, there is no net change in the system — reactants are turning into products at the exact same rate that products are turning back into reactants. Because of this balance, the macroscopic concentrations of all reactants and products remain constant over time. Note that (a) describes a completion reaction, not equilibrium.

Question 1 · Multiple Choice Questions (continued)

vi Why the gas starts coming out when you open a can of fizzy drink?

- 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

Explanation — Correct Answer: (c)

Carbonated drinks are bottled under high pressure of carbon dioxide (CO_2). According to Henry's Law, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid. When the can is opened, the pressure is suddenly released (decreased to atmospheric pressure). The solubility of the CO_2 drops dramatically, causing the excess dissolved gas to rapidly escape as bubbles.

Question 1 · Multiple Choice Questions (continued)

vii The following reaction is performed in a closed vessel. $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$. 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

Explanation — Correct Answer: (b)

Le Chatelier's principle states that if a system at equilibrium is subjected to a change in pressure, the system will adjust to counteract that change. Increasing pressure favors the side with fewer moles of gas. On the left side (reactants), there are 0 moles of gas (CaCO_3 is solid). On the right side (products), there is 1 mole of gas (CO_2). Therefore, increasing the pressure forces the equilibrium to shift to the left (backward reaction) to reduce the pressure.

Question 1 · Multiple Choice Questions (continued)

viii When a reaction will become a reversible one?

- 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.

Explanation — Correct Answer: (a)

For a reaction to be reversible, the products must be able to react to reform the reactants. If the activation energy of the forward reaction is comparable to the reverse reaction, it means the energy barrier for both directions is similar. As soon as products are formed, they have enough energy to overcome the barrier and revert to reactants, allowing both reactions to occur simultaneously and establish an equilibrium.

Question 1 · Multiple Choice Questions (continued)

ix Is reversible reaction useful for preparing compounds on large scale?

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

Explanation — Correct Answer: (c)

For a reaction to be economically viable on an industrial scale, the yield of the desired product must be high. If the equilibrium lies far to the left, very little product is formed, making the process wasteful and expensive. If the equilibrium lies far to the right (or if conditions are manipulated using Le Chatelier's principle to push it right), a high yield is obtained, making it useful for large-scale preparation.

Question 1 · Multiple Choice Questions (continued)

x What will happen to the concentrations of the products if a reversible reaction at equilibrium is not disturbed?

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

Explanation — Correct Answer: (a)

The defining characteristic of a system at dynamic equilibrium is that the macroscopic properties (like color, pressure, and concentration) remain constant over time. As long as the system is not disturbed by changes in temperature, pressure, or concentration, the rate of product formation equals the rate of product consumption, resulting in a constant concentration of products.

2

Short Answer Questions

Questions for short answers

i

How is dynamic equilibrium different from the static equilibrium?**Answer**

Static equilibrium implies a state of absolute rest where no movement or change occurs (e.g., a book resting on a table). Dynamic equilibrium, on the other hand, occurs in reversible chemical reactions where the system is highly active at the molecular level. The forward and reverse reactions are still occurring, but at the exact same rate, resulting in no net observable change in the concentrations of reactants and products.

ii

How the following reversible reaction will be affected if its temperature is increased?**Answer**

The decomposition of water into hydrogen and oxygen is an endothermic reaction (it requires energy/electricity to break the bonds). According to Le Chatelier's principle, if the temperature of an endothermic reaction is increased, the system will try to absorb the excess heat by favoring the forward reaction. Therefore, the equilibrium will shift to the right, producing more H_2 and O_2 gas.

Question 2 · Short Answer Questions (continued)

iii How can you get the maximum yield in a reversible reaction?

Answer

To get the maximum yield, you must apply Le Chatelier's principle to drive the equilibrium to the right:

1. Adjust the temperature (increase for endothermic, decrease for exothermic).
2. Adjust the pressure (increase if forward reaction produces fewer gas moles, decrease if more).
3. Continuously remove the products as they are formed.
4. Add excess reactants to push the reaction forward.

iv How can you decrease the time to attain the position of equilibrium in a reversible reaction?

Answer

The time to reach equilibrium can be decreased by adding a **catalyst**. A catalyst provides an alternative pathway with lower activation energy for both the forward and reverse reactions, allowing the system to reach its equilibrium state much faster without altering the final equilibrium position. Increasing temperature also speeds up the rate but changes the equilibrium position, so a catalyst is the primary method.

Question 2 · Short Answer Questions (continued)

v

What is the effect of increasing pressure on the following reaction at equilibrium?

**Answer**

According to Le Chatelier's principle, increasing pressure shifts the equilibrium towards the side with fewer moles of gas. In this reaction, there are 2 moles of gas on the reactant side (1 N₂ + 1 O₂) and 2 moles of gas on the product side (2 NO). Since the number of gas moles is equal on both sides ($\Delta n = 0$), increasing the pressure will have **no effect** on the position of equilibrium.

3

Constructed Response Questions

Think, reason and respond

i

Why are some reactions irreversible while others are reversible?**Answer**

Some reactions are irreversible because they go to completion. This usually happens when:

1. a gas escapes into the atmosphere,
2. a precipitate forms and settles out,
3. a large amount of heat is released (highly exothermic), or
4. the activation energy for the reverse reaction is extremely high.

Reversible reactions occur in closed systems where products can collide and react to reform reactants because conditions allow both directions to proceed.

ii

Why are combustion reactions generally irreversible?**Answer**

Combustion reactions are highly exothermic and release a large amount of energy (heat and light). Once the fuel burns, the products (like CO_2 and H_2O vapor) are released into the open atmosphere as gases. Because these gases diffuse away and cannot recombine to form the original fuel under normal conditions, the reverse reaction does not occur, making combustion irreversible.

Question 3 · Constructed Response Questions (continued)

iii Can you make an irreversible reaction reversible and vice versa?

Answer

Yes, by changing the conditions. An “irreversible” reaction can often be made reversible by conducting it in a closed system. For example, if you trap the gases produced in a combustion reaction and prevent them from escaping, the reverse reaction can theoretically occur. Conversely, a reversible reaction can be forced to go to completion (behaving irreversibly) by continuously removing one of the products (like allowing a gas to escape in an open vessel).

iv How do you know if a reaction is reversible or irreversible?

Answer

A **reversible reaction** is indicated by a double arrow ($\rightleftharpoons$) in the chemical equation. It occurs in a closed system, does not go to completion, and reaches a state of dynamic equilibrium where both reactants and products are present.

An **irreversible reaction** is indicated by a single arrow ($\rightarrow$), proceeds in only one direction to completion, and is often characterized by escaping gases, precipitates, or massive energy changes.

Question 3 · Constructed Response Questions (continued)

v

Do the phase changes in water (solid to liquid, liquid to vapour) reversible or irreversible?

Answer

Phase changes in water are **reversible** physical changes. Ice melts to form liquid water, and liquid water can freeze back into ice. Liquid water can evaporate to form water vapor, and water vapor can condense back into liquid water. These changes can be reversed by altering the temperature or pressure conditions.

4

Descriptive Questions

Explain in detail

i

How can you drive the reversible reaction at equilibrium (a) in the forward direction (b) in the backward direction?

Answer

(a) Forward direction: By adding more reactants, removing products as they form, increasing the temperature (if the forward reaction is endothermic), or increasing the pressure (if the forward reaction produces fewer moles of gas).

(b) Backward direction: By adding more products, removing reactants, decreasing the temperature (if the forward reaction is endothermic), increasing the temperature (if the forward reaction is exothermic), or decreasing the pressure (if the forward reaction produces fewer moles of gas).

ii

Explain how the rates of forward and backward reactions change when the system approaches equilibrium.

Answer

Initially, when reactants are mixed, the concentration of reactants is high, so the forward reaction rate is fast. The reverse reaction rate is zero because no products exist yet. As the reaction proceeds, reactants are converted to products, so the concentration of reactants decreases, slowing down the forward reaction. Meanwhile, products accumulate, increasing the rate of the reverse reaction. Eventually, the two rates become equal, and the system reaches equilibrium.

Question 4 · Descriptive Questions (continued)

iii Describe the effect of a catalyst on the reversible reaction.

Answer

A catalyst speeds up both the forward and the backward reactions equally by lowering the activation energy of the reaction. It helps the system reach the state of equilibrium faster. However, a catalyst does **not** affect the position of equilibrium or the final yield of the products; it only shortens the time required to reach that state.

iv How can a reversible reaction be forced to go to completion?

Answer

A reversible reaction can be forced to go to completion by continuously removing one or more of the products from the reaction mixture as they are formed. For example, in an open vessel, if a product is a gas, it escapes into the atmosphere. This constant removal prevents the reverse reaction from occurring, so the forward reaction continues until all reactants are consumed.

v How does change in temperature affect the reaction at equilibrium?

Answer

According to Le Chatelier's principle, **increasing** the temperature of a system at equilibrium favors the endothermic reaction (the one that absorbs heat) to counteract the temperature rise. **Decreasing** the temperature favors the exothermic reaction (the one that releases heat). Thus, temperature changes shift the equilibrium position depending on whether the forward or reverse reaction is endothermic or exothermic.

5

Investigate

Apply your understanding to real chemistry

i

Study the effect of heat on hydrated copper sulphate. Why does this salt look coloured and why does it lose colour upon heating?

Answer

Hydrated copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) has a **blue** color because of the water molecules (water of crystallization) that are chemically bonded to the copper(II) ions. These water molecules act as ligands, causing the d-orbitals of the copper ion to split, allowing it to absorb red light and reflect blue light.

Upon heating, the salt loses its water of crystallization to form anhydrous copper sulphate (CuSO_4), which is **white/grey**.



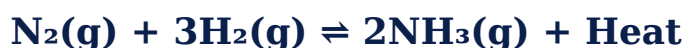
This is a reversible reaction; adding water back to the white powder restores the blue color.

Question 5 · Investigate (continued)

- 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.

Answer

The synthesis of ammonia is done via the **Haber Process**:



To get the maximum yield, the following conditions are applied based on Le Chatelier's principle:

1. **Pressure:** High pressure (around 200 atmospheres) is used. The forward reaction produces 2 moles of gas from 4 moles of gas. High pressure favors the side with fewer gas molecules (the forward reaction).
2. **Temperature:** A moderate temperature (around 450–500°C) is used. The forward reaction is exothermic. Lower temperatures would yield more ammonia, but the reaction rate would be too slow. A compromise temperature is used to ensure a reasonable yield and a practical rate.
3. **Concentration:** Ammonia is continuously removed by liquefaction as it forms. Removing the product shifts the equilibrium to the right to produce more ammonia.
4. **Catalyst:** An iron catalyst with promoters is used to speed up the attainment of equilibrium.

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Exercise Complete!

Chapter 6 • Equilibria • Class 9 Chemistry

Revise Le Chatelier's principle, the effect of catalysts and the Haber process once more — and you are ready for anything on equilibrium.

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