4

"The study of matter, from metals to gases, teaches us the universal law of change."

– Marie Curie

The World of Metals and Non-metals

The Big Question

Ever wondered why pan handles are plastic but the pans are metal, or how a tiny spark lights a room? Our world is full of amazing materials! From shiny spoons to invisible air, metals and non-metals are all around us. This chapter explores what makes them different, how they work, and why both are essential in our daily lives.

Meet EeeBee.AI

I'm EeeBee, your AI buddy. Let's dive into. The World of Metals and Non-metals—how they look, feel, and act! Shiny or dull? Heavy or light? Hard or soft? We'll learn what makes metals super-strong and why non-metals are full of surprises in everyday life!

Still curious? Talk to me by scanning the QR code.

Learning Outcomes

By the end of this chapter, students will be able to:

- Differentiate between metals and non-metals based on their physical properties.
- Analyze the chemical properties of metals and non-metals, including their reactions.
- Explain the phenomenon of corrosion, particularly rusting of iron, and its implications.
- Evaluate the importance and diverse applications of various metals and non-metals.

Science Around you

Metals and non-metals are the building blocks of our modern world! From the steel in skyscrapers and vehicles (metals) to the oxygen we breathe and the carbon in all living things (non-metals). Understanding them helps us appreciate technology like smartphones (containing various metals and non-metals), medical advancements, and even how we cook our food.

NCF Curricular Goals and Competencies

CG 4.1 – Understand that metals are generally hard, shiny, malleable, and good conductors of heat and electricity. **CG 4.2** – Recognize that non-metals are usually dull, brittle, and poor conductors, and observe how both react differently with air, water, and acids.

Mind Map

The World of Metals and Non-metals

Properties of Materials

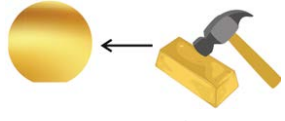
❖ **Lustre –** Metals are shiny (gold, silver, copper).

- ✓ Non-metals are dull (coal, sulfur, wood).

❖ **Hardness –** Metals are mostly hard (iron, copper).

- ✓ Non-metals are usually soft (sulfur, phosphorus).
- ✓ Diamond (non-metal) is the hardest natural substance.

❖ **Malleability –** Metals can be hammered into sheets.



- ✓ **Example:** Aluminium → foil.

❖ **Ductility –** Metals can be drawn into wires.

- ✓ **Example:** Copper, Aluminium → electrical wires.

❖ **Sonority –** Metals produce ringing sound.

- ✓ Used in bells, musical instruments.
- ✓ Non-metals give a dull sound.

Reaction of Metals with Air (Oxygen) & Water

❖ **Reaction with Oxygen**

- ✓ Metals combine with oxygen to form **basic oxides.**
- ✓ Iron + O_2 + moisture → **rust ($Fe_2O_3 \cdot xH_2O$)**.
- ✓ Magnesium burns with a bright flame → **MgO**.

❖ **Reaction with Water**

- ✓ Reactivity depends on the metal.
- ✓ Sodium & Potassium → **vigorous with cold water**, releasing H_2 + heat.

❖ **Corrosion**

- ✓ Corrosion = slow damage of metals by air & moisture.
- ✓ Silver → turns **black** (silver sulfide).
- ✓ Prevention: **painting, oiling, galvanizing, alloying**.

Characteristics of Frequently Used Materials

❖ **Reaction with Oxygen**

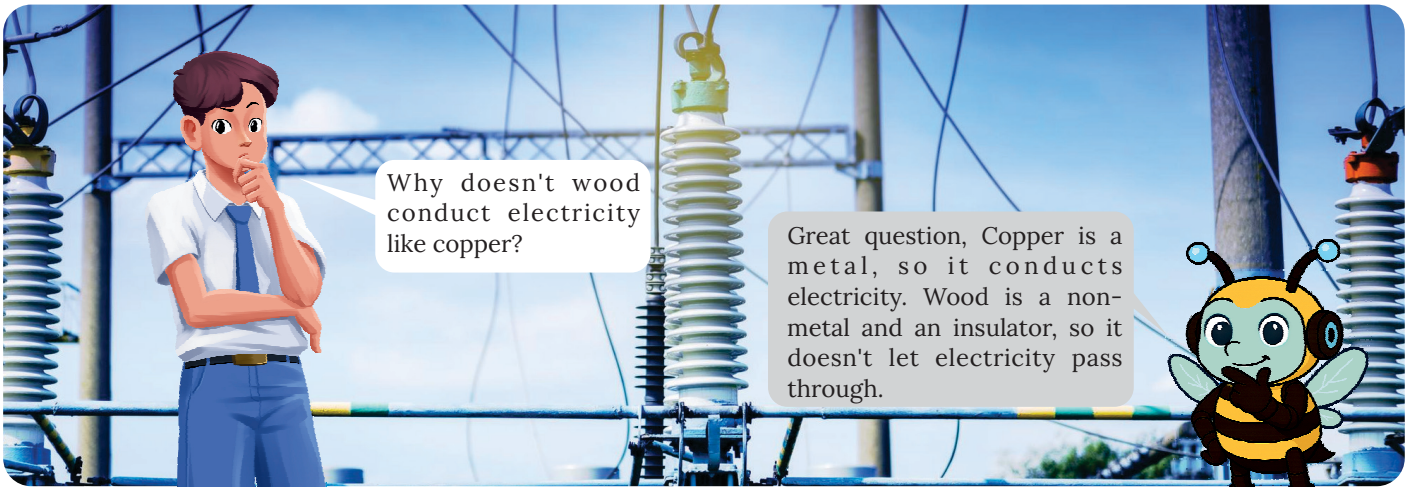
- ✓ Non-metals usually form **acidic oxides** on burning.
- ✓ Sulfur + O_2 → **SO_2** (sulfur dioxide).
- ✓ SO_2 + water → **H_2SO_3** (sulfurous acid), turns blue litmus red.
- ✓ Carbon + O_2 → **CO_2** (carbon dioxide).
- ✓ CO_2 + water → **H_2CO_3** (carbonic acid).
- ✓ Phosphorus + O_2 → **P_2O_5** (phosphorus pentoxide).
- ✓ P_2O_5 + water → **H_3PO_4** (phosphoric acid).
- ✓ Thus, non-metal oxides are **acidic** in nature.

❖ **Reaction with Water**

- ✓ Most non-metals **do not react** directly with water.
- ✓ Sulfur, carbon, and phosphorus show **no reaction** under normal conditions.

❖ **Chlorine is an exception.**

- ✓ Chlorine + water → **HCl + HOCl.**



In Focus

- Properties of Materials
- Reaction of Metals with Air (Oxygen) and Water
- Reaction of Non-metals with Air (Oxygen) and Water

Introduction

Our world is filled with a vast variety of substances, each with unique characteristics. Think about the objects around you: a shiny steel spoon, a wooden table, a plastic water bottle, a copper wire, a piece of coal. Scientists classify these materials to better understand their behavior and uses. One of the most fundamental classifications is into metals and non-metals. This classification is primarily based on their physical and chemical properties.

From History's Pages

The story of metals and non-metals is intertwined with human civilization. Early humans first used naturally occurring non-metals like stone and wood. The discovery of metals like copper (around 9000 BCE), followed by bronze (an alloy of copper and tin, around 3500 BCE) and later iron (around 1200 BCE), revolutionized tools, warfare, and agriculture, leading to the Bronze Age and Iron Age. Alchemists in the medieval period, while searching for the philosopher's stone, unknowingly experimented with many metallic and non-metallic substances. Scientists like Antoine Lavoisier in the 18th century helped establish the modern understanding of elements, including many metals and non-metals.

Properties of Materials

Materials around us—like **metals, plastics, glass, and wood**—have different properties that help us decide how to use them in our daily lives. Some are hard and shiny, while others are soft or dull. Metals, in particular, are known for special properties such as malleability, ductility, sonority, and their ability to conduct heat and electricity. Understanding these properties helps scientists, engineers, and even students choose the right materials for making tools, wires, utensils, machines, and buildings.

In this section, we will explore seven key properties that help us classify and compare different materials.

Fig. 4.1 Types of Materials

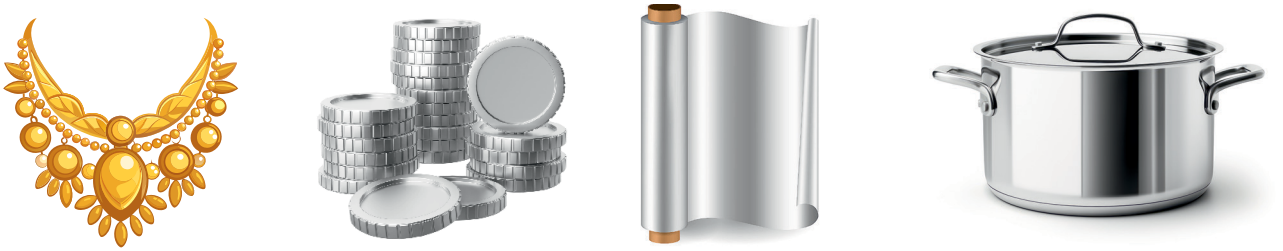
Lustre

Lustre refers to the shininess or glow of a material's surface when light falls on it. Metals, in their pure state, typically have a characteristic shine known as metallic lustre. This is because the electrons in metals are free to move and can reflect light efficiently. When you see a freshly cut piece of iron, a polished copper vessel, or a gold ornament, their shiny appearance is due to this property.

Non-metals, on the other hand, generally do not have this shine. They often appear dull. Think of sulfur powder, a piece of coal, or the oxygen in the air – they are non-lustrous. However, there are exceptions. For instance, iodine, a non-metal, has a somewhat lustrous appearance, and graphite (a form of carbon, which is a non-metal) is also shiny.

Examples

- **Metals with lustre:** Gold jewellery, silver coins, aluminium foil, stainless steel utensils, copper wires.



Gold jewellery | Silver Coins | Aluminium Foil | Stainless Steel Utensils

Fig. 4.2 Metals with lustre

- **Non-metals (generally non-lustrous):** Wood, plastic, sulfur powder, charcoal, phosphorus.

Wood | Plastic | Charcoal

Fig. 4.3 Non-metals

- **Exceptions:** Iodine crystals (non-metal with lustre), graphite (non-metal with lustre).

Hardness

Hardness refers to a material's resistance to being scratched, dented, or cut. Generally, most metals are hard. This means they are not easily scratched or deformed. Think of iron, steel, or copper – they are quite robust. This hardness is why metals are used to make tools, machinery, and building structures that need to withstand wear and tear.

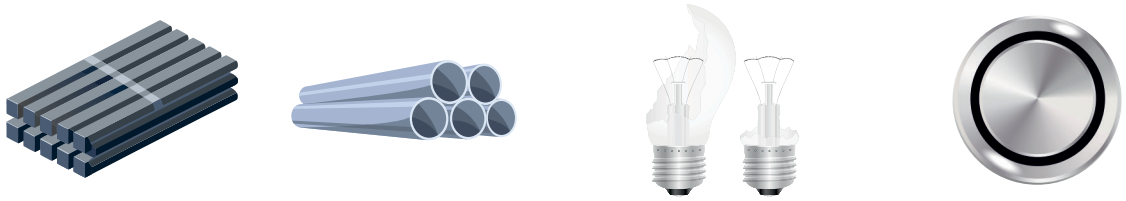
Non-metals, in contrast, are often soft. For example, sulfur can be easily crushed into a powder, and graphite (the "lead" in your pencil) is soft enough to leave a mark on paper. However, there are important **exceptions** to this general rule. Diamond, which is a form of carbon (a non-metal), is the hardest naturally occurring substance known! On the other hand, some metals like sodium and potassium are so soft that they can be easily cut with a knife. Mercury is a unique metal that is liquid at room temperature, so hardness doesn't apply in the same way.

Keywords

Exception: An exception is a case or outcome that does not follow the expected rule or pattern in a scientific process.

Examples:

- **Hard Metals:** Iron (used in construction), steel (alloys of iron), tungsten (used in filaments), chromium.



Iron Steel Tungsten (used in Filaments) Chromium

Fig. 4.4 Hard Metals

- **Soft Non-metals:** Sulfur (brittle powder), phosphorus, graphite (soft enough to write with).

Sulfur Graphite

Fig. 4.5 Soft Non-Metals

- **Exceptions (Hard Non-metal):** Diamond (extremely hard).

Diamond
Hard Non-metal

Fig. 4.6 Hard Non-metal

Malleability

Malleability is a physical property of materials, predominantly metals, that allows them to be hammered, pressed, or rolled into thin sheets without breaking or cracking. The word "malleable" comes from the Latin word 'malleus', meaning hammer. When an ironsmith, beats a hot iron block with a hammer to shape it into an axe, he is utilizing the malleability of iron. This property arises because the atoms in metals are arranged in layers that can slide over each other when a force is applied, without the metallic bonds breaking completely.

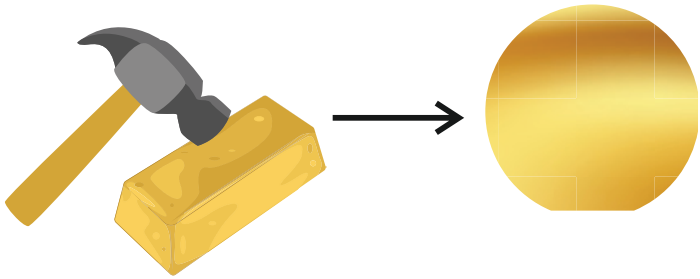


Fig. 4.7 Malleability

Non-metals, in contrast, are generally brittle. This means that when they are hammered or subjected to stress, they tend to break or shatter into pieces instead of deforming. A piece of coal or a lump of sulfur, if hit with a hammer, will break apart. Wood is an interesting case; it neither flattens into a sheet like a metal nor shatters like a brittle non-metal when hammered moderately; it might splinter or dent.

Examples:

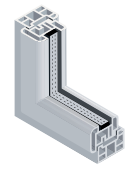
Malleable Metals

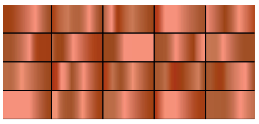
- **Aluminium:** Used to make aluminium foil for wrapping food and thin sheets for cans.
- **Copper:** Can be beaten into sheets for roofing or decorative items.
- **Silver:** Used to make thin silver foils (varak) for decorating sweets.
- **Gold:** Extremely malleable, can be beaten into incredibly thin gold leaf used for **gilding**.

Keywords

Gilding: The process of coating an object with a thin layer of gold or a gold-like substance to make it look shiny and valuable, often for decoration.

- **Iron:** Can be hammered into various shapes for tools, gates, etc.


Aluminium


Copper


Silver


Gold

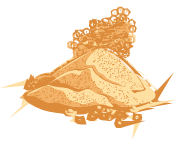

Iron

Fig. 4.8 Malleable Metals

Brittle Non-metals

- **Coal:** Breaks into pieces when hammered.
- **Sulfur:** Crumbles into powder when struck.
- **Glass (made from non-metallic elements):** Shatters easily


Coal


Sulfur


Glass

Fig. 4.9 Brittle Non-metals

Ductility

Ductility is another important physical property primarily exhibited by metals. It is the ability of a material to be drawn (stretched) into thin wires without breaking. Think of the electrical wires in your home; the copper or aluminium inside the plastic insulation is in the form of a wire because these metals are ductile. Like malleability, ductility occurs because the atoms in metals can rearrange themselves as the material is stretched.


Fig. 4.10 Copper Wires

Non-metals are not ductile. If you try to stretch a piece of sulfur or coal, it will simply break. They lack the ability to undergo significant plastic deformation under tensile (pulling) stress.

Examples:

Ductile Metals

- **Copper:** Widely used for electrical wiring due to its good ductility and electrical conductivity.
- **Aluminium:** Used for overhead power cables (often reinforced with steel) and some wiring.

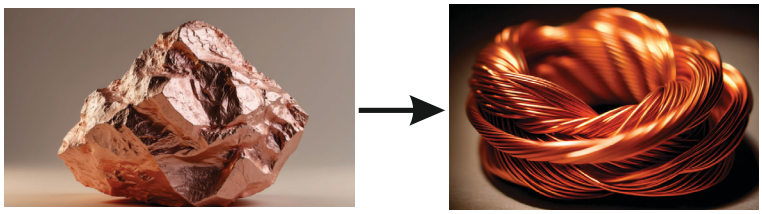


Fig. 4.11 Filigree work

- **Gold and Silver:** Highly ductile, drawn into fine wires for jewellery (e.g., filigree work) and in some electronics.
- **Tungsten:** Used to make the very thin filament in incandescent light bulbs because of its high ductility and high melting point.
- **Iron (in the form of steel):** Can be drawn into wires for ropes, springs, and reinforcing concrete.
- **Non-ductile Materials (Non-metals):** Sulfur, coal, phosphorus, oxygen.


Fig. 4.12 Reinforcing concrete

Sonority

Sonority is the property of a material, particularly metals, to produce a characteristic ringing sound when struck with a hard object or when dropped onto a hard surface. Metals that produce such a sound are said to be sonorous. This is why bells in temples, schools, and churches are typically made of metals or metal alloys like bronze. The ability to vibrate and produce a sustained sound is key to sonority.


Fig. 4.13 Bell

Non-metals, when struck, usually produce a dull sound rather than a clear ring. If you drop a piece of wood or coal on the floor, the sound is flat and short-lived.

Examples

Sonorous Metals

- **Iron/Steel:** School bells, railway tracks (ring when struck).
- **Copper/Bronze/Brass:** Musical instruments (cymbals, gongs, bells), ghungroos.
- **Aluminium:** Some wind chimes.
- **Silver:** Coins (though modern coins are often alloys).

Fig. 4.14 Sonorous Metals

Non-sonorous Materials (Non-metals)

- **Wood:** Produces a dull thud.
- **Coal:** Produces a dull sound, might break.
- **Plastic:** Produces a flat sound.
- **Sulfur:** No ringing sound.

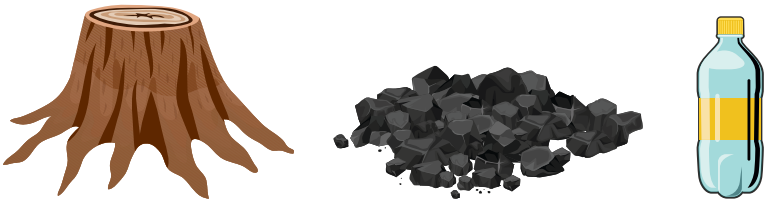


Fig. 4.15 Non-sonorous Material

Conduction of Heat

Conduction of heat is the process by which heat energy is transferred through a material from a hotter region to a cooler region, without any actual movement of the material itself. Metals are generally good conductors of heat. This means that heat can travel through them quickly and easily. This is because metals have free electrons that can move throughout the metal structure. When one part of a metal is heated, these electrons gain energy and move faster, colliding with other electrons and atoms, and transferring the heat energy rapidly.

Fig. 4.16 Metal and wooden spoons immersed in hot water

Non-metals (like wood, plastic, sulfur, air) are generally poor conductors of heat. They are also known as insulators of heat. In these materials, electrons are not free to move easily, so heat transfer by conduction is much slower.

Examples

Good Conductors of Heat (Metals)

- **Copper:** Used in the base of cooking pans, hot water pipes, and heat sinks in computers.
- **Aluminium:** Used for making cooking utensils, radiators in cars.
- **Silver:** The best conductor of heat (and electricity), but too expensive for common use.
- **Iron/Steel:** Used for cooking pots, pans, and engine blocks.


Fig. 4.17 Cooking pans

Keywords

Steel: A strong alloy of iron and carbon, used in construction, tools, and machines.
Bronze: A metal alloy of copper and tin, known for its hardness and used in statues and coins.
Brass: A yellowish alloy of copper and zinc, used in musical instruments, locks, and decorative items.

Poor Conductors of Heat (Non-metals/Insulators)

Fig. 4.18 Handles of kettles and pans

- **Wood:** Used for handles of cooking utensils, table mats.
- **Plastic:** Used for handles of kettles and pans, insulated cups.
- **Air:** A very good insulator (trapped air is used in double-glazed windows and winter clothing).
- **Glass:** A poor conductor, used in oven doors.
- **Asbestos (a mineral, but illustrates the point):** Formerly used for heat insulation (now known to be hazardous).

Conduction of Electricity

Fact Flash

Gold is so malleable that a single gram can be beaten into a sheet of 1 square meter! It's also ductile enough to stretch into a wire more than 2 km long!

Conduction of electricity refers to the ability of a material to allow electric current (a flow of electric charge, usually electrons) to pass through it. Similar to heat conduction, metals are generally good conductors of electricity. This is again due to the presence of loosely bound, free electrons in their structure. These electrons can move easily through the metal when a voltage (electrical potential difference) is applied, carrying the electric current.

Non-metals are generally poor conductors of electricity, also known as electrical insulators. In non-metals, electrons are tightly bound to their atoms and are not free to move and carry current. There is one very important exception among non-metals: graphite (a form of carbon) is a good conductor of electricity.

Examples

Good Conductors of Electricity (Metals)

- **Silver:** The best electrical conductor, but expensive. Used in specialized electronics and contacts.
- **Copper:** Excellent conductor, widely used for electrical wires and cables.
- **Aluminium:** Good conductor, lighter than copper, used for overhead power lines and some wiring.
- **Gold:** Good conductor, very resistant to corrosion, used for high-quality connectors in electronics.
- **Iron/Steel:** Conduct electricity, but not as well as copper or aluminium.

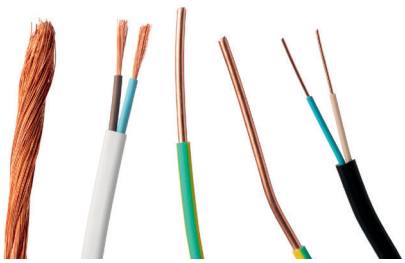


Fig. 4.19 Good Conductors of Electricity

Poor Conductors of Electricity (Non-metals/Insulators)

- **Rubber:** Used for insulating gloves, shoe soles for electricians, and wire coverings.
- **Plastic:** Used for covering electrical wires, casings of appliances, switches.
- **Wood (dry):** A poor conductor.
- **Glass:** An excellent insulator.
- **Sulfur, phosphorus, oxygen, nitrogen:** All are insulators.

Exception (Non-metal conductor)

- **Graphite (carbon):** Used in pencil "leads" (mixed with clay), electrodes in batteries and industrial processes.

Fig. 4.20 Poor Conductors of Electricity

Common Misconceptions

× **Misconception:** All shiny things are metals.
✓ **Correction:** Some non-metals like iodine and graphite are also shiny.

× **Misconception:** All metals are hard and solid.
✓ **Correction:** Metals like sodium and potassium are soft and can be cut with a knife; mercury is liquid at room temperature.

× **Misconception:** Non-metals cannot conduct electricity.
✓ **Correction:** Graphite, a non-metal, conducts electricity and is used in batteries and electrodes.

Science Around You

Metals like copper and silver are excellent conductors of electricity due to their free-moving electrons. Some non-metals, such as sulfur and phosphorus, are poor conductors and brittle, making them unsuitable for wiring or tools.

Activity

Sorting Materials by Properties

- **Materials Required:**
  Iron nail, copper wire, aluminium foil, charcoal piece, rubber, silver coin, steel spoon, graphite rod.

Fig. 4.21 Materials Required

- **Procedure:**
  1. Try scratching each object to test hardntess.
  2. Strike each material gently and note sound to test sonority.
  3. Observe shine to check lustre.
  4. Try bending or rolling to test malleability and ductility.
  5. Use a simple circuit setup to check electrical conductivity.
  6. Place over gentle flame (with supervision) to check heat conduction.
- **Observation Table:**

Material	Lustre	Hardness	Malleable	Ductile	Sonorous	Conducts Heat	Conducts Electricity
Iron Nail	*Yes*	_____	*Yes*	_____	*Yes*	_____	_____
Charcoal	_____	*Soft*	_____	*No*	*No*	_____	*No*
Graphite	*Yes*	_____	_____	_____	_____	*Moderate*	_____
Aluminium Foil	_____	*Soft*	*Yes*	*Yes*	_____	*Yes*	*Yes*

Knowledge Checkpoint

Gap Analyzer™ Homework | Watch Remedial

Remembering

Multiple Choice Questions:

1. **Which property allows copper to be used in electric wires?**
   a) Hardness ☐ b) Ductility ☐
   c) Sonority ☐ d) Lustre ☐

Understanding

2. **Which of the following is a good conductor of both heat and electricity?**
   a) Wood ☐ b) Plastic ☐
   c) Iron ☐ d) Sulfur ☐
3. **Which of the following is not malleable?**
   a) Aluminium ☐ b) Sulfur ☐
   c) Silver ☐ d) Gold ☐

Short Answer Question:

4. What is the difference between malleability and ductility?
5. Name one material that is non-metal but good conductor of electricity.

Analyzing

Long Answer Question:

6. Explain any four physical properties of metals with suitable real-life examples. Also mention how these properties differ in non-metals.

Reaction of Metals with Air (Oxygen) and Water

Metals can react with substances in their environment, such as oxygen (from the air) and water. These reactions are chemical changes, resulting in the formation of new substances, typically metal compounds.

Reaction of Metals with Oxygen (Formation of Metal Oxides)

Metals generally react with oxygen from the air to form compounds called metal oxides. This reaction usually happens more quickly when the metal is heated. These reactions are common in our daily life and are a basic part of how metals behave.

Fig. 4.22 Metal oxides

Important Points

- When metals react with oxygen, they form metal oxides.
- **The general word equation is:** Metal + Oxygen → Metal Oxide

Let's look at some common examples:

1. Magnesium reacts with oxygen when burnt in air. It produces a bright white flame and forms a white ash known as magnesium oxide.

   Equation: Magnesium + Oxygen → Magnesium Oxide

2. Iron reacts with oxygen, especially in the presence of moisture, and slowly forms a reddish-brown substance called rust or iron oxide. This process is called rusting.

   Equation: Iron + Oxygen → Iron Oxide

3. Copper, when heated in air, forms a black coating of copper oxide.

Equation: Copper + Oxygen → Copper Oxide

Nature of Metal Oxides

Most metal oxides are basic in nature. This means they can react with water to form a base, and their solutions can turn red litmus paper blue.

Example:

- When magnesium oxide is dissolved in water, it forms **magnesium hydroxide**, which is a base.
- This solution turns red litmus paper blue, showing its basic nature.

Equation: Magnesium Oxide + Water → Magnesium Hydroxide

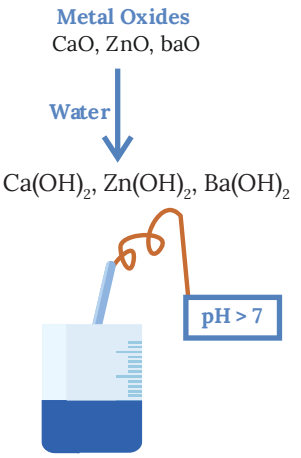


Fig. 4.23 Nature of Metal Oxides

Reaction of Metals with Water

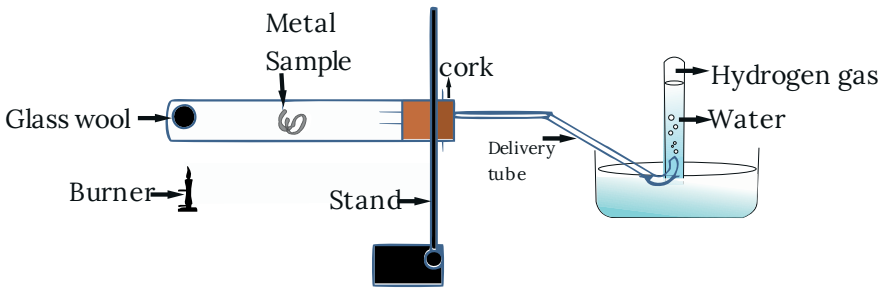


Fig. 4.24 Reaction of Metals with Water

Metals react with water to form metal hydroxides and hydrogen gas. However, not all metals react the same way. The reactivity of a metal determines how fast and strongly it reacts with water. Some react explosively, while others show little or no reaction.

Highly Reactive Metals

Metals like sodium (Na) and potassium (K) are highly reactive. They react very quickly and **vigorously** with cold water. These reactions release a large amount of heat, and the hydrogen gas formed may even catch fire due to the heat of the reaction.

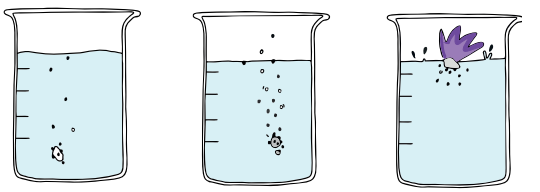


Fig. 4.25 Vigorously

Reactions

Sodium + Water → Sodium Hydroxide + Hydrogen Gas + Heat

Potassium + Water → Potassium Hydroxide + Hydrogen Gas + Heat

These metals are so reactive that they are stored under kerosene to prevent accidental contact with moisture or oxygen in the air.

Moderately Reactive Metals

Metals like magnesium (Mg) and calcium (Ca) are moderately reactive. They do not react violently with cold water.

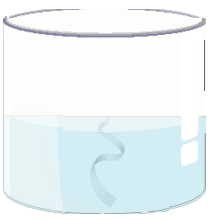


Fig. 4.26 Moderately Reactive Metals

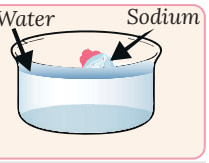
Keywords

Magnesium hydroxide: A white, powdery or milky substance formed when magnesium reacts with water; it's slightly basic and used in antacids and toothpaste.

- Calcium reacts slowly with cold water to form calcium hydroxide and hydrogen gas.
- Magnesium reacts very slowly with hot water and more readily with steam.

Real-life Note

If you drop a piece of sodium in water, it starts moving rapidly on the surface and may even produce flames due to the heat released.



Reactions

Magnesium + Hot Water → Magnesium Hydroxide + Hydrogen Gas

Magnesium + Steam → Magnesium Oxide + Hydrogen Gas

These reactions are not explosive but do show that hydrogen gas is produced.

Less Reactive Metals

Metals like zinc (Zn), iron (Fe), and aluminium (Al) are less reactive. These metals do not react with cold or hot water easily. However, they react with steam when heated to high temperatures.

Example Reaction

Iron + Steam → Iron(III) Oxide + Hydrogen Gas

- Such reactions are slower and require more energy (in the form of heat).

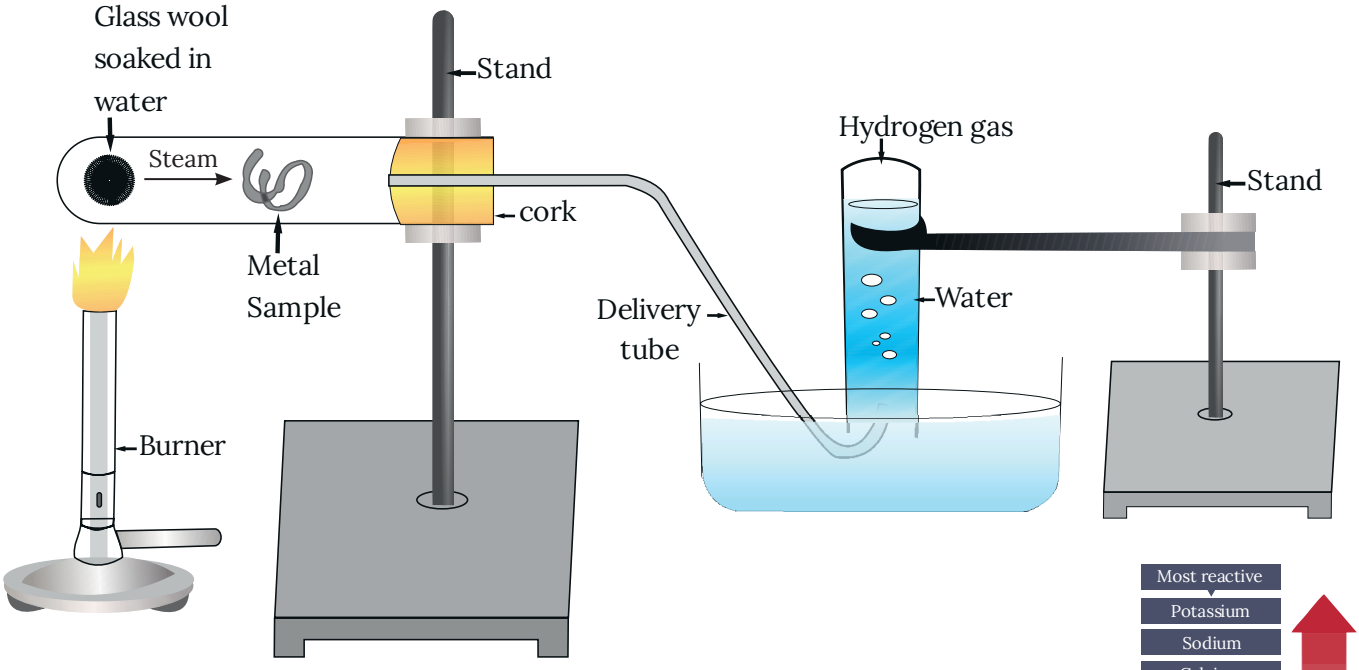


Fig. 4.27 Reaction of metal with steam

Least Reactive Metals

Metals like copper (Cu), silver (Ag), gold (Au), and platinum (Pt) are least reactive. They do not react with water or steam, even at high temperatures. This property makes them ideal for making jewellery, coins, and other decorative items because they do not **corrode** easily.

Fig. 4.28 Least Reactive Metals

Keywords

Corrode means to slowly wear away or damage a metal due to a chemical reaction, usually with air or moisture. It often leads to rusting in iron and weakening of the material over time.

Corrosion and Rusting

What is Corrosion?

Corrosion is a natural process where metals slowly get damaged by reacting with substances in the environment like oxygen, moisture (water), or chemicals. Over time, the metal surface becomes weaker, dull, and may develop a coating of another substance (like rust or **patina**).

Fig. 4.29 Corrosion and Rusting

Rusting – A Special Type of Corrosion

Rusting is a specific type of corrosion that affects iron and its alloys such as steel. When iron is exposed to air and moisture, a reddish-brown flaky substance called rust forms on its surface.

Reactions

Iron + Oxygen + Water → Hydrated Iron Oxide (Rust)

This rust does not protect the metal but continues to flake off, exposing more iron to air and moisture, and the process continues.

Conditions Needed for Rusting

1. Presence of Oxygen (from the air)
2. Presence of Water or Moisture (from humidity, rain, or dampness)

Prevention of Rusting

To protect iron from rusting, we use various **preventive methods** to stop air and water from reaching the metal surface.

Fact Flash

The Iron Pillar of Delhi, over 1600 years old, has shown remarkable resistance to rust despite being exposed to the elements. This is attributed to its high phosphorus content, low sulfur content, and the formation of a thin protective passive layer of **iron hydrogen phosphate hydrate** on its surface.

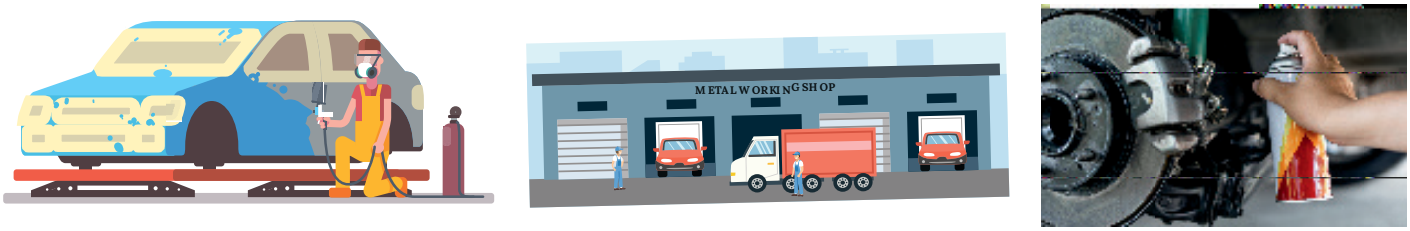


Fig. 4.30 Prevention of Rusting

Methods of Rust Prevention

1. **Painting:** Covers the surface and keeps out moisture and air.
2. **Oiling or Greasing:** Forms a protective barrier against water and air.
3. **Galvanization:** Coating iron with a layer of zinc. Zinc reacts first and protects the iron.
4. **Alloying:** Making alloys like stainless steel (iron mixed with chromium and nickel), which resists rusting.
5. **Electroplating:** Depositing a layer of less reactive metal like chromium or tin on iron to protect it.

Keywords

Patina: A green or brown layer that forms on metals like copper or bronze over time due to reaction with air or moisture.

Iron hydrogen phosphate hydrate: A compound that can form on iron surfaces during rusting, especially when iron reacts with phosphates and moisture in the environment, leading to a hydrated rust-like layer.It forms a thin, stable protective layer on the Iron Pillar, which blocks moisture and oxygen, preventing rusting.

Corrosion of Other Metals

Corrosion is not limited to iron. Many other metals also get corroded, though in different ways.

Copper:

- Forms a greenish coating called patina.
- It is a mix of copper carbonate and copper sulfate.
- Example: Green colour on the Statue of Liberty.

Silver:

- Reacts with sulfur compounds in the air and forms silver sulfide.
- This turns the shiny surface black.

Aluminium:

- Forms a thin, invisible layer of aluminium oxide.
- This layer protects the metal underneath from further corrosion.
- This is why aluminium utensils last long and do not rust.

Fig. 4.31 Corrosion of Other Metals

Common Misconceptions

× **Misconception:** All metals rust.

✓ **Correction:** "Rusting" specifically refers to the corrosion of iron and its alloys. Other metals corrode, but the process and products are different (e.g., copper forms a green patina, silver tarnishes black). Some metals like gold and platinum are very resistant to corrosion.

× **Misconception:** Water alone or air alone can cause iron to rust.

✓ **Correction:** Both oxygen (from air) and water (moisture) are essential for the rusting of iron to occur.

Science Around You

Everyday metal objects around you undergo familiar chemical transformations due to corrosion and oxidation. Iron gates, tools, and vehicles rust as iron reacts with oxygen and moisture in the air to form flaky iron oxides, weakening their structure. And when metallic sodium drops into water, it reacts violently to produce sodium hydroxide and hydrogen gas, releasing enough heat to ignite the hydrogen.

Activity

Observing Rust Formation

- **Materials Required:** Three clean iron nails, three test tubes or small glass jars, tap water, boiled (and cooled) water, a little cooking oil, anhydrous calcium chloride (or silica gel) as a drying agent, cotton wool.
- **Procedure:**
  1. Label the test tubes A, B, and C.

2. **In test tube A:** Place an iron nail and some anhydrous calcium chloride (or silica gel) on cotton wool to keep the air dry. Stopper it.
3. **In test tube B:** Place an iron nail and fill with boiled (and cooled) water until the nail is submerged. Add a layer of oil on top of the water to prevent air from dissolving. Stopper it.
4. **In test tube C:** Place an iron nail and add some tap water so that the nail is partially submerged (exposed to both air and water). Leave it unstoppered or loosely stoppered.

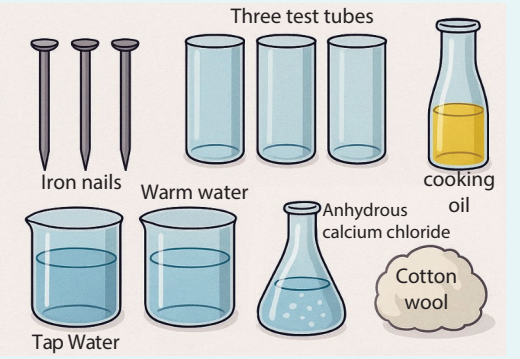


Fig. 4.32 Materials Required

5. Leave the test tubes undisturbed for a few days and observe any changes on the nails.

- **Observation:**

  The nail in test tube C (exposed to both air and water) will show rust. The nails in test tube A (dry air) and test tube B (water without dissolved air) will show little or no rust. This demonstrates that both oxygen and water are necessary for rusting.

Knowledge Checkpoint

Gap Analyzer™ Homework | Watch Remedial

Multiple Choice Questions:

Remembering

1. When metals react with oxygen, they generally form:

a) Metal hydroxides ☐ b) Metal carbonates ☐

c) Metal oxides ☐ d) Metal chlorides ☐

2. The reddish-brown deposit formed on iron objects when exposed to moist air is called:

a) Soot ☐ b) Verdigris ☐

c) Rust ☐ d) Tarnish ☐

Understanding

3. Metal oxides are generally _____ in nature.

a) Acidic ☐ b) Basic ☐

c) Neutral ☐ d) Amphoteric ☐

Short Answer Question:

4. What are the two essential conditions for the rusting of iron?
5. Write a word equation for the reaction of magnesium with oxygen. What is the nature of the product formed?

Analyzing

Long Answer Question:

6. Explain the process of rusting of iron in detail. Why is rusting considered a problem? Describe three methods to prevent rusting, explaining the principle behind each.

Reaction of Non-metals with Air (Oxygen) and Water

Non-metals also take part in chemical reactions, just like metals. However, their behavior is quite different from metals, especially in how they react with oxygen and water, and the type of compounds they form.

Reaction of Non-metals with Oxygen

Most non-metals react with oxygen (usually when heated or ignited) to form non-metal oxides. These oxides are often gaseous and have different properties compared to metal oxides.

General Word Equation: Non-metal + Oxygen → Non-metal Oxide

Examples of Reactions

Sulfur + Oxygen → Sulfur Dioxide

When sulfur powder is burned in air, it produces a gas called sulfur dioxide (SO_2).

- It burns with a faint blue flame.
- The gas has a **pungent, choking smell**.

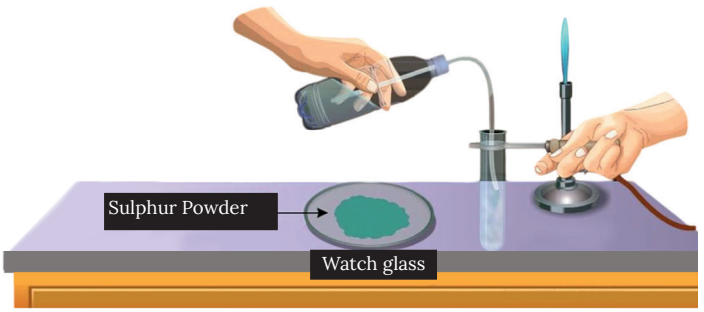


Fig. 4.33 Sulfur Dioxide

Examples of Reactions

Carbon + Oxygen → Carbon Dioxide/Carbon Monoxide

When carbon (like charcoal or coal) is burned in air

- In sufficient oxygen, it forms carbon dioxide (CO_2).
- In limited oxygen, it forms carbon monoxide (CO), which is very poisonous.

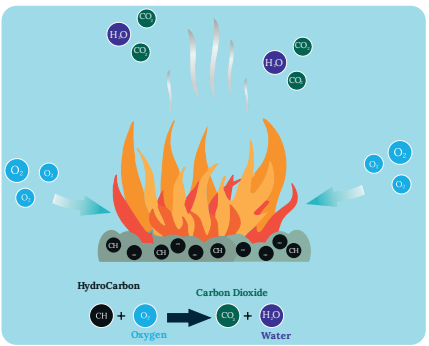


Fig. 4.34 Carbon Dioxide/Carbon Monoxide

Reactions

$C + O_2 \rightarrow CO_2$ (Complete combustion)

$2C + O_2 \rightarrow 2CO$ (Incomplete combustion)

Phosphorus + Oxygen → Phosphorus Pentoxide

Phosphorus
P_4

5x Oxygen
O_2

2x Phosphorus pentoxide
P_2O_5

Fig. 4.35 Phosphorus Pentoxide

White phosphorus is so reactive that it catches fire on its own when exposed to air at room temperature, forming a white solid called **phosphorus pentoxide (P_2O_5)**.

Nature of Non-metal Oxides

Non-metal oxides are usually acidic in nature. When they dissolve in water, they form acids. These acidic solutions can be tested using litmus paper.

Characteristics

- Turn blue litmus paper red.
- React with bases to form salts.

Examples of Acidic Oxides

Sulfur Dioxide + Water → Sulfurous Acid

$SO_2 + H_2O \rightarrow H_2SO_3$

The gas dissolves in water to form sulfurous acid, which is acidic and turns blue litmus paper red.

Carbon Dioxide + Water → Carbonic Acid

$CO_2 + H_2O \rightarrow H_2CO_3$

This forms carbonic acid, which is found in fizzy drinks, giving them a slightly sour taste.

Reaction of Non-metals with Water

In general, non-metals do not react with water under normal conditions. Most non-metals are inert or unreactive in water.

Example:

- Sulfur powder does not react with water. It simply settles down or floats.

Exception – Use of Water for Storage

Some highly reactive non-metals are stored in water, not because they react with it, but to prevent their reaction with air.

Fact Flash

Some non-metal oxides are neutral, meaning they are neither acidic nor basic. Examples include nitric oxide (NO), nitrous oxide (N_2O, laughing gas), and carbon monoxide (CO). Water (H_2O) is also an oxide of a non-metal (hydrogen) and is neutral.

Example:

- White phosphorus is extremely reactive and **spontaneously** catches fire in air. So, it is stored under water as a safety measure.

Chlorine Reacts with Water (Partial Reaction)

Though most non-metals don't react with water, chlorine, a halogen, partially reacts with water to form a mixture of acids:

Chlorine + Water ⇌ Hydrochloric Acid (HCl) + Hypochlorous Acid (HOCl)

- This reaction is important in water purification because hypochlorous acid acts as a **disinfectant**, killing germs.

Examples and Applications

- Burning sulfur in air to form sulfur dioxide.
- Burning charcoal or coal to form carbon dioxide.
- Phosphorus catching fire in air, forming phosphorus pentoxide.
- Sulfur dioxide dissolving in water to form an acidic solution that turns blue litmus paper red.
- Chlorine used in swimming pools and water tanks to kill bacteria.

Keywords

Spontaneously: When something happens on its own, suddenly and naturally, without any outside action.

Disinfectant: A chemical substance that kills germs and helps keep things clean and safe.

Summary Table

Non-metal	Reaction with Oxygen	Product Formed	Nature
Sulfur	Burns in air	Sulfur Dioxide (SO_2)	Acidic
Carbon	Burns in air	CO_2 (or CO)	Acidic
Phosphorus	Catches fire in air	Phosphorus Pentoxide	Acidic
Chlorine	Partially reacts with water	HCl + HOCl	Acidic
Sulfur Powder	No reaction with water	__	__

Common Misconceptions

× **Misconception:** All non-metal oxides are acidic.

✓ **Correction:** While most non-metal oxides are acidic, some are neutral (e.g., CO, NO, N_2O, H_2O). These neutral oxides do not form acids when dissolved in water and do not affect litmus paper.

× **Misconception:** Non-metals never react with water.

✓ **Correction:** While it's a general rule that non-metals don't react with water, some, like halogens (e.g., chlorine), do react with water to some extent. The statement "generally do not react" is more accurate.

Science Around You

Acid Rain: Oxides of sulfur (sulfur dioxide) and nitrogen (nitrogen oxides), released from burning fossil fuels in industries and vehicles, dissolve in atmospheric water to form acids (sulfuric acid, nitric acid). This falls as acid rain, which damages buildings, harms aquatic life, and affects soil.

Carbonated Drinks: Carbon dioxide (a non-metal oxide) is dissolved in water under pressure to make fizzy drinks (carbonic acid).

Disinfection: Chlorine (a non-metal) is used to disinfect water. Its reaction with water produces substances that kill harmful microorganisms.

Storage of Phosphorus: White phosphorus is stored under water due to its high reactivity with air.

Activity

Investigating the Nature of a Non-metal Oxide

- **Materials Required:** Powdered sulfur, a deflagrating spoon (or a metallic bottle cap with a wire handle), a spirit lamp or burner, a gas jar or glass tumbler with a lid, water, blue and red litmus paper (or universal indicator solution).
- **Caution:** This activity must be performed by the teacher or under strict supervision in a well-ventilated area or fume hood. Sulfur dioxide gas is irritating and harmful if inhaled.
- **Procedure:**
  1. Take a small amount of powdered sulfur in the deflagrating spoon.
  2. Heat the sulfur on the flame until it starts burning (it melts and then ignites, often with a faint blue flame).

3. Quickly introduce the spoon with burning sulfur into the gas jar and cover it with the lid to collect the gas (sulfur dioxide) produced.
4. After a few minutes, when the jar is filled with fumes, carefully remove the spoon.
5. Add a small amount of water (about 10-20 ml) into the gas jar, quickly replace the lid, and shake well to dissolve the gas in water.
6. Test the solution formed with blue litmus paper and red litmus paper.

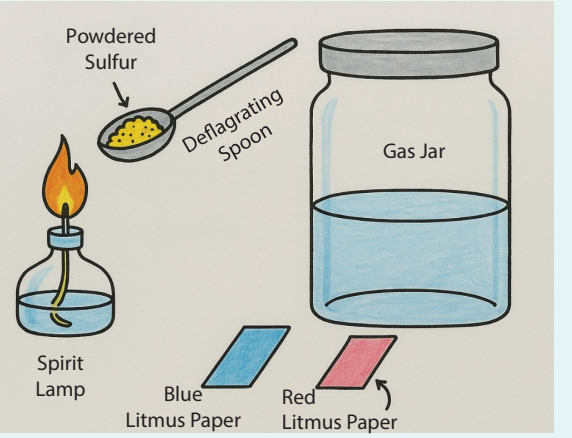


Fig. 4.36 Materials Required

- **Observation:**

The blue litmus paper will turn red, indicating that the solution is acidic. The red litmus paper will show no change (or may become a slightly brighter red). This shows that sulfur dioxide (a non-metal oxide) dissolves in water to form an acid (sulfurous acid)

Knowledge Checkpoint

Gap Analyzer™ Homework | Watch Remedial

Multiple Choice Questions:

Remembering

1. When non-metals react with oxygen, they generally form:

a) Non-metal hydroxides ☐ b) Non-metal carbonates ☐

c) Non-metal oxides ☐ d) Non-metal hydrides ☐

2. Which gas, when dissolved in water, forms sulfurous acid?

a) Carbon dioxide ☐ b) Sulfur dioxide ☐

c) Nitrogen dioxide ☐ d) Oxygen ☐

Understanding

3. The oxides of non-metals are generally _____ in nature.

a) Acidic ☐ b) Basic ☐

c) Neutral ☐ d) Amphoteric ☐

Short Answer Question:

4. Write a word equation for the reaction of carbon with excess oxygen. What is the nature of the oxide formed?
5. Why is white phosphorus stored under water?

Analyzing

Long Answer Question:

6. Describe how non-metals react with oxygen, giving at least two examples. Explain how you would demonstrate that non-metal oxides are generally acidic in nature. Discuss one environmental consequence of the formation of certain non-metal oxides.

SUMMARY

1. **Properties of Materials**

- **Lustre:** How shiny a material is (e.g., metals like gold are shiny; non-metals like wood are dull).
- **Hardness:** How resistant a material is to scratching or cutting (e.g., most metals are hard; many non-metals are soft, but diamond, a non-metal, is very hard).
- **Malleability:** The ability to be hammered into thin sheets (e.g., aluminium can be made into foil; non-metals like coal are brittle and break).
- **Ductility:** The ability to be drawn into wires (e.g., copper is used for wires; non-metals cannot be made into wires).
- **Sonority:** The ability to produce a ringing sound when struck (e.g., metal bells are sonorous; wood makes a dull sound).
- **Conduction of Electricity:** How well a material allows electricity to pass through it (metals are good conductors, like in electrical wires; non-metals are poor conductors, except for graphite).

Understanding these properties helps us choose the right materials for everything from jewellery to electrical wires to cooking pots.

2. **Reaction of Metals with Air (Oxygen) and Water**

- **Reaction with Oxygen:** Most metals react with oxygen to form metal oxides. For example, when iron is exposed to oxygen and moisture, it forms rust (iron oxide). Magnesium burns in air to form magnesium oxide. Metal oxides are generally basic in nature, meaning they can turn red litmus paper blue when dissolved in water.
- **Reaction with Water:** The reaction of metals with water varies greatly.
  - Highly reactive metals like sodium and potassium react vigorously with cold water, producing hydrogen gas and a lot of heat.
- **Corrosion:** This is the gradual destruction of metals due to reactions with their environment. Rusting (of iron) is a common example, requiring both oxygen and water. Corrosion can be prevented by painting, oiling, galvanizing (coating with zinc), or alloying (mixing metals, like in stainless steel). Other metals also corrode, like copper forming a green patina and silver turning black.

3. **Reaction of Non-metals with Air (Oxygen) and Water:**

- **Reaction with Oxygen:** Non-metals react with oxygen (often when burned) to form non-metal oxides. For instance, sulfur burns to form sulfur dioxide, and carbon burns to form carbon dioxide. Non-metal oxides are generally acidic in nature, meaning they can turn blue litmus paper red when dissolved in water (forming acids like sulfurous acid or carbonic acid).
- **Reaction with Water:** Generally, non-metals do not react with water under normal conditions.
  - Chlorine is an exception; it partially reacts with water, and this reaction is useful for disinfecting drinking water and swimming pools.

Example Based Questions

Multiple Choice Questions

1. Which of the following is a property of metals?

(a) Poor conductor of electricity
(b) Dull appearance
(c) Malleable and ductile
(d) Breaks easily when hammered

Answer: (c) Malleable and ductile

Explanation: Metals can be beaten into thin sheets (malleability) and drawn into wires (ductility). Non-metals are usually brittle and dull.

2. Which metal reacts with oxygen to form a layer of rust?

(a) Gold (b) Silver
(c) Iron (d) Copper

Answer: (c) Iron

Explanation: When iron reacts with oxygen and moisture, it forms iron oxide (rust). This weakens iron structures, making rust prevention very important.

3. Which non-metal is essential for breathing and supports combustion?

(a) Carbon (b) Oxygen
(c) Sulphur (d) Nitrogen

Answer: (b) Oxygen

Explanation: Oxygen is a non-metal. It is essential for respiration in living beings and supports burning (combustion), making it one of the most important elements for life.

Short Answer Questions

4. Why are cooking utensils made of metals but not of non-metals?

Answer:

Metals like copper, aluminium, and steel are good conductors of heat and electricity, allowing food to cook evenly. They are also strong and durable. Non-metals like wood or plastic are poor conductors and would burn or melt, so they are unsuitable for cooking utensils.

5. Why is gold used in making jewellery while iron is not?

Answer:

Gold is shiny (lustrous), does not rust, and is malleable, making it perfect for jewellery. Iron, on the other hand, rusts when exposed to air and water, losing its shine and strength. That is why iron is used in construction but not in ornaments.

6. Write one difference between the reaction of metals and non-metals with oxygen.

Answer:

- Metals react with oxygen to form metal oxides, which are generally basic in nature. **Example:** Magnesium + Oxygen → Magnesium oxide (basic).
- Non-metals react with oxygen to form non-metal oxides, which are generally acidic. **Example:** Sulphur + Oxygen → Sulphur dioxide (acidic).

Long Answer Questions

7. Explain the main physical properties of metals and non-metals with examples.

Answer:

- **Metals:**

1. Malleable: Can be hammered into thin sheets (Aluminium foil).
2. Ductile: Can be stretched into wires (Copper wires).
3. Good Conductors: Allow heat and electricity to pass (Aluminium, Copper).
4. Lustrous: Shiny appearance (Gold, Silver).

- **Non-metals:**

1. Brittle: Break easily (Sulphur, Phosphorus).
2. Poor Conductors: Do not conduct heat/electricity (Carbon in diamond is an exception).
3. Dull: Lack shine (Coal, Sulphur).
4. Lightweight: Many non-metals are gases (Oxygen, Nitrogen).

Conclusion: These differences explain why metals are used in wires, utensils, and machines, while non-metals are used in fuels, medicines, and fertilizers.

EXERCISE

Gap Analyzer™
Complete Chapter Test

A. Choose the correct answer.

1. Which property allows metals to be drawn into thin wires?
   (a) Malleability ☐ (b) Sonority ☐
   (c) Ductility ☐ (d) Lustre ☐
2. A substance breaks into pieces when hammered. This substance is likely to be:
   (a) Aluminium ☐ (b) Copper ☐
   (c) Coal ☐ (d) Iron ☐
3. An electrician wears rubber gloves while working because rubber is:
   (a) A good conductor of electricity ☐ (b) A poor conductor of electricity ☐
   (c) Malleable ☐ (d) Ductile ☐
4. The green coating on copper objects exposed to moist air is an example of:
   (a) Rusting ☐ (b) Galvanisation ☐
   (c) Corrosion ☐ (d) Alloying ☐
5. When magnesium ribbon burns in air, the white powder formed is:
   (a) Magnesium sulfide ☐ (b) Magnesium oxide ☐
   (c) Magnesium carbonate ☐ (d) Magnesium hydroxide ☐

B. Fill in the blanks.

1. The property of metals by which they can be beaten into thin sheets is called _____.
2. Metals are generally _____ conductors of heat and electricity.
3. The brown deposit formed on iron when exposed to moist air is called _____.
4. _____ is a non-metal that is essential for the growth of plants and is used in fertilisers.
5. Oxides of metals are generally _____ in nature.

C. Write True or False.

1. All metals are solid at room temperature. ____
2. Non-metals are generally good conductors of electricity. ____
3. Coal can be drawn into wires. ____
4. Rusting of iron is a chemical change that requires only dry air. ____
5. Silver foils are used for decorating sweets because silver is highly malleable. ____

D. Define the following terms.

1. Malleability
2. Ductility
3. Sonority
4. Galvanisation
5. Rusting

E. Match the columns.

	Column A		Column B
1.	Product of iron rusting	(a)	Basic in solution (iron oxide)
2.	Product of sulfur burning	(b)	Acidic in solution (sulfur dioxide)
3.	Highly reactive metal	(c)	Sodium
4.	Non-metal for disinfection	(d)	Used in water purification (Chlorine)
5.	Building block of life	(e)	Carbon

F. Assertion and Reason

Instructions: In the following questions, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is NOT the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

1. **Assertion:** Iron articles rust when exposed to moist air.
   Reason: Both oxygen and water are necessary for rusting.
2. **Assertion:** Cooking utensils are usually made of copper or aluminium.
   Reason: Metals are generally poor conductors of heat.
3. **Assertion:** Gold is widely used for making jewellery.
   Reason: Gold is highly ductile, malleable, and lustrous.

G. Give reasons for the following statements.

1. The handles of cooking utensils are often made of wood or plastic. Explain why this is done.
2. A school bell makes a loud ringing sound when it is struck. Explain why this happens.
3. Aluminium foil is commonly used for wrapping food items. Explain the reason behind this choice.
4. An iron nail begins to rust if it is left outside in the rain. Explain why this occurs.
5. Copper wires are widely used in electrical fittings and circuits. Explain why they are preferred.

H. Answer in brief.

1. Differentiate between metals and non-metals based on their malleability and ductility.
2. What happens when magnesium burns in air? What is the nature of the product formed? How can you test it?
3. Explain the process of rusting. What are the essential conditions for it?
4. List three common uses of non-metals in our daily life, explaining their importance.
5. Why is it said that the Iron Pillar of Delhi is a “wonder of ancient Indian metallurgy”?

I. Answer in detail.

1. What are metals and non-metals? Describe their main physical and chemical properties with examples.
2. Compare and contrast the reaction of metals (like magnesium) and non-metals (like sulfur) with oxygen. How do the properties of their oxides differ?
3. What roles do important non-metals like oxygen, nitrogen, and carbon play in our daily lives and the environment?

SKILL-BASED PRACTICE

Activity Time

STEM

Objective: Investigate material properties and observe simple chemical changes.

Materials Needed: Iron nail, aluminium foil, charcoal/wood, plastic item, copper coin/wire, candle & matchbox (adult supervision), small bowl of water, notebook.

Materials Required

Activity Steps:

- **Check Properties:** For each sample, note its shine, bendability (malleable/brittle), sound when tapped, and relative hardness.
- **Observe Rust:** Place an iron nail in water (partly exposed to air) for a few days. Note changes.
- **Burning:** (Adults only) Light a candle. Observe melting wax (physical change) and burning flame (chemical change).

Questions:

1. How did you classify materials as metals or non-metals based on properties?
2. What caused the iron nail to change? Was this physical or chemical?
3. What signs showed a chemical change when the candle burned?

Skills Covered: Observation, Classification, Experimentation, Differentiating Changes

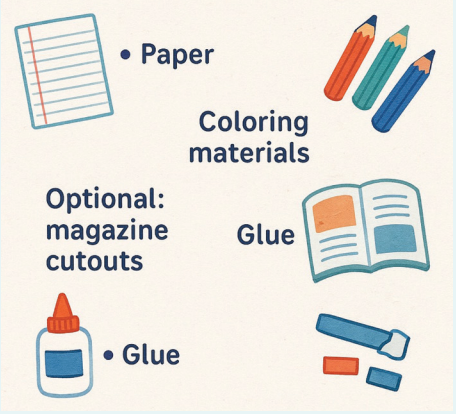
Creativity Art

Art

Metals vs. Non-Metals Poster

Objective: Visually contrast properties and common reactions of metals and non-metals.

Materials: Paper, coloring materials, optional: magazine cutouts, glue.



Materials Required

Create Your Poster: Design a poster showing:

- **Metals:** Illustrate 2-3 key properties (e.g., shiny, malleable) and a reaction (e.g., rusting). Note: metal oxides are usually basic.
- **Non-Metals:** Illustrate 2-3 contrasting properties (e.g., dull, brittle) and a reaction (e.g., carbon burning). Note: non-metal oxides are usually acidic. Use labels and simple diagrams.

Questions:

1. How did your visuals show the main differences between metals and non-metals?
2. Why is the acidic/basic nature of their oxides an important distinction?
3. Give one real-life example from your poster where understanding a metal's (or non-metal's) property or reaction is useful.

Group Material Sort & Predict

Group Activity

- **Objective:** Classify materials by properties and predict their reactions with oxygen.
- **Materials (per group):** 5-6 varied small items (e.g., steel spoon, aluminium can, coal, plastic bottle, wood), chart paper, markers.

1. **Sort Items:** Examine each item. Record its lustre, malleability/brittleness, and hardness. Group items as "Likely Metals" or "Likely Non-Metals" on your chart, giving reasons.
2. **Predict Reactions:**

- **Choose one "Metal":** Predict its reaction with oxygen (e.g., rusting) and the nature (acidic/basic) of its oxide.
- **Choose one "Non-Metal":** Predict its reaction with oxygen (e.g., burning) and the nature (acidic/basic) of its oxide.

Questions:

1. Which properties were most helpful for classifying your items?
2. What's a key difference between how metals and non-metals react with oxygen?
3. Why is it useful to know these different reactions?

Skills Covered: Scientific Testing, Data Interpretation, Teamwork, Environmental Awareness

The Frying Pan Mystery

Case Study

Read the given passage below and answer the question:

Rohan's mother is buying a new frying pan. She notices that the main body of the pan, where the food is cooked, is made of a shiny metal like aluminium or steel. However, the handle of the pan is made of a hard, black plastic or sometimes wood. Rohan wonders why the whole pan isn't made of the same material.

Questions:

1. What is the main purpose of the body of the frying pan ?
2. What property should the material for the body of the pan have to cook food efficiently?3. Metals like aluminium and steel are used for the body of the pan. Based on the chapter, are these good or poor conductors of heat?
4. What is the main purpose of the handle of the frying pan?

Skills Covered: Classification, Analysis, Teamwork, Communication, Scientific Investigation

How Metals Behave Under Pressure

Source Based Question

"New research from the University of Birmingham shows that the electronic structure of metals can strongly affect their mechanical properties. The research, published today (26th October) in the journal Science, demonstrates experimentally, for the first time, that the electronic and mechanical properties of a metal are connected. It was previously understood theoretically that there would be a connection, but it was thought that it would be too small to detect in an experiment."

Image Credit: ScienceDaily

Questions:

1. **Understanding Electronic vs Mechanical Properties**
   - What two properties of metals does the passage say are connected?
   - Why had this connection between electronic and mechanical properties been difficult to observe before?
2. **Significance of the Research**
   - Why is the discovery of this connection between electronic and mechanical properties important?
   - How did the researchers confirm what had only been theorized before?
3. **Critical Thinking**
   - Imagine you are a materials scientist. How could knowing the electronic structure help you design a lighter and stronger metal for smartphone bodies or bridges?
   - What challenges might scientists face if they try to apply this discovery on a large scale?

Skills Covered: Observation and analysis, Scientific reasoning, Classification and comparison