General Science

Year 1

SECTION

2

EXPLORING MATERIALS

EXPLORING MATERIALS

Science and Materials in Nature

INTRODUCTION

Imagine a world without solids, no clothing to wear, no smart phones to text your friends, no strong desks to sit on in class, and no bicycles and cars to ride through the park. Sounds awful, right? Well, thankfully, we live in a world filled with an incredible variety of solids, each with its own unique properties and uses. You are about to embark on a journey where you will classify and discover the hidden treasures within different types of solids. Now, think about this: What makes gold so precious, steel so strong, and crystals so fascinating? The answer lies in their composition and properties. In this section, you are not just going to admire these solids from afar. You are going to dive deep into the fascinating world of solids and explore how we can classify them based on their characteristics and discover the amazing ways they shape our lives.

At the end of this section, you should be able to:

- Classify different solids and their uses
- Apply the properties of solids to everyday use.
- Discuss the relationship between binary compounds, the composition of binary compounds and the names of compounds.

Learners at the end of this section will be able to:

- Identify the first 20 elements on the periodic table.
- Identify and classify solids into Metals, Semi-metals, and Non-metals.
- Describe the Properties of Metals, Semi-metals, and Non-metals.
- Outline and explain the Uses of Metals, Semi-metals, and Non-metals
- Identify and describe the properties of solids
- Classify solids based on their uses/properties
- Analyse and describe how the properties of these solids are applied to their everyday use

- Explain binary compounds and identify their general characteristics
- Determine the composition of binary compounds, distinguishing between ionic and covalent binary compounds
- Categorise given compounds as either binary ionic or binary covalent based on their composition
- Predict the properties of binary compounds based on their composition
- Learn how to find the chemical formula of binary compounds.
- Learn how to name a binary compound.

Key Ideas:

- Materials are broadly categorised into metals, non-metals and semi-metals. Each having distinct compositions and characteristics such as conductivity, lustre, and hardness.
- An element is the smallest particle of a pure substance that cannot be broken down into any simpler substance by chemical reactions and is made up of one or more atoms of the same kind.
- The periodic table of chemical elements organizes all discovered chemical elements in rows (called periods) and columns (called groups) according to increasing atomic number.
- An element can be a solid, liquid or gas. A solid is a state of matter which has a definite shape and volume.
- Elements are broadly categorized based on their physical and chemical properties into metals, non-metals, and semi-metals.
- Reactivity: The tendency of a metal to undergo chemical reactions, such as oxidation or displacement reactions.
- Corrosion: The deterioration of metals due to chemical reactions with substances in their environment, such as oxygen or moisture or acid.
- Solids have wide applications and uses in everyday life such as metals for construction, ceramics for electronics, and plastics for packaging.
- Solid materials – refer to substances or objects with a definite/fixed shape and volume.
- Properties of materials:

- Conductivity
- Magnetism
- Lustre
- Melting point
- Boiling point
- Density

- Binary compounds are chemical compounds composed of exactly two different elements.
- Binary compounds are grouped into two categories: Binary ionic compounds and binary covalent compounds.
- Binary ionic compounds are composed of a metal and a non-metal (e.g., NaCl, MgO, CaCl2).
- Binary covalent compounds are composed of two non-metals (e.g., CO_2, H_2O).
- The composition of a binary compound dictates its name.
- Binary compounds are widely used in daily life (e.g., water, table salt, carbon dioxide).
- The chemical formula for a binary compound can be determined by considering the valencies of the ions of which it is made. Once the chemical formula is established the compound can be named and is derived from the names of the two constituent ions.

THE PERIODIC TABLE OF ELEMENTS

What is a chemical element?

Figure 2.1: Some common elements

Activity 1:

What you need: pen/pencil, exercise book

What to do: Work alone or with up to 5 friends.

1. Identify five other elements apart from the ones in the picture above that you are familiar with.
2. Make a list of five items each found in your school and home and identify the elements they are made up of.
3. What is an element and how many do you know? Note – answer in Annex 1.

The Periodic Table

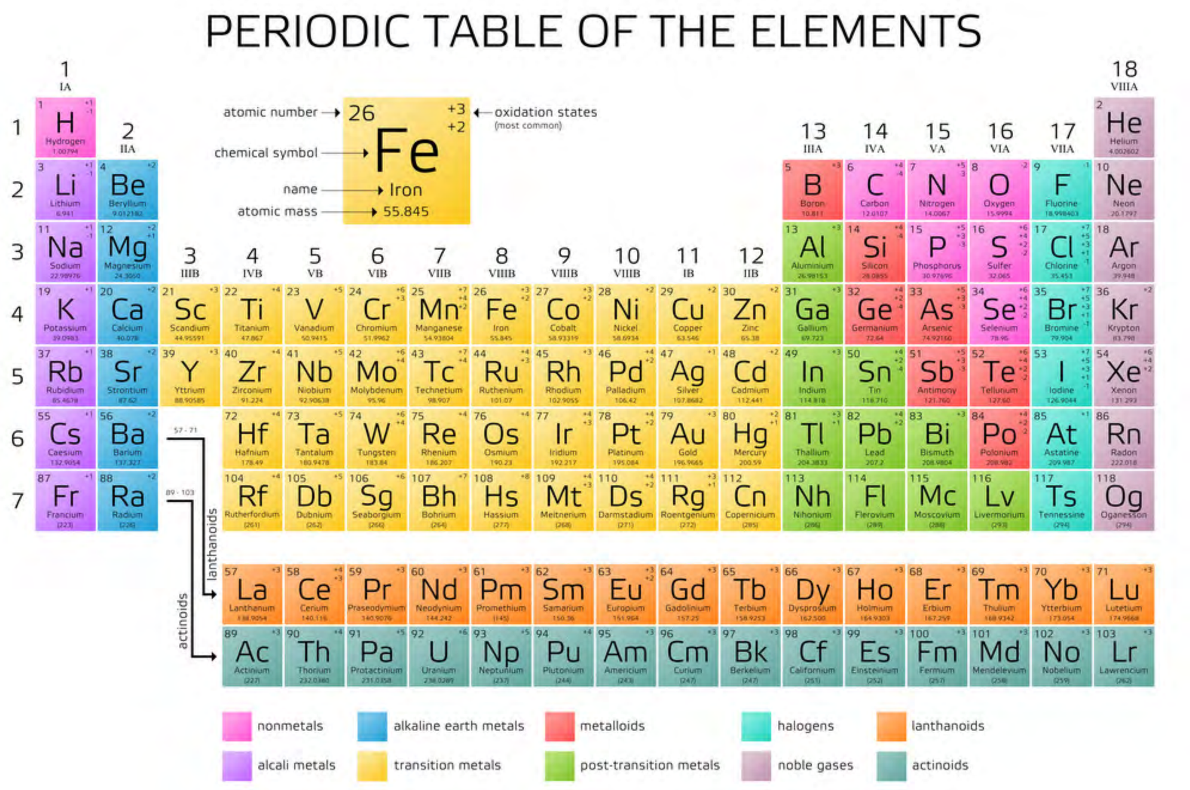


Figure 2.2: Periodic Table of elements.

The picture above shows a period table of elements. Take some time and carefully examine it.

The Periodic Table helps scientists to classify elements based on their chemical and physical properties into metals, non-metals, and semi-metals.

Elements in the same vertical column, is known as a group. "They share similar chemical properties because they have the same number of valence electrons." ("What are the vertical columns of a periodic table called?") Valence electrons are the electrons in the outermost shell (energy level) of an atom. Elements in the same horizontal row, known as a period, have the same number of shells (principal energy level) but different numbers of valence electrons. As you move across a period (from left to right or vice versa) the properties of elements change gradually. Tell your friend what this changes are.

Hello learner, it is time for an activity!

Activity 2

Scenario: Imagine you're a scientist carrying out a research in a laboratory. Your task is to study the properties and characteristics of the first 30 elements in the Periodic Table. You have access to various samples of these elements and state-of-the-art equipment to analyse them.

What you need: periodic table, pen/pencil, exercise book, ruler

What to do: Work alone or in a mixed group of not more than five learners.

Task:

1. What are the atomic numbers and symbols of the first 30 elements?
2. Identify the groups and periods to which each element belongs.
3. Examine the common properties shared by elements within the same group.
4. How do the properties of elements change as you move across a period?
5. Classify each element as a metal, non-metal, or metalloid based on its properties?
6. Identify some everyday uses of these elements.

Groups 1, 2 and 7

Group 1 elements known as alkali metals share similar properties such as high reactivity due to having one valence electron. They are so called because they react violently with water to form strong soluble bases. They are very soft and silver-like lustre. Using the periodic table find out more about them.

Group 2 elements known as alkaline earth metals have two valence electrons and are highly reactive but less reactive than alkali metals. They have a gray-white lustre when freshly cut but tarnish readily in air,

Group 7 elements also known as halogens (meaning salt makers) are highly reactive non-metals with seven valence electrons. At room temperature and atmospheric pressure the halogens in their free states exist as diatomic molecules. Research the definition of the term 'diatomic'.

The semi-metals are found in the middle of the periodic table. They have varying numbers of valence electrons and exhibit a wide range of chemical behaviours.

Periodic Table: Fast Facts

- The Periodic Table is a graphical collection of element data.
- The table lists the chemical elements in order of increasing atomic number, which is the number of protons in an atom of an element.
- The rows (periods) and columns (groups) organize elements according to similar properties. For example, all of the elements in the first column are reactive metals that have a valence of +1.
- All elements in a row have the same outermost electron shell.

METALS, NON-METALS, AND SEMI-METALS (METALLOIDS)

Welcome to the fascinating world of elements, which are broadly categorised into three distinct groups: metals, non-metals, and semi-metals (metalloids).

Imagine a bustling marketplace where each element sets up its own stall, showcasing its identity and attractiveness. Picture gleaming metals catching the sunlight, sturdy and dependable. Contrast that with the subtle elegance of non-metals, with their diverse forms and functions. And then there are the puzzling semi-metals, straddling the line between two worlds, embodying the best of both.

Metals

Metals, the true rock stars of the elemental world, comprise roughly about 70% of known elements located on the left-hand side of the periodic table. They are elements that donate electrons in a chemical reaction to form cations. *Eg*. Li, Na, K, Be, Mg and Ca.

Figure 2.3: Some common metals

They dazzle us with their thermal and electrical conductivity, malleability, ductility and strength. From the gold and silver in our jewellery to the stainless steel utensils in our kitchens, metals shape our world with their resilience and versatility.

Physical properties of metals

1. Metals are solids at room temperature except mercury and gallium which are liquids at room temperature.
2. Metals are lustrous. They have the quality of reflecting light from its surface and can be polished e.g. gold, silver, and copper.
3. Metals are malleable. They have the ability to be beaten into different shapes without breaking into pieces.
4. Metals are ductile. They can be drawn into flexible wires.
5. All solid metals are hard except alkali metals (sodium, rubidium, caesium, lithium, and potassium) which are soft and can be cut with a knife.
6. Metals have 1 to 3 electrons in the outermost shell of their atoms. They form cations by donating the electrons in their valence shells.
7. Metals are good conductors of heat and electricity because they have free electrons. Silver and copper are the two best conductors of heat and electricity. Lead is the poorest conductor of heat. Bismuth, mercury, and iron are also poor conductors.
8. Metals are very heavy and have high densities. Iridium and osmium have the highest densities while lithium has the lowest.
9. Metals have high melting and boiling points.
10. Some metals are sonorous (they produce a sharp ringing sound when hit by an object.)

Very good learners, You will do an activity!

Activity 3:

Scenario: Imagine you're a budding scientist working in a laboratory, eager to explore the fascinating world of thermal conductivity in metals. Your task is to design and conduct an experiment that demonstrates how different metals conduct heat.

Aim: To investigate the thermal conduction properties of a selection of metals.

What you need: source of heat (e.g.. Bunsen burner, coal pot), Vaseline or Shea butter, copper, iron, brass, and aluminium rods (you can use stainless steel in place of brass rods. You can also get the metals from household items such as canned drinks, iron nails, copper wire. Ensure that the sizes of rods/strips used are the same.) stopwatch, drawing pins, tripod stand, cardboard or paper, matches.

What to do:

1. Stick the flat end of a drawing pin to the end of each metal rod using the Vaseline/shea butter. Try to use the same amount for each drawing pin.
2. Place the cardboard on the tripod (this insulates the metal rod from the metal tripod).
3. Balance the metal rods on the cardboard so that one end is over the Bunsen burner but not too close that it catches fire.
4. Light the Bunsen burner.
5. Using a stopwatch, time how long until each pin drops off.
6. Record your results in a table.

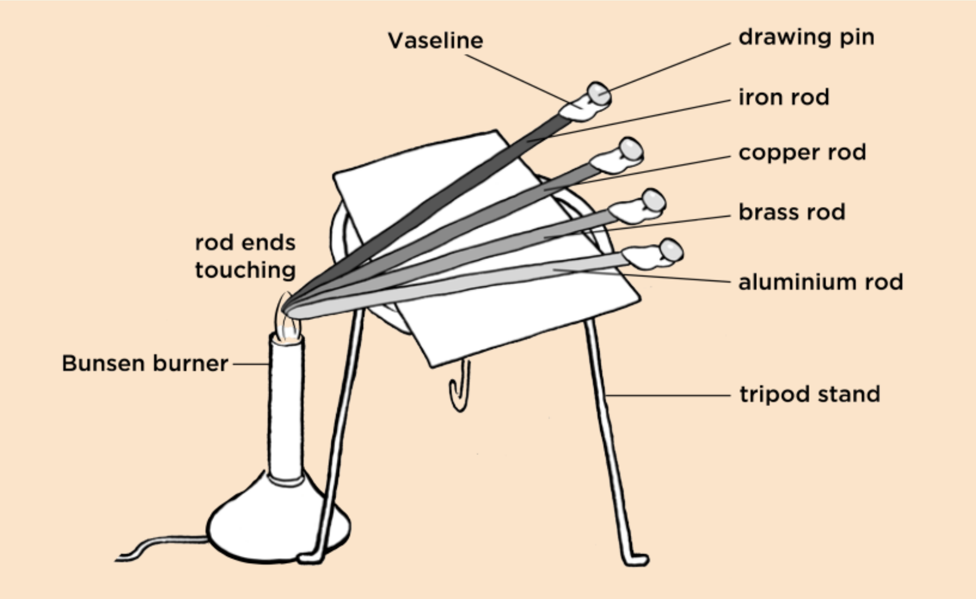


Figure 2.4: Experimental set-up for thermal conductivity of metals.

Results and recording: Record your results in the following table

Type of metal	Time taken for pin to drop off (seconds)
Iron	
Copper	
Brass	
Aluminium	

Write down your observations and conclusions.

Key Questions:

1. Which metals exhibited the fastest temperature increase along their length, indicating higher thermal conductivity?
2. How did the rate of temperature change vary between different metals?
3. Were there any observable differences in thermal conductivity among metals with similar physical properties?
4. How did the thickness or surface area of the metal samples affect their thermal conductivity?
5. What real-world applications or implications does the observed variation in thermal conductivity have for different metals?
6. How would you modify the experiment to investigate additional factors influencing thermal conductivity, such as temperature gradients or surface treatments?

Hope you enjoyed the experiment. Great, let us do another one!

Activity 4:

Scenario: Imagine you are a metal specialist conducting an experiment to demonstrate the malleability of metals. Malleability refers to the ability of a material to deform under pressure without breaking, allowing it to be shaped into various forms. Your task is to design and conduct an experiment that investigates the malleability of metal

Aim: to investigate the malleability of different metals by striking them with a hammer.

What you needed: Pieces of iron, zinc, lead, and copper, hammer, an anvil, or solid block of iron to act as an anvil. You can also include a non-metallic control sample for comparison, such as plastic or ceramic.

Task:

1. Note the initial shape and measurement of each piece of metal.
2. Take a piece of iron and place it on the block of iron or anvil.
3. Strike the piece of iron five times with a hammer.
4. Observe and record any changes in the shape of the piece of iron.
5. Repeat the same process with pieces of zinc, lead, and copper.

6. Conduct multiple trials for each metal sample to ensure consistency and reliability of results. Take measurements and observations at regular intervals during each trial.
7. Record observations and note any differences in how each metal changes shape.
8. Repeat the experiment using a non-metallic control sample (e.g., plastic or ceramic) to compare its behaviour under pressure with that of the metal samples.

Write down your observations and conclusions.

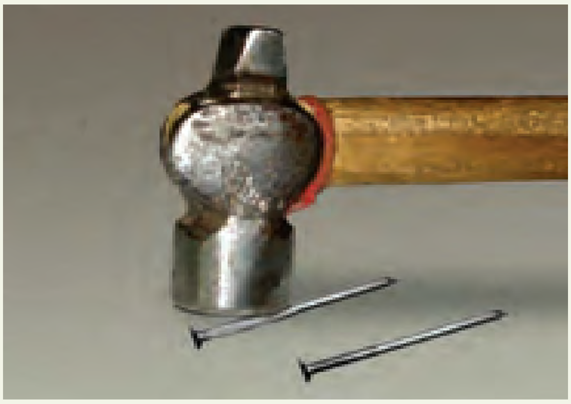


Figure 2.5: Striking an iron nail with a hammer.

Key Questions:

1. Which metals exhibited the greatest degree of deformation under pressure, indicating higher malleability?
2. How did the amount of pressure required to deform each metal sample compare to its malleability?
3. Were there any observable differences in the behaviour of metals with similar physical properties, such as density or atomic structure?
4. Did the control sample (non-metallic) exhibit similar deformation characteristics under pressure, or was there a noticeable difference compared to the metal samples?
5. How does the malleability of metals contribute to their usefulness in various applications, such as metalworking, construction, or manufacturing?
6. How would you modify the experiment to investigate additional factors influencing the malleability of metals, such as temperature or alloy composition?

Observation: Metals have varying degrees of malleability and there should be a range of deformations amongst the four metals being investigated here: copper and lead are more malleable than zinc or iron.

Conclusion: metals can be hammered into different shapes.

Hello learner, how was that activity? Interesting, isn't it? Good. You will continue with the next activity.

Activity 5:

Scenario: Imagine you are an architect conducting an experiment to showcase the lustrous nature of metals for a big project. The lustre of a material refers to its ability to reflect light, resulting in a shiny or glossy appearance. Design and conduct an experiment to help you select lustrous metals for your project.

Aim: To compare the lustre of different metals.

What you need: Samples of iron, copper, aluminium, gold, silver and sandpaper. Plastic, ceramic, wood. Ensure that the samples are clean and free from tarnish or corrosion. A bright light source, such as a lamp or flashlight, to provide uniform illumination for the experiment. A dark non-reflective surface to be used for the testing.

What to do:

1. Observe and note the appearance of each metal sample under normal ambient lighting conditions. Note any inherent lustre or shine present on the surface of the metals.
2. Clean the surface of each sample by rubbing it with sandpaper.
3. Position the light source at an angle relative to the metal samples, ensuring that the light reflects off the surface of the metals.
4. Observe and note any changes in appearance of the samples.
5. Repeat the experiment using non-metallic materials, such as plastics, ceramics, or wood, as control samples. Note any differences in the appearance and reflectivity of the non-metallic materials compared to the metals.

   Write down your observations and conclusions.

Key Questions:

1. Which metals exhibited the most pronounced lustre or shine when exposed to direct light, and why?

2. Were there any noticeable differences in lustre among metals with similar physical properties, such as density or atomic structure?
3. Did the non-metallic control samples exhibit any lustre or reflective properties similar to the metals, or was there a distinct difference in appearance?
4. How does the lustrous nature of metals contribute to their aesthetic appeal and value in various applications, such as jewellery, architecture, or decorative arts?
5. How would you modify the experiment to investigate additional factors influencing the lustre of metals, such as surface finish, alloy composition, or surface treatment?

Good job learners. Now let us explore on the hardness of metals in the next activity.

Activity 6:

Scenario: Imagine you are a materials scientist tasked with conducting an experiment to demonstrate the hardness of metals. Hardness refers to a material's ability to withstand deformation, indentation, or scratching when subjected to external forces. Design and conduct your experiment.

Aim: To demonstrate the hardness of metals compared with other non-metal materials

What you need: Various objects made of varied materials (e.g., metal spoon, key, rubber band, plastic ruler, piece of cloth, wood), a coin.

What to do:

1. Place each metal sample on the testing surface and position the hardness testing device directly above it (in this experiment you can use a coin). Apply a controlled force to the surface of the metal sample using the coin, ensuring uniform pressure across the entire surface. Try to scratch the surface of each object with the coin.
2. Record your observations.
3. Repeat the experiment using non-metallic control samples, such as plastics, ceramics, or wood, to compare their hardness properties with those of the metal samples.

Write down your observations and conclusions. Try to explain these using your scientific knowledge of metals.

Key Questions:

1. Which metals exhibited the highest resistance to indentation or deformation when subjected to the applied force, indicating greater hardness?
2. How did the observations obtained for each metal sample compare to their known hardness ratings or properties?
3. Were there any noticeable differences in hardness among metals with similar physical properties, such as density or atomic structure?
4. Did the non-metallic control samples exhibit similar hardness properties to the metals, or was there a distinct difference in resistance to deformation?
5. How does the hardness of metals influence their suitability for specific applications, such as cutting tools, machinery components, or structural materials?

How would you modify the experiment to investigate additional factors influencing the hardness of metals, such as alloy composition, heat treatment, or surface finish?

Well done learner! Let us take a dive into the chemical properties of metals.

Chemical Properties of Metals

Reactivity: This is the ability of metals to undergo chemical reactions with oxygen, water or acids. Metals vary in their reactivity with oxygen, water or acids. Some metals, like zinc and aluminium, react with acids to produce hydrogen gas and a metal salt. Others are resistant to reaction. Some metals are more reactive than others and can be ordered into a reactivity series from most to least reactive (e.g., Mg, Al, Zn, Fe, Sn)

Let us do an activity!

Activity 7:

Scenario: Assume you are a chemist tasked with creating a metal reactivity series to predict the relative reactivity of different metals. Design and conduct your experiments to verify the reactivity series of samples of metals.

Aim: To show the reaction of metals with acids.

What you need: sample metals e.g., magnesium, zinc, iron, copper, and lead, test tubes, dilute HCl, test tube rack, matches or splint

What to do:

1. Obtain samples of several metals, including magnesium, zinc, iron, copper, and lead.
2. Prepare and label test tubes containing solutions of dilute hydrochloric acid.
3. Place small pieces of each metal into a labelled test tube and observe the reactions.
4. Record your observations, noting any effervescence (formation of bubbles), colour changes, or the release of gas.
5. Test bubbles with a flaming splint and observe a pop sound.
6. Based on your observations, arrange the metals in order of decreasing reactivity, creating a metal reactivity series.

Write down your observations and conclusions.

Hello learner, well done with the experiment. Let us turn our attention now to *corrosion*.

What is corrosion?

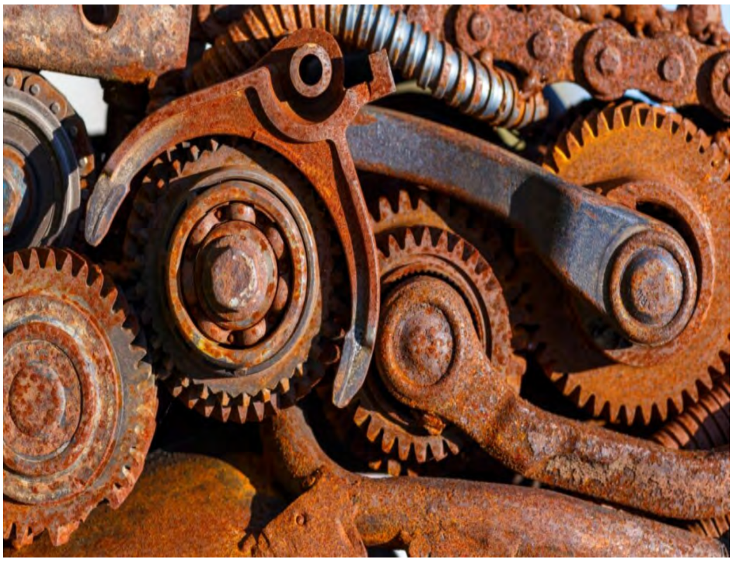


Figure 2.6: metal parts under going rusting

Look at the picture above and write your observations. You may discuss with your friends. If you work in groups, the should not be more than 5 members. Cite examples of similar situations in your environment and discuss with your group.

Corrosion

Many metals undergo corrosion. It is a chemical reaction with substances in the environment that leads to the deterioration of the metal. Iron, for example, corrodes to form rust in the presence of oxygen and water.

Corrosion is a natural chemical process (oxidation) that occurs when a metal reacts with oxygen/air in the presence of water to form an oxide. Rusting refers specifically to the corrosion of iron or steel (an alloy of iron). Other metals such as aluminium can also corrode.

Formation of Alloys

Metals can form alloys which are mixtures of two or more metals or a metal and a non-metal. Alloying often enhances the properties of metals such as increased strength or resistance to corrosion.

Hello learners, you will explore the uses of metals!

Uses of metals

- Gold, silver, platinum, and copper are widely used in jewellery.
- Iron and steel (an alloy of iron) are widely used in building and home construction.

- Cooking utensils are best made from metals like steel, aluminium, and copper.
- Sodium (Na), potassium (K), magnesium (Mg), and many others are available as micro-nutrients in our body.
- Iron, steel, titanium and aluminium are used in machinery and auto-mobile construction.

Dear learner, surf the internet to find three further examples of the uses of metals.

Activity 8:

Scenario: Imagine you are a Chemist studying the corrosion of iron in different environmental conditions. Design and conduct an experiment to investigate the corrosion of iron.

Aim: To demonstrate the conditions necessary for rusting of iron

What you need: Test tubes, iron nails, cork, distilled water, oil, Anhydrous calcium chloride.

What to do:

1. Take three test tubes and place clean iron nails in each
2. Label these A, B, and C.
3. Pour some water into a test tube A and cork it. The water should cover the nails.
4. Pour enough previously boiled and cooled water into test tube B to cover the nails, add about 1 ml of oil and cork it. The oil will float on water and prevent the oxygen from dissolving into the water. Boiling removes dissolved oxygen from the water.
5. Put approximately 5g of anhydrous calcium chloride in test tube C and cork it. Anhydrous calcium chloride will absorb any moisture from the air.
6. Leave the test tubes for a week and then observe and note the results.

Write down your observations and conclusions.

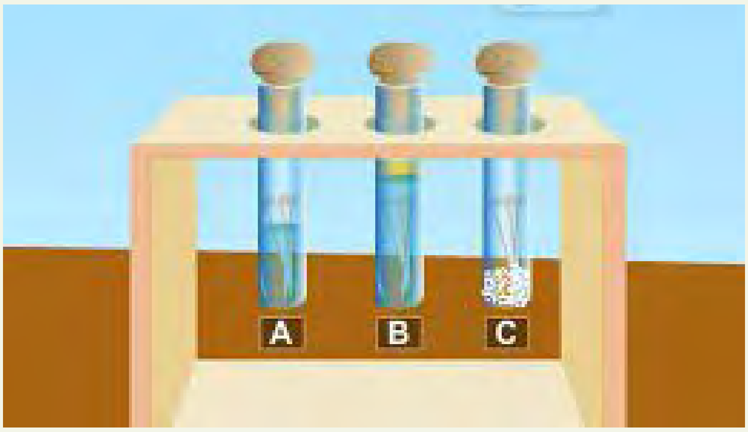


Figure 2.7: laboratory set-up for rusting experiment

https://www.youtube.com/watch?v=XMr4vse7Ybo

Key Questions

1. What was the role of the oil in test tube B?
2. How can you relate the oil in test tube B to the use of oil based paints on iron or steel based materials exposed to harsh weather conditions?
3. What are the mechanisms by which environmental conditions promote corrosion?

Great work done my dear learner. End the activity by researching the following ways in which the rusting of metals can be prevented:

1. Painting
2. Clear Coats and Sealants coating
3. Galvanising
4. Plating
5. Alloying
6. Keeping the metal in cool dry place
7. Desiccants
8. Let us explore the corrosion of iron a bit deeper.
9. Corrosion of Iron (Rusting)

Welcome learner, do you remember what you read about corrosion of metals? Yes, corrosion is said to happen when metals deteriorate due to a reaction between the metal and chemical elements within its environment. Corrosion in other metals are referred to as tarnish. However, corrosion in iron is referred to as rust.

Let us explore the chemical process of rust.

The chemical reaction involved in rusting can be represented as follows:

Iron (Fe) + Oxygen (O_2) + Water (H_2O) →Hydrated Iron (III) Oxide (Rust)

$4Fe + 3O_2 + 2H_2O \rightarrow 2Fe_20_3.H_2O$

From the chemical equation,

Conditions necessary for rusting to occur are:

1. Water (moisture)
2. Air (oxygen)

Rust is a reddish-brown coating that forms on the surface of the iron. It weakens the metal over time, causing it to deteriorate and lose its structural integrity. This process can be accelerated in warm, salt-water, or acidic conditions.

Non- Metals

Non-metals, from the essential oxygen we breathe to the vibrant carbon in all living things, play crucial roles in the chemistry of life and the environment. Non-metals are chemical elements that do not have the properties of a metal for example, Hydrogen (H), Helium (He), Carbon (C), Nitrogen (N), Oxygen (O). they are found on the right-hand side of the Periodic Table. They accept electrons from metals in a chemical reaction to become anions. They also share valence electrons to form covalent bonds.

Physical properties of Non-metals

1. ***Physical state***: Most non-metals exist in two of the three states of matter at room temperature: gases such as oxygen and solids such as carbon.
2. ***Low Ductility:*** Non-metals are usually very brittle and cannot be rolled into wires or pounded into sheets.
3. ***Poor conductivity:*** Non-metals are typically poor conductors of electricity and heat. However, graphite (a form of carbon) is a notable exception.
4. ***Poor lustre:*** Non-metals often have dull, non-reflective surfaces.
5. ***Low malleability:*** Solid non-metals cannot be easily hammered or pressed into different shapes without fracturing.

Chemical Properties

1. ***Reactivity:*** They form acidic or neutral oxides with oxygen. Non-metals tend to gain electrons in chemical reactions, making them reactive towards metals.
2. ***Electronegativity:*** They have higher electronegativity compared to metals, meaning they attract electrons more strongly.
3. ***Ionization:*** Non-metals easily gain electrons to form negative ions (anions) or share electrons to form covalent bonds.
4. ***Acidity:*** Many non-metals form acidic oxides when they react with oxygen, such as sulphur dioxide (SO_2) and carbon dioxide (CO_2).
5. ***Hydrogen Bonding:*** Non-metals like oxygen and nitrogen exhibit hydrogen bonding, influencing their properties in compounds.

Well done learners, let us explore the uses of non-metals. Great!

Uses of Non-metals.

- Nitrogen can be used as a food preservative and in light bulbs. Nitrogen and phosphorus are used in fertilizers to help plants grow. Nitrogen and phosphorus are used in fertilizers to help plants grow.
- Sulphur is used in making black gunpowder, matches, and fireworks. Sulphur is used to vulcanize rubber.
- Chlorine can be used as a bleaching agent and in the treatment of water to make it safe to drink.
- Hydrogen fuel cells generate electricity from oxygen and hydrogen.
- Oxygen used in space rockets as fuel, in respiration, in welding.
- Iodine is used as an antiseptic in a purple solution on wounds.
- Carbon in the form of Charcoal is used in the sugar industry for decolorization. Graphite another form of carbon is used to make pencil leads.
- Other materials: Non-metals are used to make gunpowder, fireworks, matches, rubber, cement, ceramics, glass, and lime products.

Well done my dear learner. Let us explore semi-metals.

Semi-Metals (Sometimes called Metalloids)

What are semi-metals?

Semi-metals are elements found along the “staircase” line in the periodic table, bordering the region between metals and non-metals. The semi-metals include boron, silicon, germanium, arsenic, antimony, and tellurium.

Semi-metals show some properties of both metals and non-metals making their classification intermediate between the two groups.

Properties of semi-metals

Conductivity of electricity: Partial conductivity - better than non-metals but not as good as metals.

Malleability: Intermediate between metals and non-metals

Ductility: Also intermediate between metals and non-metals.

State: All semi-metals are solid at room temperature

Look at the picture below carefully. You may work alone or with friends in a group. Use the internet to search more about the characteristics of each of the elements.

Figure 2.8: semi-metals

Differences Between Metals and Non-Metals

The classification of solids into metals, non-metals, and semi-metals helps in understanding the fundamental properties and behaviours of different elements, and it provides a foundation for studying their various chemical interactions and applications.

Find in the Table 1 below differences between metals and non-metals

Table 1: Differences between metals and non-metals

Metals	Non-metals
Metals are good conductors of electricity due to the mobility of their valence electrons that can move freely within the metal.	Non-metals are typically poor conductors of electricity because their valence electrons are tightly held and do not move as freely.
Metals are higher conductors of heat, allowing heat to be transferred quickly through the material.	Non-metals have lower heat conductivity, so they are less efficient at conducting heat.
Many metals have a shiny appearance or lustre when freshly cut or polished.	Non-metals lack lustre and appear dull in their natural state.
Metals are malleable and can be hammered or pressed into various shapes without breaking.	Non-metals are brittle and cannot be easily hammered.
Metals are ductile and can be drawn into thin wires without fracturing.	Non-metals cannot be drawn into wires without breaking.

Differences between semi-metals and non-metals

Table 2: Differences between semi-metals and non-metals.

Semi-metals	Non-metals
They may be brittle like non-metals and have intermediate malleability and ductility.	They are typically brittle in solid form.
Semi-metals often have intermediate thermal conductivity.	They have low thermal conductivity making them good insulators in most cases.
Semi-metals have intermediate electrical conductivity.	They are bad conductors of electricity.

Differences Between Metals and Semi-Metals

Table 3: Differences between metals and semi-metals.

Metals	Semi-metals
Are excellent conductors of electricity.	Have intermediate electrical conductivity.
Metals have high heat conductivity.	Have intermediate heat conductivity.
Metals are often malleable and ductile.	Semi-metals can be brittle, making them less suitable for applications where malleability and ductility are important.
Metals tend to be reactive.	Semi-metals have intermediate reactivity.
Metals typically have a shiny, metallic lustre due to the reflection of light from their surface.	Semi-metals may have a metallic appearance but can also appear dull or non-metallic.

Activity 9

Create a poster summarising your understanding of the classification of metals, non-metals and semi-metals.

ANNEX 2.1 – POSSIBLE SOLUTIONS TO ACTIVITIES

Activity 1

An element is a pure chemical substance that cannot be broken down or changed into another substance by chemical means. It is made up of only one kind of atom. They are thought of as basic building blocks for everything around us, whether solids, liquids or gases. Some examples of elements are hydrogen (H), carbon (C), oxygen (O), fluorine (F) and calcium (Ca). Elements are represented by symbols (like those in the brackets) and fit into the Periodic Table of elements, which shows them all. There are 118 elements on the periodic table, with 94 of them occurring naturally. The rest are synthetic elements that have been created in a laboratory.

Activity 3

Observation: The pin stuck to the copper rod should drop off first as copper is the best conductor of heat and the Vaseline will melt first.

Conclusion: Metals vary in their thermal conductivity with copper having the best in this selection.

Activity 4

Observation: Metals have varying degrees of malleability and there should be a range of deformations amongst the four metals being investigated here: copper and lead are more malleable than zinc or iron.

Conclusion: Metals can be hammered into different shapes.

Activity 5

Observation: Silver and gold shine the most (are the most lustrous) than other metals such as copper, iron and aluminium.

Conclusion: Metals exhibit a shining surface known as metallic lustre, the degree of lustre varies amongst metals.

Activity 6

Observe: You should have noted which objects resist scratching and which ones are easily scratched by the coin.

Conclusion: The metal objects should be difficult to scratch, whilst the softer materials should show visible scratches indicating that they are less hard.

Explanation: Metals are harder than other materials because their atoms are arranged in strong, ordered structures. This makes it difficult to deform or break the metal's surface when scratched. Softer materials have weaker atomic bonds, making them more susceptible to scratches and dents.

Activity 7

Observation: effervescence will be observed in each of the test tubes with the most reactive showing more and rapid release of bubbles and the least reactive showing slow and least release of bubbles.

Conclusion: the metals arranged from the most to the least reactive metal are magnesium, zinc, iron, lead and copper.

Activity 8

Observation: Iron nails will rust in test tube A but they should not rust in test tubes B and C. In test tube A, the nails are exposed to both oxygen and water. In test tube B, the nails are exposed to only water, and the nails in test tube C are exposed to only to oxygen.

Conclusion: Oxygen (in air) and water are required for rusting to take place.

Methods for the prevention of corrosion include:

1. ***Painting:*** Paint provides a protective layer that seals the metal surface and blocks moisture and oxygen from reaching the metal.
2. ***Clear Coats and Sealants coating:*** Transparent coatings like lacquers and clear sealants can be used to protect metal surfaces while preserving their natural appearance.
3. ***Galvanising:*** Galvanising involves electro-coating the iron (or steel) with a thin layer of zinc. This has two modes of protection - the thin layer of zinc acts as a barrier to water and oxygen; and zinc is more reactive than iron and corrodes instead of the iron (called sacrificial protection).
4. ***Plating:*** Plating involves depositing a layer of another metal onto the surface of the base metal. This outer layer serves as a protective barrier. For example, chrome plating is commonly used for decorative and corrosion-resistant purposes.
5. ***Alloying:*** Alloying involves mixing two or more different metals or non-metal and a metal. This helps to improve its corrosion resistance. An example of this is stainless steel which contains chromium which reacts with oxygen to form a thin, invisible oxide layer on the metal's surface. This layer acts as a barrier, protecting the underlying metal from rust.
6. ***Keeping the metal in cool dry place:*** Keeping metal objects dry and clean reduces the likelihood of corrosion.
7. ***Desiccants:*** The use of moisture-absorbing substances like silica gel packets or other desiccants when storing metal objects in enclosed spaces can reduce corrosion and is used in many commercial products within the packaging.

EXTENDED READING

Access the links below to read more about metals, Non-metals, and metalloids and their characteristics.

https://www.meadmetals.com/blog/whats-the-difference-between-metals-nonmetals-and-metalloids#:~:text=Metals%3A%20Metals%20are%20highly%20ductile,ductile%2C%20while%20others%20are%20not.

https://chemistrytalk.org/properties-of-metals-nonmetals-semimetals/

Hello, learners! In the with the next topics, you will revisit the discussions on the properties of solids and further describe how these properties apply to everyday uses.

Remember, whilst all solids have fixed shapes and volumes, each material has its own unique properties that play a critical role in its use.

PROPERTIES OF SOLIDS

From your previous discussions, you classified solids as either metal, non-metal or metalloid (semi-metals). Unlike liquids and gases, which can flow and change shape easily, solids maintain their shape and volume under normal conditions. As mentioned earlier, solids are characterised by intermolecular forces which are greater in magnitude than the energy of the individual particles. These forces hold their constituent particles such as atoms, ions, or molecules in a fixed arrangement.

Activity 10

A) In a mixed group with no more than 3 other members of your class, sort the following materials into metallic and non-metallic groups. As an extension think about how each of these materials would be used in the construction of a house:

Materials:

- Concrete
- Aluminium
- Wood
- Zinc
- Plastic
- Iron
- Copper
- Glass

B) Now discuss and list materials that are used or needed in constructing the following items and form concept map for each – glassware, vehicles, computers, bottles, bowls, tables, sculptures and bridges. Generate a concept map (similar to the example solution to Activity 10 part A, found in Annex 2.2) for each.

Solids can be sub-categorised into the following groups which share similar properties:

- Polymers
- Crystalline structures
- Metals
- Fibrous materials

Table 4: Classification of materials

Classification	Examples of solids	Reason(s)
Polymers	Polyethylene, polyvinyl chloride (PVC)	• They are large molecules made up of repeating subunits called monomers • They are flexible and have a high strength-to-weight ratio • Low conductivity of electricity and heat
Crystalline	Table salt, sugar (sucrose), diamond, quartz	• Exhibit well-defined geometric shapes • They have a highly ordered and repeating arrangement of particles (crystals) • High melting point
Fibrous material	Wood	• Flexible • They do not form crystals • Low conductivity of electricity and heat
Metal	Copper	• Conducts electricity • High melting point • Good thermal conductivity

From Table 4, some solids have been sampled and classified. Now discuss with your friends the reasons assigned to each classification.

Properties of solid metals and some of their uses

Study the following properties of solid metals as captured in the Table 5 and see how it applies to everyday use.

Table 5: Properties of solid metals and some of their uses

Property	Examples use(s)
Conductivity: A high conductivity allow fast movement of heat and/or electricity.	This property is valuable in electrical wiring, power transmission, electronics, and heating.
Magnetic properties: Iron, nickel, and cobalt exhibit magnetic properties. This means they will exhibit a force on each other when brought into one another's magnetic fields.	This characteristic or property is essential for electrical motors, generators, transformers, and magnetic storage devices.
Lustre/Reflectivity: Solids which often have a smooth surface and have high reflectivity for light and heat.	This property is used in applications such as mirrors, reflectors, and solar panels where efficient reflection is required.
High melting and boiling points: Most metals have high melting and boiling points allowing them to withstand high temperatures (mercury is the exception to this rule as it is a liquid at room temperature).	Metals with extremely high melting points, such as tungsten and molybdenum, produce refractory materials capable of withstanding very high temperatures. Metals with high melting points are used to make crucibles and moulds for casting other materials such as ceramics and alloys. The crucible or mould remains stable and doesn't deform during casting. Other metals (such as lead) with lower melting points are used in soldering and brazing processes to join different components.

Property	Examples use(s)
Density: The density of metals refers to how much mass is packed into a given volume of the material.	In military and defence applications, high-density metals like depleted uranium are used in armour-piercing ammunition due to their ability to penetrate heavily armoured targets. Understanding the density of metals is crucial for recycling and waste management. By identifying and sorting metals based on their densities, recycling facilities can efficiently separate and process different metals for reuse, reducing the environmental impact of metal production.

Having discussed the properties of solid metals and how they are used in everyday life, I want you and your group members to try the following experiments to prove the realities of these properties.

Activity 11:

(You can do this activity alone or in a group of 2-4 classmates)

Aim: To compare the magnetic properties of various materials.

Materials needed: Bar magnet, iron nail, copper wire, aluminium foil, coin, paper clips, plastic ruler, wooden stick, plastic bottle cap, Styrofoam ball and rubber band.

Task

a) Position the bar magnet on a level surface.

b) In turn, bring each of the other pieces of equipment close to the bar magnet one at a time to see if there is any attraction or repulsion between them.

c) Classify each object as magnetic or non-magnetic and list these in a table.

Observations

What are your observations? Discuss it with your friends and compare them with the observations and conclusions in Annex 2.2.

Extension task:

Think of some activities where magnetism would be beneficial, as well as some where magnetism would be detrimental. Outline in a few sentences why magnetism can be useful or not for use in the applications you have chosen.

Activity 12:

(You can do this activity alone or in a group of 2-4 classmates)

Aim: To investigate the densities of different solid materials.

Materials needed: Various metal samples such as iron (e.g., nail, iron rod piece), lead (e.g., lead from electronic shops), aluminium (e.g., canned drink containers), copper (e.g., copper wires from electrical wires), zinc (e.g., battery case or disposed zinc roofing sheet), balance, measuring cylinder, beaker, water, forceps, scale.

Task:

a) Start by collecting samples of the metals you want to test. Make sure they are clean and free of any dirt or debris.

b) Weigh the mass of each metal sample and record in grams.

c) Fill the measuring cylinder with a known volume of water and record.

d) Carefully lower the first metal sample into the water using a pair of forceps. Make sure the metal is fully submerged.

e) Measure and record the new increased in volume of water after adding the metal sample. Measure volume in ml/cm3 (1 ml = 1cm3).

f) Repeat for each metal sample.

g) Calculate the volume of each metal sample by subtracting the initial volume of water from the final volume of water.

h) Use the formula: Density = Mass / Volume to calculate the density of each metal sample.

i) Record your results and compare the densities of the different metals.

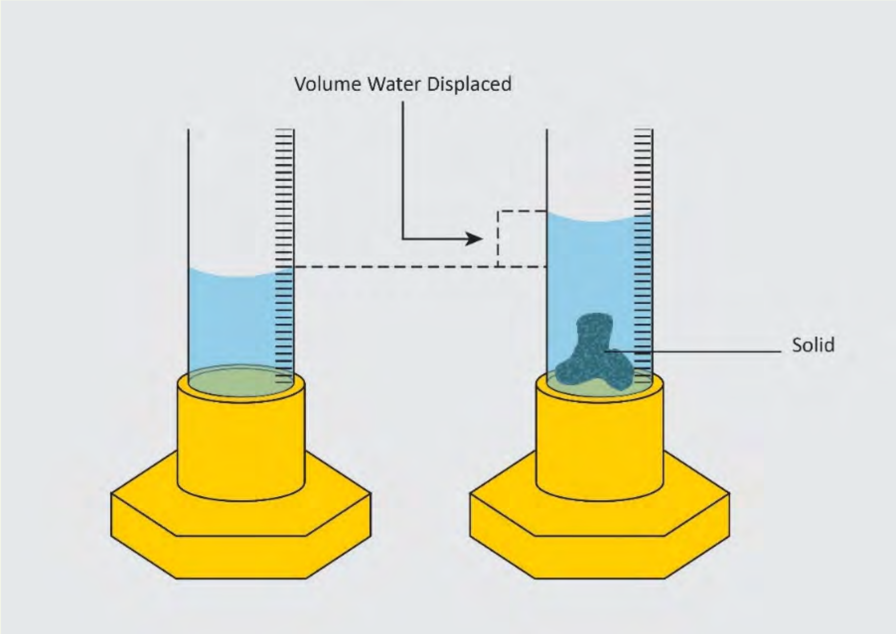


Fig. 2.9: illustrates how the volume of the metals are determined

Observations: What are your observations? Discuss it with your friends and compare them with the observations and conclusions in Annex 2.2.

Activity 13:

Aim: To investigate the electrical conductivity of different solid materials.

Materials needed: Solid objects composed of a range of materials *e.g.*, metal rod, key, wooden stick, plastic ruler, graphite rod, pencil, etc., battery, LED bulb and wires. Be guided by the image in Figure 2.10

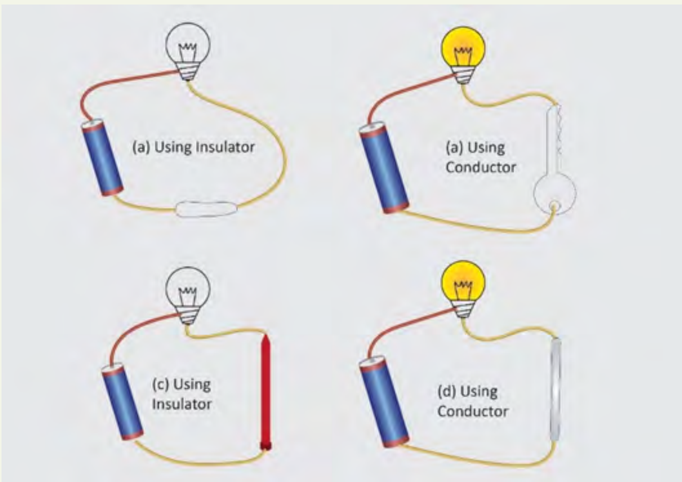


Figure 2.10: activity to show which materials are good conductors of electricity

Task:

a) For each material you are going to test; predict whether or not they will conduct electricity. Make a note of your predictions, justifying them with a reason.

b) Construct a simple circuit set-up with a battery, LED bulb, and wires.

c) Check if the circuit conducts electricity, the battery is functioning, and the bulb is working by connecting the free wire ends to complete the circuit. If the bulb lights, the circuit is working.

d) One by one, introduce the metal rod, wooden stick, plastic ruler, graphite rod, and pencil lead into the circuit to complete it.

Note: the pencil lead is in fact graphite, ensure the wires are connected to the lead of the pencil rather than the surrounding wood.

e) Does the bulb light up? Record your results in a suitable table and write a suitable set of conclusions to your experiment. Remember to refer back to your predictions.

Observations: What are your observations? Discuss it with your friends and compare them with the observations and conclusions in Annex 2.2.

Activity 14

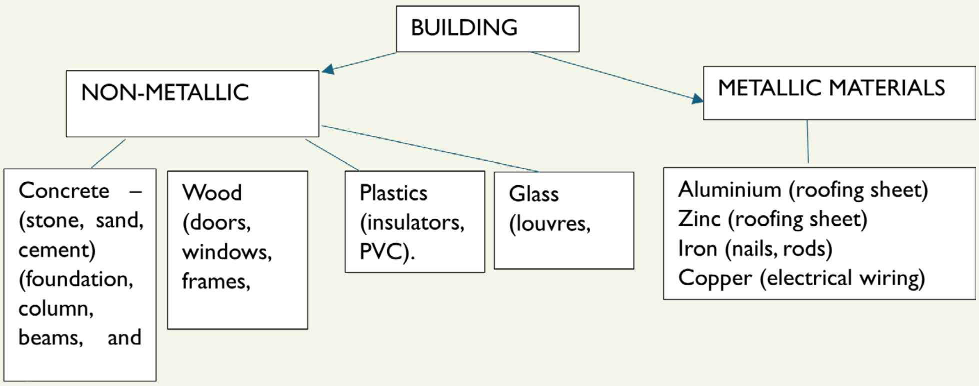
Your group should create a poster or oral presentation to demonstrate your findings from the three experiments outlined above, considering how you can make your presentation of most interest to an

ANNEX 2.2 – POSSIBLE SOLUTIONS TO ACTIVITIES

Activity 10

A)

Example answer:



B)

Structures	Examples of solids used in the structures
Building	Concrete, Steel, wood, brick.
Glassware	Sand is a raw material in the making of glass, glass wool, glass beads.
Vehicle	Metals, glass, plastics, leather, cushion, connecting wires.
Gadgets (e.g., computer)	Glass, plastics, Copper, metals, etc.
Plastic materials (e.g., bottles, bowls)	Polyethylene, Polyvinyl Chloride (PVC).
Table	Wood, nails, Steel, plastic, glass.
Sculptures	Stones, marble, metal, or wood.
Bridges	Steel, concrete, stone.

Activity 11

Observation

From this activity, you are likely to observe that:

- Materials such as the iron nail, paper clips, and copper wire will be attracted to the magnet, showing magnetic properties.
- Materials like the aluminium foil, plastic ruler, wooden stick, plastic bottle cap, styrofoam ball, and rubber band will not be attracted to the magnet and are considered non-magnetic.

Conclusion: You will now come to the realisation that certain materials exhibit magnetic properties and are attracted to a magnet whilst others do not show any magnetic response.

Activity 12

Observations: From the activity, you will observe that different metals will have different densities.

Conclusion: Metals vary in density and have different uses e.g. Lead is often used in adding ballast (weight) as it is very dense and therefore heavy for its volume. Aluminium is one of the less dense metals and is often used in applications which require low weight such as spaceflight or aviation.

Activity 13

Observations: You will observe that the metal rod, pencil lead and graphite rod will all conduct electricity (the bulb lights up) and the wooden stick and plastic ruler will not.

Annex 2.2 – Further Information

Uses of Polymers in relation to their properties

Read the table below to identify how the properties of polymers are used in everyday life.

Table 6: Properties and example uses of polymers

Property	Polymer(s) exhibiting this property	Use(s)
Strength (ability to withstand load without deformation) and **Durability** (resistance to wear)	Polyethylene (PE) and Polypropylene (PP) Polyvinyl Chloride (PVC) Aramid fibres	Packaging Pipe work Bulletproof vests
Flexibility and Elasticity (ability to bend and stretch without breaking)	Rubber	Elastic bands
Thermal Stability	Polyimides (PI)	Aerospace
Chemical Resistance (resistance to acids, corrosion or solvents)	Polyvinylidene fluoride (PVDF) Polytetrafluoroethylene (PTFE)	Storage tanks Pipework
Electrical Insulation	Polyethene (PE) and Polypropylene (PP)	Cable insulation
Transparency	Polymethyl methacrylate (acrylic)	Lenses
Water Resistance	Polyethylene terephthalate (PET)	Water bottles
Biodegradability (can be degraded naturally by decomposers and environmental processes over time)	Polylactide (PLA)	Compost bags
Adhesive	Cyanoacrylate	Glue

The properties and uses of crystalline solids (e.g. glass)

Table 7 shows the properties of different types of glass and its everyday uses.

Table 7: The properties and uses of crystalline solids

Glass	Properties	Use
Soda-lime glass	Transparent Chemical resistance - it is non-reactive Soda-lime glass has a moderate coefficient of thermal expansion meaning it expands and contracts evenly when exposed to temperature changes	Windows, bottles, and jars and scientific glassware
Borosilicate	Exhibits high chemical resistance High thermal resistance Durability	Laboratory glassware, chemical storage containers, and pharmaceutical packaging where the material needs to withstand corrosive substances. Also, cookware e.g., Pyrex and high-end lighting fixtures.
Lead crystal	It contains a significant amount of lead oxide giving it exceptional clarity, brilliance, luxurious appearance, and weight.	Fine glassware, chandeliers, and decorative items.

Glass	Properties	Use
Fused silica	Its high purity, thermal stability, optical transparency, and chemical resistance makes fused silica is a versatile material used in a wide range of industries	Lenses, mirrors, and precision optics in scientific instruments.
Aluminosilicate glass	Contains aluminium oxide and silica offering high strength, chemical resistance, and thermal shock resistance.	Smart phone screens, armoured vehicle windows, and aerospace components.

EXTENDED READING:

1. Properties of solid materials
   https://www.vaia.com/en-us/explanations/physics/solid-state-physics/solids/
2. The property of materials and their everyday uses
   https://www.primaryresources.co.uk/science/pdfs/rsc_tc_nc1.pdf
3. Images of solid materials
   https://www.sciencelearn.org.nz/resources/2659-properties-of-materials-introduction

BINARY COMPOUNDS

Figure 2.11: Table salt (NaCl) Figure 2.12 - Water (H_2O)

Hello, learner. Think about the ingredients in your favourite dish! Like cooking, chemistry is all about combining the right elements in proportions to create something new and useful. Instead of using vegetables and fish, we use elements and valencies to form compounds. Just like in cooking, knowing the name of each 'ingredient' and how they come together is crucial. In this session, you will explore how two elements combine to form a binary compound, and how you can identify these compounds just like a chemist. You will also understand the logic behind their composition. Ready to solve some chemical mysteries? Let's get started with an activity!

Activity 15

1. Define the following terms:

- **a)** Element
- **b)** Ion
- **c)** Molecule
- **d)** compound

2. Categorise the following into element, ion, molecule or compound (note, they could belong to more than one of these categories!

H2O, O_2, NaCl, Fe, Ca^{2+}

Activity 16:

You are going to become a chemical detective and unlock the secrets of binary compounds. To start, let's see if you can solve a few mysteries about some common compounds.

Materials needed: Periodic table, pen/pencil and exercise book.

What to do: You are provided with three clues. Carefully read each of the following clues and answer the questions:

a) What is the common name of this compound?

b) What two elements make up this compound?

Clue 1: "I am a white crystalline substance commonly found in kitchens. I am essential for flavouring food and preserving it."

Clue 2: "I am a liquid that is vital for all known forms of life. I cover about 71% of the Earth's surface."

Clue 3: "I am a colourless gas. I am produced by burning fossil fuels. Plants need me for photosynthesis."

Find the answers in **Annex 2.3**.

What is a binary compound?

A binary compound is a chemical compound composed of exactly two different elements. These elements combine in fixed ratios to form a new substance with unique properties.

Binary compounds are basic building blocks in chemistry. They can be classified into two main types based on the nature of the elements involved:

Binary Ionic Compounds

Composition: These compounds consist of a metal and a non-metal.

Formation: Metals lose electrons to become positively charged ions (cations), while non-metals gain electrons to become negatively charged ions (anions). These oppositely charged ions attract each other to form an ionic bond. Thus, the metals transfer electrons to the non-metals to form the compound.

Example: Sodium chloride (NaCl), where sodium (Na) is a metal that loses one electron to become Na^+, and chlorine (Cl) is a non-metal that gains one electron to become Cl^-. The resulting compound is NaCl.

Let us learn how to draw the individual elements, followed by the bond that is formed in table salt (sodium chloride).

1. Draw the electron configuration of each atom in the compound (sodium and chlorine).

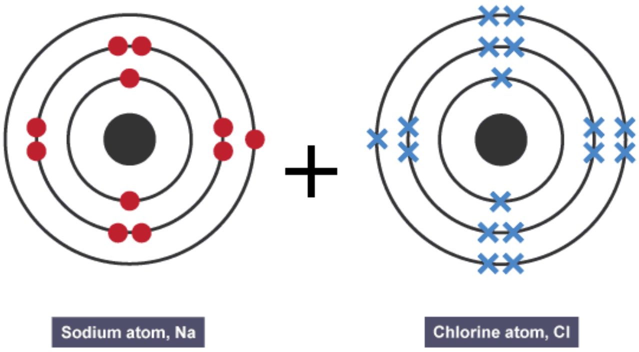


Figure 2.13:

2. Draw the electron configuration of the two ions after the transfer of electrons from sodium to chlorine, surround them with square brackets, and write the charge of each ion in the top right hand corner.

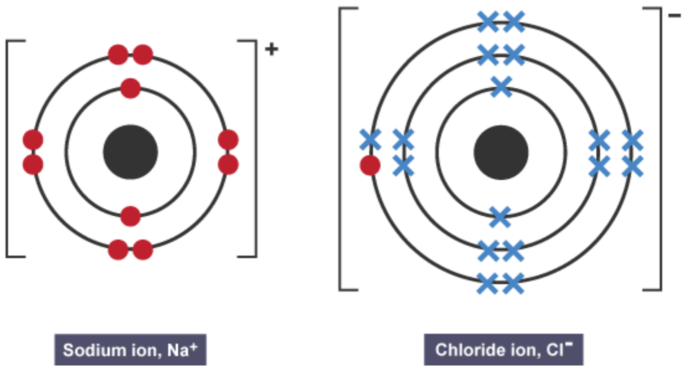


Fig. 2.14:

Figure 2.13 and 2.14 - Transfer of electron from Sodium to Chlorine resulting in Na^+ and Cl^-

The electrostatic force of attraction between the two ions results in the formation of sodium chloride (NaCl).

This can be represented in another way:

Sodium atom (Na) loses an electron to become sodium ion (Na^+)

$Na - e^-$ -------> Na^+

(2,8,1) (2, 8)

Chlorine atom (Cl) accepts the electron from sodium to become chloride ion (Cl^-)

$Cl + e^-$ ---------> Cl^-

(2,8,7) (2,8,8)

The electrostatic force of attraction between the two ions pulls them together to form a compound.

$Na^+ + Cl^-$ ---------> NaCl

Activity 17

Scenario: You are a chemist tasked with identifying a newly discovered ionic compound composed of calcium and chlorine.

Question: How is the compound formed?

Materials needed: Periodic table, pens/pencils, exercise book

What to do:

1. Use the periodic table to identify the elements.
2. Draw the electron configuration diagram of the elements.
3. Draw the electron configuration diagrams of the two ions after the transfer of electrons.
4. Write the formula of the compound formed.
5. Confirm your result with the solution in Annex 2.3.

Follow up questions:

Using the same method draw the electron configuration for the following atoms and then the ions they form when combined into compounds:

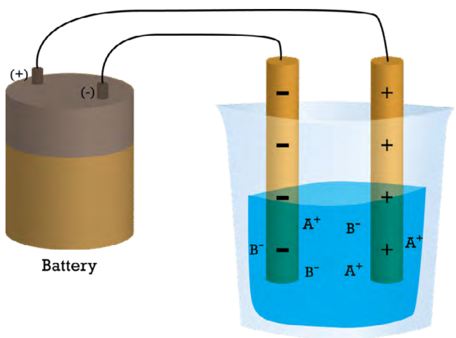
1. Fluorine and lithium
2. Beryllium and chlorine
3. Oxygen and calcium
4. Magnesium and iodine

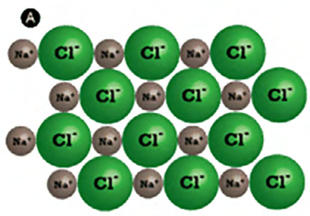
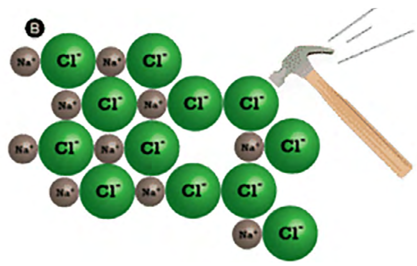
5. Aluminium and fluorine

6. Gallium and oxygen.

Good job learner, now explore the properties of ionic compounds.

Properties of Ionic Compounds

Property	Description
State of matter	Most ionic compounds exist in a solid state at room temperature. The strong electrostatic forces between positively and negatively charged ions create a stable crystal lattice structure.
Melting and boiling points	Ionic compounds have high melting and boiling points. The strong ionic bonds require a substantial amount of energy to break. High temperatures are needed for these compounds to undergo phase changes.
Solubility in water	Many ionic compounds are soluble in water. When placed in water, the ions separate and disperse throughout the solution. However, not all ionic compounds are equally soluble, and some may show limited solubility or are insoluble.
Conductivity in aqueous solutions	Ionic compounds conduct electricity when dissolved in water or in molten form. In these states, the ions are free to move and carry an electric current. However, in their solid state, ionic compounds do not conduct electricity and are good insulators.  **Figure 2.15:** In an ionic solution, the A+ ions migrate toward the negative electrode, while the B− ions migrate toward the positive electrode.

Crystal structure	Ionic compounds form a regular and repeating three-dimensional crystal lattice structure. The arrangement of positive and negative ions in this structure contributes to the stability of the compound.  **Figure 2.16 (a):** Sodium Chloride  **Figure 2.16(b):** Copper (II) crystals
Hardness and brittleness	Ionic compounds are typically hard and brittle. The crystal lattice structure can fracture when subjected to force as like-charged ions repel each other.  **Figure 2.17:** (a) The Sodium Chloride crystal is shown in two dimensions.  **Figure 2.17(b):** C(b) When struck by a hammer, the negatively charged. Chloride ions are forced near each other and the repulsive force causes the crystal to shatter.
Density	Ionic compounds have high densities. The arrangement of ions in the crystal lattice contributes to the overall mass of the compound in each volume.
Colour	Pure ionic compounds are often colourless. However, certain metal ions, especially transition metals, can impart colour to the compound. For example, Copper ions can give a blue or green colour to an ionic compound as seen in ***figure (2.16b).***

Binary Covalent Compounds

Composition: These compounds consist of two non-metals.

Formation: Non-metals share electrons to form covalent bonds. This sharing allows each atom to attain a stable electron configuration.

Example: Carbon dioxide (CO_2), where carbon (C) shares electrons with two oxygen (O) atoms forming covalent bonds, water (H_2O), ammonia (NH_3) and methane (CH_4).

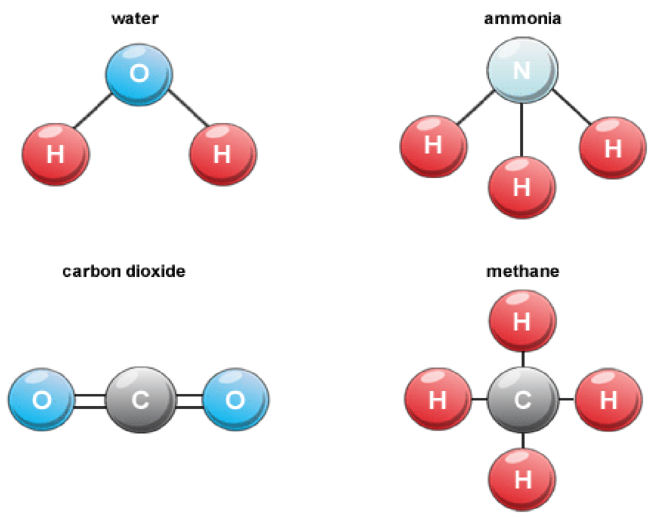


Figure 2.18: Examples of covalent compounds

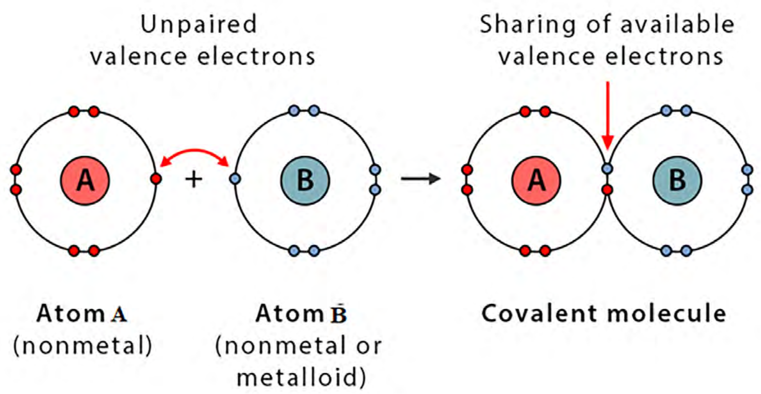


Figure 2.19: the sharing of valence electrons to form a covalent bond

Molecules such as hydrogen (H_2) and oxygen (O_2) also consist of covalent bonds. In the formation of hydrogen gas, each of the two atoms of hydrogen contributes its electron to be shared with the other hydrogen atom. Sharing of electrons ensures that each hydrogen atom gains an additional electron in its valence shell. This ensures that the shell has a stable configuration.

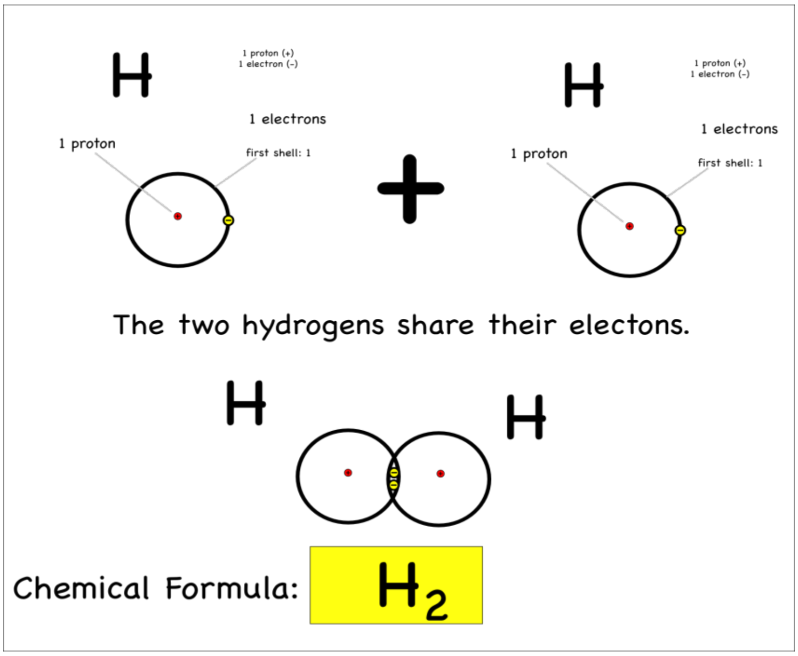


Figure 2.20: Formation of hydrogen gas (H_2)

Similarly in a molecule of Oxygen Gas (O_2), the two atoms of Oxygen contribute a pair of electrons each to be shared. This ensures that each of the two atoms attains an inert configuration of 8 electrons in the valence shell.

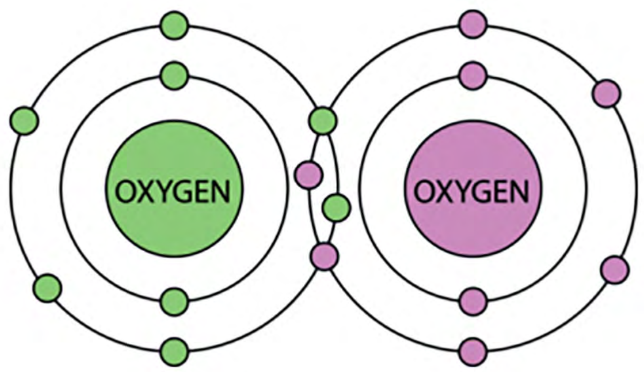


Figure 2.2: Formation of oxygen gas (O2)

Covalent bonds can be single, double or triple bond.

Activity 18:

Scenario: Imagine you are an environmental scientist studying the water cycle. To understand how water forms, you need to investigate the bonding between hydrogen and oxygen atoms to form water (H_2O). You are tasked to construct a model of water molecule.

Materials needed: Molecular model kits or play dough/plasticine/coloured clay/coloured polystyrene materials and toothpicks/broom sticks.

What to do:

1. Draw the electron configuration of H_2O on paper.
2. Ensure that each Hydrogen atom shares one electron with the Oxygen atom, forming two covalent bonds.
3. Select and use suitable materials to build a model of a water molecule, showing the sharing of electrons between Hydrogen and Oxygen.
4. Answer the following key questions:

Key Questions:

a) What is a covalent bond, and how does it differ from an ionic bond?

b) How do hydrogen and oxygen atoms share electrons to form a water molecule?

c) Why is water considered a binary covalent compound?

d) How do the shared electrons create a stable molecule.

Very good learner, compare your electron configuration diagram of water molecule to the one provided.

Compare your home-made water model to the one in the picture in Annex 1.

Properties of Covalent compounds

Covalent compounds contain covalent bonds and exhibit the following properties:

- They normally exist as gases, liquid, or soft solids
- Their melting and boiling points are very low
- They can be insoluble in water but soluble in organic solvents
- They are non-conductors of electricity in solid, molten, or aqueous state
- They have weak intermolecular forces of attraction.

Activity 19:

Aim: To examine water's electrical conductivity as a representative covalent compound.

Materials needed: Two electrodes (e.g., copper or graphite), electrical circuit with connecting wires, ammeter, switch, batteries, beaker and distilled water.

a) Set up an electrical circuit by connecting two electrodes to an ammeter, switch, and battery in series.

b) Fill a beaker with distilled water and place the electrodes into the water, ensuring they do not touch each other.

c) Observe and record changes in the ammeter reading as the electrodes are submerged in the water.

d) Repeat the experiment with other substances like salt (NaCl) dissolved in water and sugar (sucrose) dissolved in water.

Take safety precautions while conducting the experiment, such as wearing safety goggles, lab coats, and following standard laboratory practices.

Perform each test multiple times to ensure reliability of results.

Use distilled water to maintain consistency and reduce the influence of impurities on the experiment.

Observations: What are your observations? Discuss it with your friends and compare them with the observations and conclusions in Annex 1.

Activity 20:

Scenario: The Chemistry Detective

Imagine you are a detective in a forensics lab. You have been given two mysterious white powders found at a crime scene. Your job is to determine whether these powders are ionic or covalent compounds by investigating their properties through a series of tests.

Key Questions to answer before starting the investigation:

1. Physical properties of ionic and covalent compounds.

- **a)** How do their melting points and boiling points differ?
- **b)** How do their electrical conductivity and solubility in water differ?

2. Molecular structures of ionic and covalent compounds.

a) How do ionic compounds arrange their ions?

b) How do covalent compounds arrange their atoms?

3. How do ionic and covalent compounds behave when dissolved in water?

4. What happens to their electrical conductivity in aqueous solutions?

Activity 21:

Aim: To compare the properties of the given powders to determine whether they are ionic or covalent compounds.

Materials needed: Two white powders (e.g., NaCl (table salt) and $C_{12}H_{22}O_{11}$ (sugar)), distilled water, multimeter, beakers or clear cups, stirring rods, hot plate, thermometer, measuring spoons, safety goggles and gloves.

What to do:

1. Solubility Test:

a) Fill two beakers with equal amounts of distilled water.

b) Label them as Powder A and Powder B.

c) Add a teaspoon of Powder A to one beaker and a teaspoon of Powder B to the other.

d) Stir each solution until the substances dissolve.

Note how quickly each substance dissolves and whether any residue is left.

2. Conductivity Test:

a) Use a multimeter to measure the electrical conductivity of both solutions.

b) Record the readings for the solutions of Powder A and Powder B.

Note which solution conducts electricity and which does not.

3. Melting Point Test:

a) Place a small amount of Powder A on one side of a hot plate and a small amount of Powder B on the other.

b) Slowly increase the temperature and observe the temperature at which each substance starts to melt.

Note the melting points of both substances.

From your observations, conclude which substance is table salt (ionic) and which is sugar (covalent). Find explanations in Annex 2.3.

Understanding the composition and naming of binary compounds is crucial for identifying the types of chemical bonds and the elements involved. Ionic compounds form through the transfer of electrons between metals and non-metals, leading to the creation of cations and anions. Covalent compounds form through the sharing of electrons between non-metals.

ANNEX 2.3 – POSSIBLE SOLUTIONS TO ACTIVITIES

Activity 15

1.

Element - An element is a substance that is made up of only one kind of atom.

Ion - Atom or molecule with a net electric charge due to the loss or gain of one or more electrons.

Molecule - A particle which consists of two or more atoms chemically bonded together.

Compound - A substance made up of two or more different chemical elements combined in a fixed ratio.

2.

H_2O – molecule and compound

O_2 - molecule

NaCl – molecule and compound

Fe - element

Ca^{2+} - ion

Activity 16

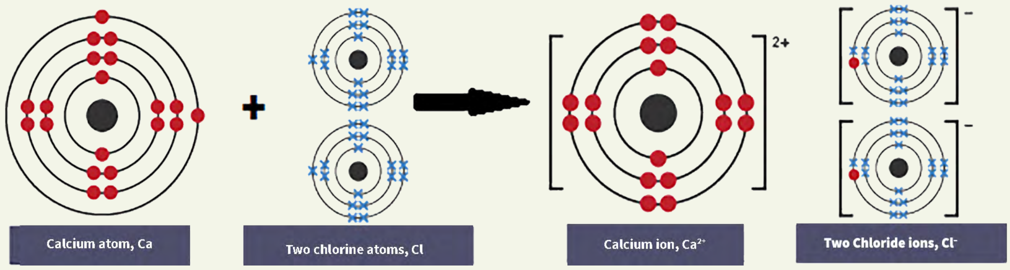
Clue 1: This is table salt. The elements in table salt are sodium (Na) and chlorine (Cl).

Clue 2: This is water. The elements in water are hydrogen (H) and oxygen (O).

Clue 3: This is carbon dioxide. The elements in clue 3 are carbon (C) and oxygen (O).

Activity 17

You will observe that calcium loses two electrons while chlorine receives one electron. Two chlorine atoms are therefore needed to take up or accept the two electrons from calcium to balance the reaction. Your diagram may look like this:



Giving $CaCl_2$.

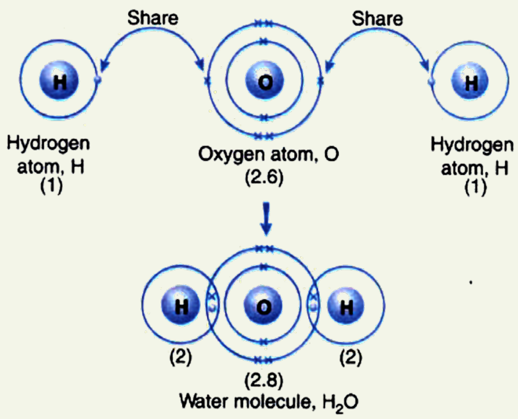
$Ca – 2e^-$ -------> Ca^{2+}

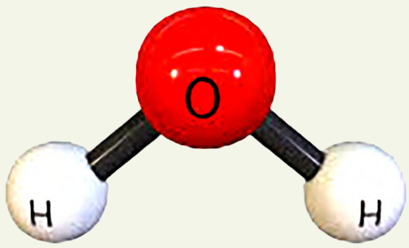
(2,8,8,2)   (2,8,8)

$2Cl + 2e^-$ ---------> $2Cl^-$

(2,8,7)   (2,8,8)

$Ca^{2+} + 2Cl^-$ ---------> $CaCl_2$





Activity 18

You would observe that there was no reading by the ammeter when the probes were placed in the distilled water. Pure water does not conduct electricity because it does not contain ions, so the electrons do not move through the solution. Thus, pure water is a poor conductor of electricity and is actually an excellent insulator.

There was no reading either when sugar was dissolved in the water. Sugar solution is also a poor conductor of electricity because sugar molecules are neutral and don't have a charge. When sugar is dissolved in water, it doesn't break apart into ions, so the solution only contains neutral sugar and water molecules. These neutral molecules can't attract to and move to opposite ends of electrodes like ions can, so they can't conduct electricity.

However, when the salt (NaCl) was added, the ammeter gave some readings. This is because the salt dissolves into ions, which means that the electrons can move freely through the solution.

Activity 19

Solubility Test - Usually, ionic compounds like NaCl dissolve easily/faster in water, dissociating into ions, while covalent compounds like sugar disperse without dissociation**.**

Conductivity Test - The solution of the ionic compound (NaCl) conducts electricity because it dissociates into ions. The solution of the covalent compound (sugar) does not conduct electricity because it does not form ions in water.

Melting Point Test - The ionic compound (NaCl) has a higher melting point due to strong ionic bonds. The covalent compound (sugar) has a lower melting point because covalent bonds are generally weaker than ionic bonds.

Conclusion:

- Ionic Compounds: High melting and boiling points, conduct electricity in solution, generally soluble in water, composed of positive and negative ions.
- Covalent Compounds: Low melting and boiling points, do not conduct electricity in solution, may or may not be soluble in water, composed of molecules with shared electrons.

EXTENDED READING

Build models for Carbon dioxide (CO_2), Methane gas (CH_4) and Ammonia (NH_3) molecules using local materials from your environment.

https://gardenandplate.com/water.html

https://www.toppr.com/ask/question/5-differences-between-ionic-compound-and-covalent-compound/

https://hydrogenatomgirikosa.blogspot.com/2017/06/hydrogen-atom-bond.html

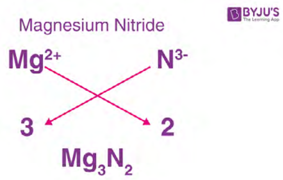
Read more on the uses of common ionic and covalent compounds such as NO_2, CO_2, MgO, CaO, SiO_2 in everyday life.

Welcome learners! In this lesson you will learn about a standardised way to identify and communicate the composition of compounds. The naming conventions for compounds help to convey vital information about the elements present and their respective charges. By following specific naming rules, chemists can determine the exact combination of cations (positively charged ions) and anions (negatively charged ions) within a compound. This knowledge is essential for understanding chemical reactions, predicting the behaviour of substances, and effectively communicating information about the structure and properties of compounds.

WRITING OF CHEMICAL FORMULAE FOR AND NAMING OF BINARY COMPOUNDS

Hello, learner. Please follow the steps below to learn how to write the chemical formula for a compound!

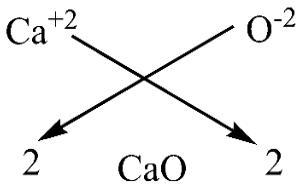
1. Identify the two elements present in the compound.
2. Write the chemical symbols of the two elements that combine to make up the binary compound. In an ionic compound, the atom that forms a positive ion (cation) is written first followed by the negative ion (anion).
3. Determine the valency of each of the atoms. Valency is the combining power of an element. It refers to the number of electrons that an atom loses or gains to form a compound with a different element. Knowing the charge on an ion gives an important clue about its valency. E.g., Mg^{2+} has a valency of 2, N^{+} has a valency of 1, O^{2-} has a valency of 2 and Cl^{-} has a valency of 1.
4. Exchange the valencies of the two different elements and write them as subscripts at the right-hand side of the chemical symbol of each atom. In the example below, the cation of magnesium (Mg^{2+}) has a valency of 2 which is exchanged with the valency of the anion of nitrogen (N^{3-}) which is 3.
5. Simplify the subscripts by finding the common factor. This step is often skipped if the values are already simplified.
6. Additionally, if the valency is one (1), it is not written.



Another example: Let us consider the compound formed between calcium (Ca) and oxygen (O).

Calcium is a metal and forms cations with a charge of +2. Oxygen is a non-metal and forms anions with a charge of -2.

Based on their charges, it can be inferred that each of these atoms has a valency of 2.



The valences of the two atoms are exchanged as shown in the preceding paragraph. Because 2 is a common factor to the two subscripts, the subscripts are simplified by dividing each of them by two, giving us the chemical formula of the compound as CaO.

Activity 20:

When naming a binary compound, the first word is always the name of the positive ion (cation). The second word is derived from the name for the negative ion (anion) but ends in the letters ‘ide’. For each of the following compounds A-E, give the correct word that would appear as the second word in its name:

1. KCl

2. CaS

3. AlI3

4. Al2O3

5. Ba3N2

6. NaCl

Indicate which of these is a common household substance and give the name of the substance.

Activity 21:

Aim: To write the formula for various compounds including sodium chloride

Materials needed: Cuttings of cardboard with names of different elements, written in words and symbols with different charges e.g.

Na 1+	Na 2 -	Na 2-	Na 3+
Cl 3+	Cl 2 -	Mg 2-	Mg 2+
Mn 2-	I 1+ I -	1- I 2+	I 2-
O 2-	O 2+ -	O 2-	O 1-

Method:

1. Create your cards (as listed above).
2. Pick a pair of cards with the correct symbols and charge for the following named elements: sodium and chlorine, manganese and chlorine, potassium and iodine, sodium and iodine.
3. Put the pair side by side.
4. Draw a cross (X) as shown in the examples above for the pair of elements you have selected.
5. Write their charges and exchange their numbers as valencies.
6. Write the formula of the combination of the pair of elements.
7. Simplify the result if required.
8. Name the resultant compound formed.
9. Have a go with a few more pairs of elements!

Activity 22

Create a flowchart for writing the formula of the binary compound KCl

Aim: To draw a flowchart to write the formula of a binary compound

Materials needed: Potassium metal, boiling tube containing chlorine gas, fume cupboard.

Method: (note: this demonstration should only be performed by your teacher; chlorine gas is poisonous):

1. Observe your teacher drop the piece of the potassium metal in the tube of chlorine gas.
2. Observe what happens in the boiling tube.
3. Draw a flowchart or write a step-by-step method which could be used by another student to find the chemical formula of the compound produced. Include an explanation as to how the compound should be named.

ANNEX 2.4 – POSSIBLE SOLUTIONS TO ACTIVITIES

Activity 20

A) KCl - Chloride

B) CaS - Sulfide

C) AlI3 - Iodide

D) Al2O3 - Oxide

E) Ba3N2 – Nitride

F) NaCl – Chloride (sodium chloride – table salt)

Activity 22

IDENTIFICATION OF THE ELEMENTS AND THEIR CHARGES: Potassium and chlorine

WRITE THEIR SYMBOLS: K1+ and Cl1-

CONVERT THE NUMBERS TO ABSOLUTE NUBERS: **K 1 Cl 1**

EXCHANGE THE NUMBERS AND WRITE THEM AS SUBSCRIPTS **K_1Cl_1**
(WHERE THE VALUE OF THE NUMBERS IS THE SAME LEAVE THEM OUT AND WRITE IT AS: **KCl**)

NAME THE COMPOUND (THE NAME OF THE POSITIVE ELEMENT COMES FIRST FOLLWED BY THAT OF THE NEGATIVE ELEMENT)
Potassium Chloride

Annex 2.4 – Further information

- **Element**: An element is a substance that cannot be broken down into any other substance. Every element is made up of its own type of atom. This is why the chemical elements are all very different from each other. Examples iron, Sulphur, gold, chlorine.
- **Atom**: The smallest part of a substance that can be broken down chemically into fundamental particles. Each atom has a nucleus (centre) made up of protons (positive particles) and neutrons (particles with no charge). Electrons (negative particles) move around the nucleus.
- **Electron:** is a negatively charged subatomic particle that can be either bound to an atom or free (not bound). An electron that is bound to an atom is one of the three primary types of particles within the atom - the other two are protons and neutrons.
- **Valence:** A whole number that represents the ability of an atom or a group of atoms to combine with other atoms or groups of atoms. The valence is determined by the number of electrons that an atom can lose, add, or share.
- **Valency:** is the number of atoms of a particular element that is combined with one atom of another element to form a molecule. Valency is a measure of the combining power of an atom. The valency of an element is determined by the number of electrons in its outermost shell.
- **Ion**: any atom or group of atoms that bears one or more positive or negative electrical charges. Positively charged ions are called cations; negatively charged ions, anions. For example, Na^+, Cl^-
- **Compound**: a substance made from two or more different elements that have been chemically joined. Examples of compounds include water (H_2O), which is made from the elements hydrogen and oxygen, and table salt (NaCl), which is made from the elements Sodium and Chlorine.
- **Binary Compound:** is a chemical substance that is made of two different elements only. An element is the fundamental building block of all chemical compounds. The presence of only two different elements in a compound is what classifies a compound as a binary compound.
- **Chemical Formula:** A chemical formula identifies each constituent element by its chemical symbol and indicates the proportionate number of atoms of each element.

EXTENDED LEARNING:

1. Find out the social uses of the following binary compounds: CO_2; NaCl; $CaCl_2$; H_2O; MgO by browsing the internet entering "Social uses of binary compounds" in your search bar.
1. Refer to the following references on Page and read about other forms of naming binary compounds. E.g. IUPAC Naming.

REVIEW QUESTIONS

Review Questions 2.1

1. Enumerate three properties each of metals, non-metals and semi-metals.
2. In tabular form, outline four differences between metals and non-metals.
3. Explain why metal objects should be kept dry and clean.
4. Explain how metals are used in the production of cooking utensils and why certain metals are chosen for specific cooking tasks.
5. Discuss the role of non-metals in the manufacturing of electronic devices and semiconductor components.

Research Work

6. Use the internet and other resources to search on the topic 'how are semi-metals utilized in the production of solar panels and other renewable energy technologies?' Present your report which should include posters, diagrams and charts about your findings to the class.

Review Questions 2.2

1. For each of the following properties, list as many everyday items as you can think of which rely on them:
   - o High conductivity
   - o Magnetic properties
   - o Lustre
   - o High melting and boiling points
2. Why is it important for metallic cookware be designed including materials that are good conductors but also materials that are good insulators?

Review Questions 2.3

1. Identify at least four examples of binary compounds in everyday life.
2. Describe how magnesium oxide is formed.

3. Explain the role of electron transfer in the formation of binary ionic compounds.
4. Explain how covalent compounds are different from ionic compounds. Give precise examples to support your explanation.

Research Work

Evaluate the importance of understanding the differences between ionic and covalent compounds in practical applications, such as in medicine, materials science, and environmental science and present your findings in class.

Review Questions 2.4

1. Two elements X and Y have charges +3 and -2 respectively. Write the molecular formula for the compound formed.
2. Write the formula of a compound made of elements Y and Z whose valences are 2 and 2 respectively.
3. What basic concepts of naming binary compound will you consider if you are working alone? You may work with a friend to share your views on the concepts of naming binary compounds and put your views together and come out with patterns and rules to be used in naming binary compounds.
4. Name the following compounds and indicate the valencies of each component element in the compound:
   a) $MgCl_2$
   b) CO_2
   c) Na_3N
   d) BeO
   e) MgH_2
   f) KI

ANSWERS TO REVIEW QUESTIONS

Review Questions 2.1

1. Refer to the reading.

Metals	Non-metals
Metals are good conductors of electricity due to the mobility of their valence electrons that can move freely within the metal.	Non-metals are typically poor conductors of electricity because their valence electrons are tightly held and do not move as freely.
Metals are higher conductors of heat, allowing heat to be transferred quickly through the material.	Non-metals have lower heat conductivity, so they are less efficient at conducting heat.
Many metals have a shiny appearance or lustre when freshly cut or polished.	Non-metals lack lustre and appear dull in their natural state.
Metals are malleable and can be hammered or pressed into various shapes without breaking.	Non-metals are brittle and cannot be easily hammered.
Metals are ductile and can be drawn into thin wires without fracturing.	Non-metals cannot be drawn into wires without breaking.

To prevent contact with oxygen and moisture which will cause corrosion/rusting.

2. Conductivity, durability, non-reactivity, non-stick properties and appearance are the factors that influence the use of metals for cooking utensils.

Review Questions 2.2

1. Properties of metals for everyday usage

Solid Metal Properties	Everyday Usage
High conductivity	Used in everyday electrical wiring, power transmission, electronics, and heating.
Magnetic properties	This is used essentially for electrical motors, generators, transformers, and magnetic storage devices.
Lustre	This property is used in the applications such as mirrors, reflectors, and solar panels where efficient reflection is required.
High melting and boiling points	Metals with high melting points are used to make crucibles and moulds for casting other materials such as ceramics and alloys. The crucible or mould remains stable and does deform during casting. Other metals (such as Lead) with lower melting points are used in soldering and brazing processes to join different components.
Density	In military and defence applications, high-density metals like depleted Uranium are used in armour-piercing ammunition due to their ability to penetrate heavily armoured targets.

2. Importance of conductivity and insulation properties of solid materials in heat transfer (such as metallic cookware)

Conductivity	Insulation
Ability to transfer heat making it possible for cooking	Ability to withstand heat making it possible to handle hot utensils.

Review Questions 2.3

1. Some examples include: NaCl (table salt), CO_2 (carbon dioxide), NH_3 (ammonia), NO_2 (nitrogen dioxide), H_2O (water), SiO_2 (silicon dioxide (silica)), HCl (hydrogen chloride (hydrochloric acid)), CH_4 (methane), $MgCl_2$ (magnesium chloride).
2. Magnesium has two electrons in its outer shell, making it easier for it to lose two electrons and form the Mg^{2+} cation with an electronic configuration of 2,8. Oxygen has six electrons in its outer shell, so it gains the two electrons lost by magnesium to form the O^{2-} anion with an electronic configuration of 2,8. The transfer of electrons between the magnesium and oxygen atoms forms an ionic bond between them, resulting in magnesium oxide, which appears as a white powder.
3. Atoms involved become ions. The atom that gains the electrons becomes an anion, the atom that loses the electrons becomes a cation. The opposite charges on the ions cause the ions to be held together, by electrostatic forces.
4. Covalent Compounds: Atoms share one or more pairs of electrons, forming a stable arrangement. The shared electron pairs create a strong, directional bond between the atoms. Covalent compounds are typically formed between non-metal elements, such as carbon, hydrogen, oxygen, nitrogen, and halogens (e.g., chlorine, fluorine, bromine). Examples of covalent compounds: water (H_2O), methane (CH_4), carbon dioxide (CO_2).

   Ionic Compounds: Atoms transfer one or more electrons from a metal to a non-metal. The resulting positively charged cation and anion (non-metal) are held together by strong electrostatic forces, forming an ionic bond. Examples of ionic compounds: sodium chloride (NaCl), calcium oxide (CaO)

Review Questions 2.4.

1. X2Y3
2. YZ
3. Basic concepts to be considered include elements and their symbols, valencies, electron configuration.

Pattern / rules: Name the compounds, write their symbols, determine the valences of the elements, exchange the valencies, write the formula and name the compound.

NOTE Always the name of the element that has positive charge comes first followed by the element with negative charge. Chlorine becomes chloride, oxygen becomes oxide, nitrogen becomes nitride, and iodine becomes iodide.

4. a) Magnesium Chloride: Magnesium has valency of 2 and chlorine I

b) Carbon Dioxide: Carbon has valency of 4 and oxygen 2

c) Sodium Nitride: Sodium has valency of 1 and nitrogen 3

d) Beryllium Oxide: Beryllium has valency of 2 and oxygen 2

e) Magnesium Hydride: Magnesium has valency of 2 and hydrogen1

f) Potassium Iodide: Potassium has valency of 1 and iodine 1.

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(GAST)

List of Contributors

Name	Institution
Prof. Christian A. Krueger	UCC, Cape Coast
Emmanuel O. Ocquaye	GES, Science Education Unit, Accra
Rev. Thomas K. Arboh	Police Education Directorate, Accra
Samuel Bismark Larbi	Mfantsipim School, Cape Coast