9th Class Chemistry Chapter # 6 Exercise Solutions – Punjab Board

Equilibria

Multiple Choice Questions (MCQs)

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

Options:

- (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.

Correct Answer: (a) The equilibrium point will reach very soon.

Explanation:
If **both forward and reverse reactions are fast**, equilibrium will be established **quickly**. The system will still reach **dynamic equilibrium**, just **faster**.

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

Options:

- (a) N_2 and H_2O
- (b) O_2 and H_2O
- (c) CO_2 and O_2
- (d) N_2 and O_2

Correct Answer: (d) N_2 and O_2

Explanation:
Nitrogen and oxygen in the air react during lightning because high energy provides enough activation energy to form **nitric oxide (NO)**:
$N_2 + O_2 \rightarrow 2NO$

(iii) An inorganic chemist places one mole of Cl_2 and one mole of PCl_5 in container A and one mole each of Cl_2 and PCl_3 in container B… Guess the composition.

Options:

- (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.

Correct Answer: (a) Both the containers will have the same composition of mixtures.

Explanation:
In a **reversible reaction**, regardless of starting point, the system reaches the **same equilibrium composition** (at same temperature and pressure).
$PCl_5 \rightleftharpoons PCl_3 + Cl_2$ — no matter where you start, the **equilibrium position** is the same.

(iv) CaO is produced from $CaCO_3$ in an exothermic reversible reaction… Choose condition to produce max CaO.

Options:

- (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

Correct Answer: (b) Heating at high temperature in an open vessel

Explanation:

- The reaction: **$CaCO_3 \rightleftharpoons CaO + CO_2$** is **endothermic in forward direction** (although exothermic in total energy release from formation of CaO).
- **High temperature** favors decomposition.

- **Open vessel** allows **CO_2 to escape**, shifting equilibrium forward (Le Chatelier's Principle).
  → So, **more CaO is formed**.

(v) What condition should be met for the reversible reaction to achieve equilibrium?

Options:

- (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.

Correct Answer: (c) The concentrations of all the reactants and the products should become constant.

Explanation:
At **dynamic equilibrium**, the **rate of forward reaction = rate of reverse reaction**, so the **concentration of reactants and products remains constant**, even though reactions are still occurring.

(vi) Why does gas start coming out when you open a can of fizzy drink?

Options:

- (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

Correct Answer: (c)

Explanation:
In fizzy drinks, **CO_2 is dissolved under high pressure**. When the can is opened, **pressure drops**, so the solubility of gas decreases and CO_2 **escapes as bubbles**.

(vii) The following reaction is performed in a closed vessel:

CaO (solid) + CO_2 (gas) ⇌ $CaCO_3$ (solid)
How is equilibrium affected if pressure is increased?

Options:

- (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

Correct Answer: (a)

Explanation:
Since **CO_2 is a gas** and other substances are solids, **increasing pressure favors the side with fewer gas molecules**, i.e., the **forward reaction** (formation of $CaCO_3$).

(viii) When will a reaction become reversible?

Options:

- (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

Correct Answer: (a)

Explanation:
A reaction is **reversible** if both forward and backward reactions can occur. This is possible when their **activation energies are comparable**, allowing both directions to proceed under the same conditions.

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

Options:

- (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

Correct Answer: (c)

Explanation:
A **reversible reaction** is useful **only if equilibrium lies far to the right**, meaning **products are favored**. That way, **maximum yield** of the desired product can be obtained.

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

Options:

- (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

Correct Answer: (a)

Explanation:
At **equilibrium**, the **rate of forward and reverse reactions are equal**, so the **concentrations of products and reactants remain constant** (but not necessarily equal in value).

Short Answer Questions

i. How is dynamic equilibrium different from static equilibrium?

Answer:

- **Dynamic equilibrium** occurs in **reversible reactions**, where the **forward and reverse reactions continue to occur**, but at **equal rates**, so the **concentrations of reactants and products remain constant**.

    Reaction is active, but balanced.

- **Static equilibrium** occurs in systems where **no changes happen over time**, and there is **no movement or reaction** taking place at all.

No chemical activity continues.

Dynamic = Moving but balanced

Static = No movement, no change

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ii. How will the following reversible reaction be affected if temperature is increased?

2H2O(liquid)→Electricity2H2(gas)+O2(gas)

Answer:
This reaction is **endothermic** (requires energy/electricity to break water into hydrogen and oxygen).

According to **Le Chatelier's Principle**, **increasing temperature** favors the **endothermic direction** (forward reaction).

So, increasing temperature will **increase the production of H_2 and O_2 gases**.

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

Answer:
To get **maximum yield** in a reversible reaction, you must apply **Le Chatelier's Principle**:

- **Change conditions** (temperature, pressure, concentration) to favor the **forward reaction**.
- **Remove products** continuously to shift the equilibrium forward.
- Use **catalysts** to reach equilibrium faster (though they don't affect yield directly).

The ideal is to **shift equilibrium toward the product side**.

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

Answer:
To reduce the time to reach equilibrium:

- **Add a catalyst** — it lowers activation energy for both forward and reverse reactions.
- **Increase temperature** (if applicable) — raises kinetic energy, increasing reaction speed.
- **Increase concentration** of reactants — faster collision rate.
- **Increase pressure** (for gases) — especially if fewer gas molecules are on one side.

These changes **speed up both reactions**, making equilibrium reach **more quickly**.

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

N2+O2\⇌2NO

Answer:

- On the **left side**: 1 mol N_2 + 1 mol O_2 = **2 moles of gas**
- On the **right side**: 2 mol NO = **2 moles of gas**

Since the **number of gas molecules is equal on both sides**, increasing pressure has **no effect** on the position of equilibrium.

Equilibrium remains unchanged.

Constructed Response Questions

i. Why are some reactions irreversible while others are reversible?

Detailed Answer:
Chemical reactions are classified as **irreversible or reversible** based on whether the **products can change back into reactants** under the same conditions.

- **Irreversible Reactions:**
In these reactions, the **products are so stable** or the energy released is so high that the **reverse reaction does not occur**. Also, if a **gas escapes** or a **precipitate forms**, it removes the product from the reaction mixture, pushing

the reaction in only one direction.
Example: Combustion of methane → CO_2 and H_2O (cannot be reversed).

- **Reversible Reactions:**
  In these reactions, **both forward and reverse reactions can take place**. The system can reach a point called **dynamic equilibrium**, where the rate of the forward and reverse reactions become equal.
  Example:
  $N_2+3H_2 \rightleftharpoons 2NH_3$

  Here, ammonia can decompose back into nitrogen and hydrogen under suitable conditions.

Key Point:
Whether a reaction is reversible or not depends on **bond energies, system conditions (like temperature and pressure), and the stability of products**.

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ii. Why are combustion reactions generally irreversible?

Detailed Answer:
Combustion reactions involve the **burning of a substance in oxygen**, producing **heat, light, and stable products** such as **carbon dioxide and water**.

- These reactions are **highly exothermic**, meaning they release a large amount of energy.
- The **products formed (like CO_2 and H_2O)** are very stable and do not easily react to form the original substance again.
- Most combustion occurs in **open systems**, so **gases escape**, and it's practically impossible to reverse the process.

Example:

$CH_4+2O_2 \rightarrow CO_2+2H_2O+\text{Heat}$

Once methane is burned, it cannot be recovered from carbon dioxide and water under normal conditions.

Conclusion:
Due to the **stability of products**, **gas evolution**, and **high energy release**, combustion reactions are generally **irreversible**.

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

Detailed Answer:

- **Irreversible to Reversible:**
  Generally, **no**. If a reaction is naturally irreversible (like combustion or neutralization), we **cannot reverse it** under normal conditions because the products are **too stable** or have **left the system** (e.g., as gas).
- **Reversible to Irreversible:**
  Yes, conditionally. A reversible reaction can be **made to behave irreversibly** if:
  - One of the products is **removed continuously** (e.g., by distillation, precipitation, or gas escape).
  - Conditions like **temperature or pressure** are changed to stop the reverse reaction.

Example:
In the reaction:

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(Esterification is reversible)
If water is **removed**, the reaction is **forced to complete**, behaving like an irreversible reaction.

Conclusion:
You **cannot reverse truly irreversible reactions**, but **can control reversible ones** to favor one direction.

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

Detailed Answer:
To determine the nature of a reaction:

- **Reversible Reactions:**
  - Take place in **closed systems**.
  - Have a **dynamic equilibrium**, where forward and reverse reactions occur at the same rate.
  - The **concentrations of reactants and products remain constant** at equilibrium.
  - Can be represented by a **double arrow (⇌)**.

- Usually **slow** and **sensitive to temperature, pressure, and concentration changes**.
- **Irreversible Reactions:**
  - Proceed in **one direction only**.
  - Often involve **gas evolution**, **precipitate formation**, or **energy release**.
  - The **products cannot convert back** into reactants easily.
  - Represented by a **single arrow (→)**.

Conclusion:
You can identify reversibility by **reaction conditions**, **system closure**, and **product stability**.

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

Detailed Answer:
Phase changes in water are **physical changes**, not chemical ones. They are **reversible** under the right conditions:

- **Melting:** Ice → Water
- **Freezing:** Water → Ice
- **Evaporation:** Water → Steam
- **Condensation:** Steam → Water
- **Sublimation/Deposition:** Ice ⇌ Water vapour (in special conditions)

These changes **do not alter the chemical structure (H_2O)** of the substance, so water remains water — only the **state changes**.

Conclusion:
All phase changes of water (solid ⇌ liquid ⇌ gas) are **reversible**, and can be repeated by changing **temperature or pressure**.

Descriptive Questions

i. How can you drive a reversible reaction at equilibrium?

(a) In the forward direction
(b) In the backward direction

Answer:
To control the direction of a reversible reaction, we apply **Le Chatelier's Principle**, which says that if conditions are changed, the equilibrium will shift to oppose that change.

(a) Driving the reaction in the forward direction:
You can favor the **forward direction** by:

- **Increasing the concentration of reactants**
- **Removing products** as they are formed
- **Changing temperature**: For an **endothermic** reaction, **increase temperature**
- **Increasing pressure** (if forward reaction has fewer gas molecules)

Example:

$N_2+3H_2 \rightleftharpoons 2NH_3+\text{Heat}$

To favor forward reaction: use **high pressure**, **low temperature**, and **remove ammonia**.

(b) Driving the reaction in the backward direction:
You can favor the **reverse reaction** by:

- **Adding products**
- **Removing reactants**
- For **exothermic** reactions, **increase temperature**
- **Lower pressure** (if reverse reaction produces more gas molecules)

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

Answer:
At the beginning of a reversible reaction:

- **Forward reaction is fast** (high concentration of reactants)
- **Reverse reaction is slow** (few or no products)

As products form:

- **Reactants decrease** → forward reaction slows down
- **Products increase** → reverse reaction speeds up

Eventually:

- **Rate of forward = Rate of reverse**
- **Dynamic equilibrium** is established

At equilibrium, reactions **continue**, but concentrations **remain constant**.

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

Answer:
A **catalyst**:

- **Speeds up both forward and backward reactions equally**
- **Does NOT affect the position of equilibrium**
- **Lowers the activation energy** for both directions

Its role is to help the system **reach equilibrium faster**, not to change the amount of products or reactants at equilibrium.

Example:
In the Haber process, **iron catalyst** is used to accelerate the production of ammonia without shifting the equilibrium itself.

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

Answer:
A reversible reaction can be **forced to go in one direction** (toward completion) by:

- **Removing one or more products** (e.g., distilling water, filtering a precipitate, or allowing gas to escape)
- **Using excess reactants**
- **Applying temperature and pressure conditions** that heavily favor one direction
- **Changing solvent** or **concentration** to disrupt reverse reaction

Example:
In esterification:

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

Removing water shifts the reaction to **product side**, forcing completion.

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

Answer:
The effect of temperature on a reaction at equilibrium depends on whether the reaction is **exothermic or endothermic**:

- **Exothermic Reaction (releases heat):**
  $A+B \rightleftharpoons C+D+Heat$
  - **Increasing temperature** shifts equilibrium **backward**
  - **Decreasing temperature** shifts equilibrium **forward**
- **Endothermic Reaction (absorbs heat):**
  $A+B+Heat \rightleftharpoons C+D$
  - **Increasing temperature** shifts equilibrium **forward**
  - **Decreasing temperature** shifts equilibrium **backward**

Conclusion:
Changing temperature affects both the **position of equilibrium** and the **rate of reaction**.

Investigate

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 ($CuSO_4 \cdot 5H_2O$) is a **bright blue crystalline solid**.

Why it is coloured:
- The blue color is due to the presence of **water of crystallization**.
- Water molecules are **coordinated with Cu^{2+} ions**, which cause **electronic transitions** that **absorb certain wavelengths of light**, making the salt appear blue.

Effect of heat:
When heated:

$CuSO_4$\cdotp5H_2O (blue)→heat$CuSO_4$ (white)+5H2O(g)

- The **water of crystallization is lost**.
- The salt turns **white**, indicating the formation of **anhydrous copper sulphate**.

Conclusion:

- The hydrated salt is **blue** because of water molecules attached to copper ions.
- On **heating**, water is removed, the structure changes, and the color changes to **white**.

Note: If water is added back, the blue color **returns**, showing this is a **reversible physical change**.

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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:
Ammonia is synthesized by the **Haber process**, which is a **reversible reaction**:

$N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g)+\text{Heat}$

To get **maximum yield** of ammonia, the following **conditions are applied**:

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1. High Pressure (~200 atm):

- The forward reaction produces **fewer gas molecules (4 → 2)**.
- **According to Le Chatelier's Principle**, high pressure shifts the equilibrium **toward ammonia**.

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2. Moderately Low Temperature (~450–500°C):

- The reaction is **exothermic**.
- Lower temperature favors forward reaction, but too low temperature makes the reaction **too slow**.
- So, a **compromise temperature** is used to balance **yield and rate**.

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3. Catalyst (Iron with potassium and aluminum oxide promoters):

- Increases the **rate of reaction** without affecting the **position of equilibrium**.
- Helps the system reach equilibrium **faster**.

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4. Removal of Ammonia Continuously:

- As ammonia forms, it is **condensed and removed**.
- This **shifts the equilibrium forward**, producing more NH_3.

Conclusion:
To get the maximum yield of ammonia in industry:

- Use **high pressure**
- Use **moderately low temperature**
- Use an **efficient catalyst**
- **Remove ammonia** as it forms

This ensures a **high production rate** suitable for fertilizer (urea) manufacturing.