Reaction of Metals with Air (Oxygen) and Water

i. Definition

A chemical reaction is a process where substances (called reactants) change to form new substances (called products) with different properties. In this topic, we will study how metals, which are one type of reactant, change when they come into contact with air (specifically oxygen) and water.

Not all metals behave the same way. Some are very eager to react, while others are very lazy. This "eagerness" to react is called reactivity.

Reaction with Air (Oxygen): When a metal reacts with the oxygen present in the air, it forms a new substance called a metal oxide.

Reaction with Water: When a metal reacts with water, it can form a metal hydroxide and hydrogen gas, or a metal oxide and hydrogen gas, depending on the metal's reactivity.

ii. Key Points and Important Terms

- **Metal:** A class of elements that are typically hard, shiny, malleable (can be hammered into sheets), ductile (can be drawn into wires), and good conductors of heat and electricity. Examples: Iron, Copper, Gold, Sodium.
- **Reactivity:** The tendency of a substance to undergo a chemical reaction. A highly reactive metal reacts quickly and sometimes violently.
- **Metal Oxide:** A compound formed when a metal reacts with oxygen. For example, when magnesium reacts with oxygen, it forms magnesium oxide.
- **Basic Nature:** Most metal oxides are basic in nature. This means when they are dissolved in water, they form a base, which turns red litmus paper blue.
- **Metal Hydroxide:** A compound formed when a reactive metal reacts with water. For example, when sodium reacts with water, it forms sodium hydroxide.
- **Hydrogen Gas (H_2):** A colorless, odorless gas that is produced when a reactive metal reacts with water. It can be tested by bringing a burning splint near it, which will produce a 'pop' sound.
- **Corrosion:** The gradual destruction of a metal due to its reaction with substances in its environment, like air and water.

- **Rusting:** The specific name for the corrosion of iron. Rust is a reddish-brown, flaky substance called hydrated iron(III) oxide.

iii. Detailed Examples with Solutions

Part A: Reaction of Metals with Air (Oxygen)

- General Equation: Metal + Oxygen → Metal Oxide

Examples based on Reactivity:

Highly Reactive Metals (e.g., Sodium, Potassium):

- **Reaction:** They react so vigorously with oxygen that they catch fire if left in the open air.
- **Storage:** This is why they are stored under kerosene or oil to prevent contact with air.
- **Example:** Sodium + Oxygen → Sodium Oxide

Moderately Reactive Metals (e.g., Magnesium, Zinc):

- **Reaction:** These metals react with oxygen when heated.
- **Example (Magnesium):** When a magnesium ribbon is heated, it burns with a brilliant, dazzling white flame to form a white powder.

Solution:

- **Reactants:** Magnesium (a shiny, silver metal) and Oxygen (a gas in the air).
- **Product:** Magnesium Oxide (a white, powdery ash).
- **Word Equation:** Magnesium + Oxygen → Magnesium Oxide
- **Nature:** If you dissolve this magnesium oxide powder in water, it will turn red litmus paper blue, proving it is basic.

iv. Less Reactive Metals (e.g., Iron, Copper):

- **Reaction:** These metals react with oxygen slowly over a long period, especially in the presence of moisture.
- **Example (Iron):** Iron objects left outside slowly develop a reddish-brown flaky layer called rust.
- **Word Equation:** Iron + Oxygen + Water → Hydrated Iron Oxide (Rust)

- **Example (Copper):** Copper vessels slowly develop a dull, greenish layer when exposed to moist air. This green substance is a mixture of copper hydroxide and copper carbonate.

Least Reactive Metals (e.g., Gold, Silver, Platinum):

- **Reaction:** They do not react with oxygen in the air, even at high temperatures.
- **Reason for Use:** This is why they are used to make jewelry and coins; they stay shiny and do not corrode.

Part B: Reaction of Metals with Water

- General Equation (for reactive metals): Metal + Water → Metal Hydroxide + Hydrogen Gas

Examples based on Reactivity:

Highly Reactive Metals (e.g., Sodium, Potassium):

Reaction: They react violently and exothermically (release heat) with cold water.

Example (Sodium): When a small piece of sodium is dropped into water:

- It fizzes rapidly, producing bubbles of hydrogen gas.
- It darts around the surface of the water.
- It may catch fire due to the heat produced.

Solution:

- **Reactants:** Sodium and Water.
- **Products:** Sodium Hydroxide (which makes the water basic) and Hydrogen Gas.
- **Word Equation:** Sodium + Water → Sodium Hydroxide + Hydrogen

Moderately Reactive Metals (e.g., Magnesium, Calcium):

- **Reaction:** These metals react with hot water or steam.
- **Example (Magnesium):** Magnesium does not react much with cold water but reacts with hot water to form magnesium hydroxide and hydrogen gas. It reacts even faster with steam to form magnesium oxide and hydrogen.

Less Reactive Metals (e.g., Iron, Zinc, Aluminium):

- **Reaction:** These metals do not react with cold or hot water. They react only with steam to form a metal oxide and hydrogen gas.
- **Word Equation:** Iron + Steam → Iron Oxide + Hydrogen

Least Reactive Metals (e.g., Copper, Silver, Gold):

- **Reaction:** They do not react with water or steam at all.

v. Common Misconceptions and Clarifications

Misconception: All metals are strong and unreactive, like iron.

Clarification: Reactivity varies greatly. Sodium is a metal that is soft enough to be cut with a knife and reacts explosively with water. Gold is a metal that doesn't react at all.

Misconception: Rust is just iron getting dirty or old.

Clarification: Rust is a completely new chemical substance (hydrated iron oxide) formed from a chemical reaction between iron, oxygen, and water. The iron is chemically changed.

Misconception: Burning a metal (like a magnesium ribbon) and the rusting of iron are completely different processes.

Clarification: Both are oxidation reactions (reaction with oxygen). Burning is just a very fast, high-energy oxidation, while rusting is a very slow oxidation.

vi. Practice Problems with Step-by-Step Solutions

Problem 1: A student leaves her iron bicycle out in the rain for a few weeks. She observes a reddish-brown, flaky substance on the chain and frame. (a) What is this substance called? (b) What two things were necessary for it to form?

Solution:

- (a) The reddish-brown, flaky substance is rust.
- (b) For rust to form on iron, two things are essential: oxygen (from the air) and water (from the rain).

Problem 2: Anjali is given two metal strips, one made of magnesium and one made of copper. She heats both of them in a flame. The magnesium strip burns with a bright white light, but the copper strip just glows red and turns black on the surface. Explain this difference in observation.

Solution:

- **Step 1:** Identify the concept. The problem is about the difference in reactivity of metals with oxygen (from the air in the flame).
- **Step 2:** Explain Magnesium's reaction. Magnesium is a moderately reactive metal. When heated, it reacts quickly and vigorously with oxygen in the air,

producing a lot of light and heat. This is burning. The product is white magnesium oxide powder.

- **Step 3:** Explain Copper's reaction. Copper is a less reactive metal. It does not burn. When heated, it reacts slowly with oxygen on its surface to form a black layer of copper oxide.
- **Step 4:** Conclude. The difference in observation is due to magnesium being much more reactive than copper.

Problem 3: A science teacher carefully drops a tiny piece of potassium into a beaker of water containing red litmus solution. The solution immediately turns blue, and a gas is produced. What gas is it, and how could you prove it?

Solution:

- **Step 1:** Identify the reactants and reaction type. The reaction is between a highly reactive metal (potassium) and water.
- **Step 2:** Predict the products. A highly reactive metal reacts with water to form a metal hydroxide and hydrogen gas. So, the products are potassium hydroxide and hydrogen gas.
- **Step 3:** Answer the questions.
- The gas produced is hydrogen gas.
- The reason the litmus turned blue is that the other product, potassium hydroxide, is a strong base.
- To prove the gas is hydrogen, you would carefully bring a burning splint to the mouth of the beaker (or a test tube collecting the gas). The gas would extinguish the flame with a characteristic 'pop' sound.

vi. Summary of Main Concepts

- Metals react with oxygen to form metal oxides.
- Most metal oxides are basic in nature (turn red litmus blue).
- The reactivity of a metal determines how fast it reacts.
- Highly reactive metals (Sodium, Potassium) react violently with air and cold water.
- Moderately reactive metals (Magnesium) burn when heated in air and react with hot water.

- Less reactive metals (Iron, Copper) react slowly with air (rusting/tarnishing) and only with steam.
- Least reactive metals (Gold, Silver) do not react with air or water.
- The reaction of a metal with water produces a metal hydroxide (or oxide) and hydrogen gas.
- Rusting is the corrosion of iron and requires both oxygen and water.