# CHEMISTRY

STUDENT TEXTBOOK
Grade 8

CHEMISTRY STUDENT TEXTBOOK Grade 8

ISBN 978-99944-2-287-6

FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
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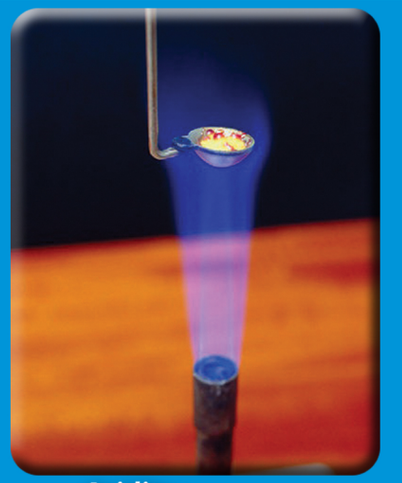

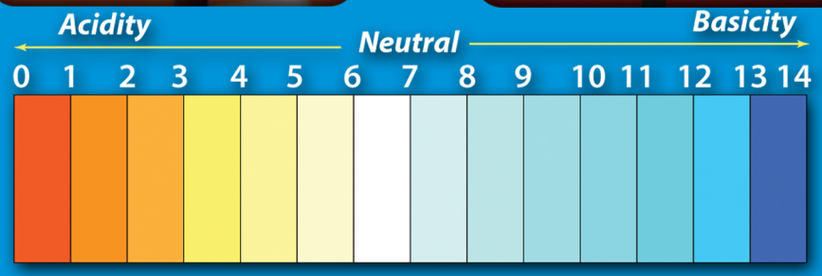


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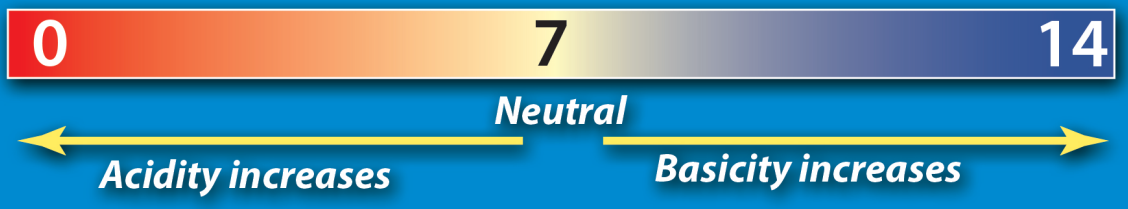


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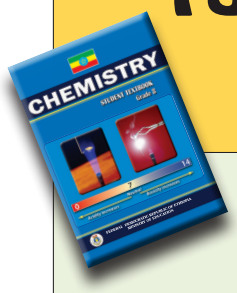


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# CHEMISTRY

## STUDENT TEXTBOOK

### GRADE 8


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**FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA**

**MINISTRY OF EDUCATION**


Published E.C. 2006 by the Federal Democratic Republic of Ethiopia, Ministry of Education, under the General Education Quality Improvement Project (GEQIP) supported by IDA Credit No. 4535-ET, the Fast Track Initiative Catalytic Fund and the Governments of Finland, Italy, Netherlands and the United Kingdom.



The Ministry of Education wishes to thank the many individuals, groups and other bodies involved– directly and indirectly – in publishing this textbook and the accompanying teacher guide.



PHOTO CREDIT: *Addis Ababa University Faculty of Scince; Department of Chemistry, Microsoft ® Encarta ® 2009; http://en.wikipedia.org, http://google.com/Images.*

***Developed and Printed by***

STAR EDUCATIONAL BOOKS DISTRIBUTORS Pvt. Ltd.

24/4800, Bharat Ram Road, Daryaganj,

New Delhi – 110002, INDIA

**and**

ASTER NEGA PUBLISHING ENTERPRISE

P.O. Box 21073

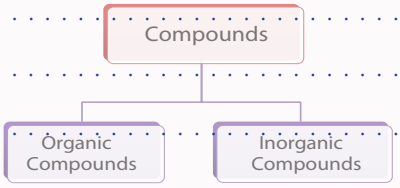
ADDIS ABABA, ETHIOPIA

*Under GEQIP Contract No. ET-MoE/GEQIP/IDA/ICB/G07/09-F.*

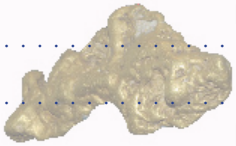
ISBN 978-99944-2-287-6

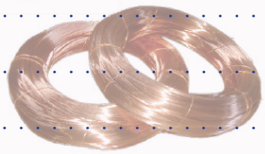
# Content



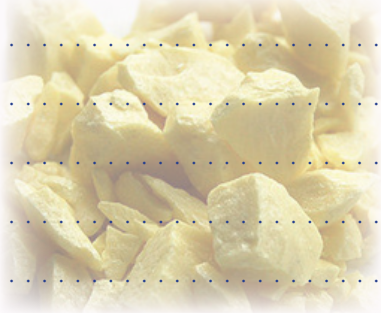


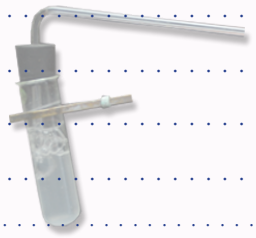




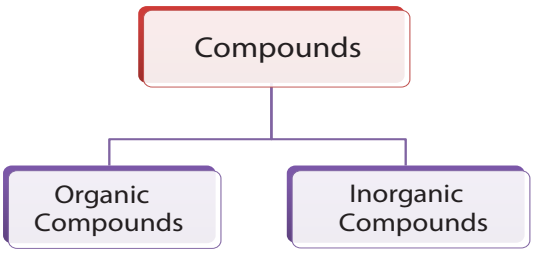






# UNIT 1

# CLASSIFICATION OF COMPOUNDS




## MAIN CONTENTS



## UNIT OUTCOMES

***After completing this unit, you will be able to:***

- ✓ explain the classification of compounds into organic and inorganic;
- ✓ know the formulas, names and importance of hydrocarbons;
- ✓ explain the classification of inorganic compounds into oxides, acids, bases and salts;
- ✓ know the properties, preparations and uses of common oxides, acids, bases and salts;
- ✓ develop skills in identifying acidic, basic and neutral solutions;
- ✓ explain the safety precautions while working with acids and bases; and
- ✓ demonstrate scientific inquiry skills along this unit: observing, classifying, comparing and contrasting, communicating, asking questions, designing experiment, drawing conclusion, applying concepts and problem solving.

## START-UP ACTIVITY

In Grade 7 Unit 2, you have learned about substances. Form groups and discuss the following.

1 What are compounds and how are they classified?

2 Assume that you are given two compounds (water and alcohol) in two different containers. Explain how you could distinguish between these two substances.

3 What are the differences between elements, compounds and mixtures?

After the group discussion, choose a group representative to present the group's opinion to the class.

# 1.1 INTRODUCTION

***After completing this section, you will be able to:***

- ✓ tell that compounds are classified as organic and inorganic;
- ✓ define organic chemistry as the study of carbon containing compounds; and
- ✓ define inorganic chemistry as the study of non-carbon containing compounds.

## HISTORICAL NOTE

**Freidrick Wöhler**

**(1800 - 1882)**

In 1828, Friedrich Wöhler, a German chemist, converted ammonium cyanate, an inorganic compound, into the organic substance urea. Wöhler's discovery revolutionized the study of chemistry by redefining the way chemists distinguished between inorganic and organic substances. He was also credited for his work in isolating the elements aluminum and beryllium.

### *What is the need to classify compounds?*

A huge number of chemical compounds are known. Just as biologists group plants and animals to show their fundamental similarities, chemists group compounds to show patterns and trends in the physical and chemical properties of substances. Classification helps us to systematically arrange the vast information of science and makes it easy to remember and understand.

Until the early 19$^{th}$ century, chemists classified compounds based on their sources as **organic** and **inorganic**. They classified compounds obtained from living organisms as *organic compounds* and compounds obtained from the constituents of the earth (minerals) as *inorganic compounds*.

The term "*organic*" was originally used by the chemists of the eighteenth century to describe compounds obtained from living sources (plants and animals). These chemists believed that nature possessed a certain vital force or '*vis vitalis*' which occurs only in living things. According to their thought, only living things could produce organic compounds. This belief was disproved in 1828 by Friedrich Wöhler, a German chemist who prepared urea, an organic compound, from the reaction between solutions of inorganic compounds *ammonium chloride* and *silver cyanate*.

$$\underset{\text{Ammonium chloride}}{NH_4Cl\ (aq)} + \underset{\text{Silver cyanate}}{AgCNO\ (aq)} \longrightarrow \underset{\text{Ammonium cyanate}}{NH_4CNO\ (aq)} + \underset{\text{Silver chloride}}{AgCl\ (s)}$$

$$NH_4CNO\ (aq) \xrightarrow{\text{Heat}} \underset{\text{Urea}}{(NH_2)_2CO\ (s)}$$

Today, *organic chemistry* is defined as the study of carbon containing compounds. Nearly all compounds found in living organisms are organic. Besides this, the vast majority of compounds encountered in our daily lives are organic.

*Inorganic chemistry* is the study of non-carbon containing compounds. Note that inorganic chemistry also includes the study of certain carbon containing compounds such as carbonates, hydrogen carbonates, carbon monoxide and carbon dioxide which are not organic compounds. The properties of these compounds are more closely related to those of inorganic substances.

## Exercise 1.1

1 Classify each of the following compounds as organic or inorganic.

| | | | |
|---|---|---|---|
| a | Common salt | e | Vinegar (Aceto) |
| b | Animal fat | f | Carbon dioxide |
| c | Sugar | g | Vegetable oil |
| d | Iron (II) oxide | h | Water |

2 Which field of study (organic chemistry or inorganic chemistry) includes the study of the properties and preparation of each of the following substances?

| | | | |
|---|---|---|---|
| a | Chalk | c | Plastics |
| b | Aspirin (*anti-pain*) | d | Urea |

# 1.2 Organic Compounds

***After completing this section, you will be able to:***

- ✓ write the general formula of alkanes, alkenes and alkynes;
- ✓ write the specific chemical formulas of the first ten members of alkanes, alkenes and alkynes;
- ✓ name the first ten members of alkanes, alkenes and alkynes; and
- ✓ list some common uses of organic compounds.

## 1.2.1 Formula of Hydrocarbons

### ACTIVITY 1.1

Form a group and perform the following activity. Share your opinion with your group members.

1 Why do you think hydrocarbons are classified as organic compounds?

2 Which elements are constituents of hydrocarbons?

3 Why is the name "hydrocarbon" given to the compounds mentioned above?

Organic compounds are classified based on their functional groups. Each group of organic compound is called a **homologous series**.

Organic compounds containing only hydrogen and carbon are called *hydrocarbons*. The three major classes of hydrocarbons are alkanes, alkenes and alkynes.

### Alkanes

*Alkanes* are hydrocarbons with the general formula of $C_nH_{2n+2}$, where n = 1, 2, 3, etc and stands for the number of carbon atoms in each alkane. For example, if n is 1, the formula of the alkane becomes $C_1H_{2\times1+2} = CH_4$. Similarly, if n is 2, the formula of the alkane becomes $C_2H_{2\times2+2} = C_2H_6$. If you closely observe the formulas of the two compounds, they differ by $CH_2$ group. Compounds that differ by a constant group like $CH_2$ are called *homologues*.

$$CH_4 \xrightarrow{CH_2} C_2H_6 \xrightarrow{CH_2} C_3H_8 \xrightarrow{CH_2} C_4H_{10}$$

A group of compounds whose consecutive members differ by a $CH_2$ group is known as a homologous series. It is a series of compounds of similar properties.

### Exercise 1.2

1 Write the formulas of alkanes that contain three, five, seven, and nine carbon atoms.

2 Give the formulas for the alkane homologues immediately coming before and after $C_6H_{14}$.

### Alkenes

*Alkenes* are hydrocarbons with the general formula of $C_nH_{2n}$ where n = 2, 3, 4, etc. Alkenes have fewer hydrogen atoms than the corresponding alkanes. For example, if n is 2, the formula of the alkene becomes $C_2H_{2\times2} = C_2H_4$, whereas the corresponding alkane has the formula $C_2H_6$. Similarly, if n is 3, the formula of the alkene becomes $C_3H_{2\times3} = C_3H_6$ and the formula of the corresponding alkane is $C_3H_8$.

## Exercise 1.3

1 What is the difference between alkanes and alkenes?

2 Write the formulas of the alkenes that contain four, six, eight and ten carbon atoms.

3 For the first 6 members in the series of alkenes, plot the number of carbon atoms on one axis and the number of hydrogen atoms on the other axis. Use this graph to derive the formula of the alkene that has 10 carbon atoms.

## Alkynes

*Alkynes* are hydrocarbons with the general formula of $C_nH_{2n-2}$. For instance, if n is 2, the formula of the alkyne becomes $C_2H_{2x2-2} = C_2H_2$. Similarly, if n is 4, the formula of the alkyne is $C_4H_{2\times4-2} = C_4H_6$. Note that the number of hydrogen atoms present in an alkyne is always twice the number of carbon atoms minus two.

## Exercise 1.4

1 Write the formulas of the first nine members in the series of alkynes.

2 Write the formulas of the corresponding alkane, alkene and alkyne which contain 9 carbon atoms. Compare and contrast the formulas of these hydrocarbons.

## 1.2.2 Nomenclature (Naming) of Hydrocarbons

### Activity 1.2

Form a group and perform the following activity. Share your opinion with your group members.

1 How do we give specific name to a hydrocarbon?

2 Are hydrocarbons named based on certain rules or randomly?

We name alkanes, alkenes and alkynes by combining prefixes and suffixes. To name a hydrocarbon (an alkane, an alkene, an alkyne), we use one of the prefixes given in Table 1.1 prefixes of the first ten hydrocarbons to indicate the number of carbon atoms in the hydrocarbon. We then add an appropriate suffix to indicate the type of hydrocarbon. In general:

| Number of carbon atoms | Prefix |
|---|---|
| 1 | Meth- |
| 2 | Eth- |
| 3 | Prop- |
| 4 | But- |
| 5 | Pent- |
| 6 | Hex- |
| 7 | Hept- |
| 8 | Oct- |
| 9 | Non- |
| 10 | Dec- |

⇨ *The names of alkanes, alkenes and alkynes end with the suffixes '-ane', '-ene' and '-yne', respectively.*

For instance, the formula of the alkane containing one carbon atom is $CH_4$. The prefix is '*meth-*' and we add the suffix '*-ane*' to the prefix. Thus, the name of the compound becomes methane. Similarly, $C_5H_{12}$ contains five carbon atoms in its molecule, so its prefix is '*pent-*'. It is an alkane, hence the name ends with '*-ane*'. Thus, $C_5H_{12}$ is named pentane.

***What is the name of the alkane that has the formula $C_7H_{16}$?***

The method used for naming alkanes also applies to alkenes. But, the ending (*suffix*) '*-ene*' is used instead of '*-ane*'. For example, an alkene that has the formula $C_5H_{10}$ is named pentene. The prefix '*pent-*' indicates that the compound contains five carbon atoms, and the suffix '*-ene*' shows that the compound is an alkene.

***What is the name of an alkene having the formula $C_3H_6$?***

Alkynes are also named using the same method. The names of alkynes are obtained by changing the suffix '*-ane*' of alkanes to '*-yne*'. For example, the formula of alkyne containing two carbon atoms is $C_2H_2$. The prefix is '*eth-*' and the suffix is '*-yne*'. Combining the prefix and suffix gives ethyne.

***What is the name of an alkyne having the formula $C_3H_4$?***

## Exercise 1.5

1 Write the molecular formulas of the following hydrocarbons.

   a Butane, butene, and butyne

   b Hexane, hexene and hexyne

2 Copy and complete the following table in your exercise book.

| Number of Carbon atoms | Formula of Alkane | Name of Alkane | Formula of Alkene | Name of Alkene | Formula of Alkyne | Name of Alkyne |
|---|---|---|---|---|---|---|
| 1 | | | — | — | — | — |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |

## 1.2.3 Importance of Organic Compounds

### ACTIVITY 1.3

Form a group and perform the following activity. Share your opinion with your group members.

1 Give some examples of organic compounds that are used in your locality.

2 Explain how these organic compounds have made life more comfortable for human beings.

Many organic compounds are very useful in our daily life. Some important organic compounds and their uses are described in the following section.

### Importance of Some Hydrocarbons

#### Methane, $CH_4$

Methane is mainly used as a source of energy for cooking, heating and generating electricity. Biogas that is used as a domestic fuel mainly consists of methane.

#### Propane and Butane

Both propane and butane are gaseous alkanes. The mixture of propane and butane is compressed at a moderate pressure and stored in steel cylinders. It is marked as bottled gas and commonly known as "butagas". It is mainly used for cooking and heating.

***What is the physical state of the fuel in a lighter? What happens if you press the lighter in order to let the fuel to flow out?***

#### Octane

Octane is a liquid alkane. Octane is one of the components of petrol. It is used as fuel in engines. *Figure 1.1* shows a fuel station where octane and other hydrocarbons are stored and sold.

*Figure 1.1:* **Fuel station**

## Decane

***Do your parents use kerosene? If your answer is yes, for what purpose do they use it?***

Decane is one of the components of kerosene. Kerosene is used for lighting and cooking. It is also used as jet fuel.

## Ethene and Propene

Ethene and propene are gaseous alkenes. Both ethene and propene are used for the production of plastics. Ethene is the starting material in the synthesis of polyethylene plastics. Propene is used for the production of polypropylene plastics. *Figure 1.2* shows containers made from plastics.

**Plastic bottles** **Plastic containers** **Water tank**

*Figure 1.2:* **Containers made from plastics**

## Ethyne

Ethyne is the simplest alkyne. One of the main uses of ethyne is to produce oxyacetylene flame, which is used in the cutting and welding of steel and iron (*Figure 1.3*).

*Figure 1.3:* **Oxyacetylene torch**

# Importance of Other Organic Compounds

## Ethanol (Ethyl alcohol)

***What is the common constituent of 'Tella', 'Tej', 'Katikalla', 'Wine', 'Ouzo', etc?***

All alcoholic beverages contain ethanol. Nowadays ethanol mixed with petrol is used as a fuel. It is also used in the production of acetic acid, and in hospitals and clinics for cleaning wounds.

## ACTIVITY 1.4

In your group, discuss the negative effects of drinking alcohol. After the discussion, choose a group representative to present the group's opinion to the class.

### Ethanoic Acid (Acetic acid)

When we eat uncooked vegetables such as salad, we usually add 'acheto' or vinegar. Vinegar is used as food flavoring agent. It is also used as a disinfectant. For table vinegar, the acetic acid concentration typically ranges from 4% to 8%, by volume. For use in preserving vegetables (pickling) it typically ranges up to 18%.


*Figure 1.4:* **Vinegar in a glass bottle**

### Formalin

The water solution of formaldehyde is referred to as formalin. Formalin contains 40%, by volume, of formaldehyde. Formalin is used for the preservation of biological specimens, because it makes proteins hard and insoluble.


*Figure 1.5:* **Formalin in a plastic bottle**

## Exercise 1.6

1 Write the formula of each of the following hydrocarbons.

a Pentene
b Heptane
c Hexyne
d Octene
e Nonane

2 Classify each of the following hydrocarbons as alkane, alkene or alkyne.

a $C_5H_{10}$
b $C_{14}H_{30}$
c $C_{15}H_{28}$
d $C_7H_{16}$

3 Write the formula and name of each hydrocarbon described below.

a An alkane that contains eight carbon atoms.
b An alkane that contains seven carbon atoms.
c An alkene that contains nine carbon atoms.

d An alkene that contains eight carbon atoms.

e An alkyne that contains eight carbon atoms.

f An alkyne that contains seven carbon atoms.

4 Name the hydrocarbons or an organic compound described by each of the following.

a Bottled gas used as fuel.

b Component of fuel for engines.

c Component of kerosene.

d Starting materials for the production of plastics.

e A fuel to produce flame used for cutting and welding metals.

f A constituent of all alcoholic beverages.

g Organic chemical used to preserve biological specimens.

h A chemical used as food flavoring agent.

## 1.3 INORGANIC COMPOUNDS

***After completing this section, you will be able to:***

- ✓ tell that inorganic compounds are classified into oxides, acids, bases and salts;
- ✓ define oxides;
- ✓ classify oxides into metallic and non-metallic oxides;
- ✓ give examples of metallic and non-metallic oxides;
- ✓ define acidic oxide and basic oxide;
- ✓ give examples of acidic and basic oxides;
- ✓ describe the properties of acidic oxides and basic oxides;
- ✓ explain the preparation of acidic oxides and basic oxides;
- ✓ prepare sulfur dioxide in the laboratory by burning sulfur in air;
- ✓ use moist blue litmus paper to test the acidic nature of sulfur dioxide;
- ✓ prepare magnesium oxide in the laboratory by burning magnesium ribbon in air;
- ✓ use red litmus paper to test the basicity of magnesium oxide in water solution;
- ✓ define acid as a substance that releases hydrogen ions in water solution;
- ✓ give common examples of acids;
- ✓ define pH as the measure of acidity or alkalinity of a solution;
- ✓ describe pH scale;
- ✓ explain preparation of acids by direct combination of elements and reaction of acidic oxide with water;
- ✓ describe the properties of acids;

- ✓ conduct experiments on the properties of acids;
- ✓ list some common uses of hydrochloric acid, nitric acid and sulphuric acid;
- ✓ define base as a substance that neutralises an acid;
- ✓ define an alkali as a substance that releases hydroxide ions in aqueous solution;
- ✓ give some common examples of bases;
- ✓ prepare bases by the reaction of metals with water and basic oxides with water;
- ✓ describe the properties of alkalis;
- ✓ investigate properties of bases experimentally;
- ✓ list some common uses of sodium hydroxide, magnesium hydroxide and calcium hydroxide;
- ✓ define dilute and concentrated acid and base;
- ✓ describe concentrated acidic and alkaline solutions;
- ✓ describe dilute acidic and alkaline solutions;
- ✓ explain the safety precautions while working with acids and bases;
- ✓ give some common examples of salts;
- ✓ name some common salts;
- ✓ define salts as compounds that are composed of the positive ions of a base and the negative ions of an acid;
- ✓ tell that salts are classified as binary and ternary;
- ✓ define binary salts;
- ✓ define ternary salts;
- ✓ give examples of binary and ternary salts;
- ✓ explain direct elemental combination and neutralization reactions as methods of salt preparation; and
- ✓ list some uses of common salts.

## ACTIVITY 1.5

Form a group and discuss the following activity.

What do you like to eat for your breakfast? What are some of the substances in your breakfast? Look at the label on the boxes or any container from which your breakfast is prepared. What names of substances can you identify on the label? Compare the names of elements on the label with the names of elements in the periodic table.

Just like organic compounds, inorganic compounds can be classified into groups according to their composition and their properties. These include *oxides*, *acids*, *bases* and *salts*.

## 1.3.1 Oxides

### ACTIVITY 1.6

Form a group and perform the following activity. Write the answers to the questions in your notebook.

Answer the following questions based on the given compounds

| | | | | | |
|---|---|---|---|---|---|
| a | Magnesium oxide | c | Sulphur dioxide | e | Carbon dioxide |
| b | Calcium oxide | d | Sodium oxide | | |

1 Write the formulas of the above compoounds and the symbols of its elements.

2 Which element is common to all compounds given above?

3 How can the compounds mentioned above be classified? Give reasons for your classifications.

4 Based upon the constituent elements, predict which compound is a metallic oxide and which one is a non-metallic oxide?

Now join your group and discuss your answers together. After the discussion, choose a group representative to present the group's opinion to the class.

Oxides are binary compounds that contain oxygen. Many elements react with oxygen to form oxides.

Element + Oxygen → Oxide

The noble gases (He, Ne, Ar, etc.) and inactive metals such as *gold*, *platinum* and *palladium* do not react with oxygen to form oxides. Some examples of oxides are $Li_2O$, $Na_2O$, $NO_2$, $SO_2$, $CO_2$, etc.

### Exercise 1.7

Which of the following compounds are binary compounds? Which of them are oxides?

| | | | | | |
|---|---|---|---|---|---|
| a | HCl | d | $NO_2$ | g | $Fe(OH)_2$ |
| b | KOH | e | $HClO_3$ | h | $Pb(NO_3)_2$ |
| c | $H_2O_2$ | f | $MnO_2$ | | |

## Types of Oxides

Most oxides are classified as ***metallic oxides*** and ***non-metallic oxides.***

Metallic oxides are binary compounds containing only metals and oxygen. Examples are CaO, $Na_2O$, $Al_2O_3$, MgO, etc.

***Non-Metallic Oxides*** are binary compounds containing only non-metals and oxygen.

$NO_2$, $H_2O$, $CO_2$, etc are common example of non-metallic oxides.

***Acidic oxides*** are oxides of non-metals. They are also called **acid anhydrides**. Acid anhydride means acid without water. There are some oxides of metals that are acidic. For example, $CrO_3$ and $WO_3$. All non-metallic oxides are not necessarily acidic oxides. For example, CO and NO are neutral. Some examples of acidic oxides are $SO_2$, $NO_2$, $P_4O_6$, $CO_2$, etc.

***Basic oxides*** are oxides of metals. They are also called **basic anhydrides.** All metallic oxides are not necessarily basic oxides. Some examples of basic oxides are $Na_2O$, $Li_2O$, CaO, MgO, etc.

## Exercise 1.8

1 What products are formed when the following metals react with an excess oxygen?

a Magnesium
b Zinc
c Iron
d Lithium

2 Classify the following oxides as acidic or basic oxides. Give reasons for your classifications.

a CuO b CO c $K_2O$ d $P_2O_5$

## Properties of Oxides

An *acidic oxide* or acid anhydride reacts with water, to form an acid.

Acidic oxide + Water → Acid

**Examples**

$SO_3$ (*Sulphur trioxide*) + $H_2O$ (*Water*) → $H_2SO_4$ (*Sulphuric acid*)

$CO_2$ (*Carbon dioxide*) + $H_2O$ (*Water*) → $H_2CO_3$ (*Carbonic acid*)

Acidic oxides react with bases to form salts and water.

Acidic oxide + Base → Salt + Water

**Example**

$SO_3$ (*Sulphur trioxide*) + $Ca(OH)_2$ (*Calcium Hydroxide*) → $CaSO_4$ (*Calcium sulphate*) + $H_2O$ (*Water*)

A *basic oxide* or basic anhydride reacts with water to produce a base.

Basic oxide + Water → Base

**Examples**

CaO (*Calcium oxide*) + $H_2O$ (*Water*) → $Ca(OH)_2$ (*Calcium hydroxide*)

$K_2O$ (*Potassium oxide*) + $H_2O$ (*Water*) → 2KOH (*Potassium hydroxide*)

Basic oxides react with acids to form salts and water.

Basic oxide + Acid → Salt + Water

**Example**

$$\underset{\text{Calcium oxide}}{CaO} + \underset{\text{Hydrochloric acid}}{2HCl} \rightarrow \underset{\text{Calcium chloride}}{CaCl_2} + \underset{\text{Water}}{H_2O}$$

## Exercise 1.9

1 Classify the following oxides as acidic or basic and give one possible reason to support your statement.

a Barium oxide
b Sulphur dioxide
c Sodium oxide
d Carbon dioxide

2 The observations given below are related to two oxides, **A** and **B**. Classify the oxides as acidic and basic oxides.

**A** *is a white crystalline solid which reacts vigorously with water, forming a solution which turns blue litmus paper red.*

**B** *is a white solid which reacts vigorously with water, forming a white suspension. When this is filtered, the filtrate turns red litmus paper blue.*

3 Predict whether or not the oxide formed from each of the following elements is a basic oxide and an acidic oxide.

a Sodium
b Calcium
c Carbon
d Phosphorus

4 How do oxides of metals differ chemically from those of non-metals?

5 Classify the following oxides as acidic or basic oxides.

a $P_4O_{10}$
b $N_2O_5$
c BaO
d $SO_3$
e $K_2O$

6 Identify the anhydrides of the following acids and bases.

a $HNO_3$
b NaOH
c KOH
d $H_2SO_4$
e $H_2CO_3$

## Preparation of Oxides

There are two common methods for preparing oxides. These are:

i direct combination of elements with oxygen (direct synthesis) and

ii thermal decomposition of some compounds.

### I *Direct combination of elements with oxygen*

Direct synthesis involves the combination of oxygen with active metals and non-metals.

a **Non-metal + Oxygen → Non-metallic oxide**

**Examples**

$$\underset{\textit{Carbon}}{C} + \underset{\textit{Oxygen}}{O_2} \rightarrow \underset{\textit{Carbon dioxide}}{CO_2}$$

$$\underset{\textit{Phosphorus}}{4P} + \underset{\textit{Oxygen}}{5O_2} \rightarrow \underset{\textit{Phosphorus pentoxide}}{2P_2O_5}$$

b **Metal + Oxygen → Metallic oxide**

**Examples**

$$\underset{\textit{Iron}}{4Fe} + \underset{\textit{Oxygen}}{3O_2} \rightarrow \underset{\textit{Iron (III) oxide}}{2Fe_2O_3}$$

$$\underset{\textit{Magnesium}}{2Mg} + \underset{\textit{Oxygen}}{O_2} \rightarrow \underset{\textit{Magnesium oxide}}{2MgO}$$

### ACTIVITY 1.7

Form a group and discuss the following activity.

Write chemical equations that show preparations of oxides of nitrogen and sodium by direct synthesis.

### Experiment 1.1

***Title:*** **Preparation of Sulphur Dioxide**

***Objective:*** To prepare sulphur dioxide and test whether it is an acidic oxide or a basic oxide.

***Materials required:*** Sulphur, litmus paper (blue and red), gas jar, Bunsen burner, deflagrating spoon.

***Procedure:***

1. Put some powdered sulphur in a deflagrating spoon and ignite it as shown in *Figure 1.6*.
2. When it starts burning, put it into a gas jar.
3. When the burning stops, add 5 mL of water to the gas jar and shake.
4. Put blue and red litmus paper, one after the other, in the jar.
5. Record your observations.

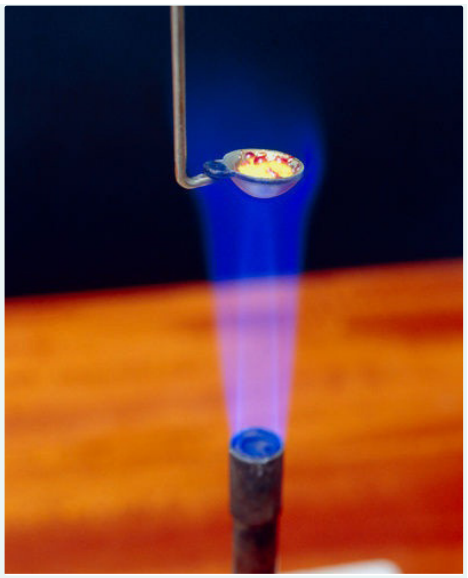


*Figure 1.6:* **Burning sulphur in air**

***Observation and Analysis:***

a. What is the color of the flame when sulphur burns in air? What happens to the color of blue and red litmus papers in step 4?

b. Write the chemical equation for this combustion reaction.

c. Classify the oxide formed by the combustion of sulphur as acidic or basic.

## Experiment 1.2

***Title:*** **Preparation of Magnesium Oxide**

***Objective:*** To prepare magnesium oxide and test whether it is an acidic oxide or a basic oxide.

***Materials required:*** Magnesium ribbon, red and blue litmus papers, Bunsen burner, tongs, crucible.

***Procedure:***

1. Cut about 2 cm of magnesium ribbon.
2. Hold the ribbon with a tong and burn it over a flame from the Bunsen burner as shown in *Figure 1.7*. The moment it starts burning, put the burning metal into a crucible and collect the product.
3. Add a small amount of water to the resulting powder in the crucible and shake it.
4. Rub the resulting substance between your fingers.
5. Test the solution with red and blue litmus paper.
6. Record your observations.

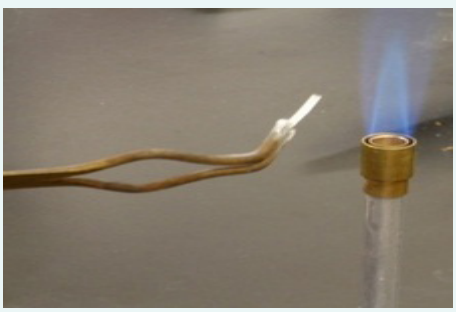


*Figure 1.7:* **Burning of magnesium in air**

***Observation and Analysis:***

a What is the color of the flame produced when magnesium burns in air?

b Write the chemical equation for the reaction.

c What do you feel when you rub the magnesium oxide solution between your fingers?

d What happens to the color of the red and blue litmus papers?

e Is the resulting solution basic or acidic?

## II *Thermal decomposition of some compounds*

Thermal decomposition of a compound (also called *indirect synthesis*) is its decomposition by the action of heat. The following examples indicate the formation of oxides by thermal decomposition.

### a Thermal decomposition of metal hydroxides

Metal hydroxides decompose by heat to form metal oxides and water.

$$\text{Metallic hydroxide} \xrightarrow{\text{heat}} \text{Metallic oxide} + \text{Water}$$

**Examples**

$$\underset{\textit{Zinc hydroxide}}{Zn(OH)_2} \xrightarrow{\text{heat}} \underset{\textit{Zinc oxide}}{ZnO} + \underset{\textit{Water}}{H_2O}$$

$$\underset{\textit{Lead(II) hydroxide}}{Pb(OH)_2} \xrightarrow{\text{heat}} \underset{\textit{Lead(II) oxide}}{PbO} + \underset{\textit{Water}}{H_2O}$$

### b Thermal decomposition of carbonates

Some metal carbonates decompose by heat to form metal oxides and carbon dioxide.

$$\text{Metallic carbonate} \xrightarrow{\text{heat}} \text{Metallic oxide} + \text{Carbon dioxide}$$

**Examples**

$$\underset{\textit{Zinc carbonate}}{ZnCO_3} \xrightarrow{\text{heat}} \underset{\textit{Zinc oxide}}{ZnO} + \underset{\textit{Carbon dioxide}}{CO_2}$$

$$\underset{\textit{Calcium carbonate}}{CaCO_3} \xrightarrow{\text{heat}} \underset{\textit{Calcium oxide}}{CaO} + \underset{\textit{Carbon dioxide}}{CO_2}$$

### c Thermal Decomposition of nitrates

Nitrates decompose by heat to give metallic oxides, nitrogen dioxide and oxygen.

$$\text{Metallic nitrate} \xrightarrow{\text{heat}} \text{Metallic oxide} + \text{Nitrogen dioxide} + \text{Oxygen}$$

**Examples**

$$2Zn(NO_3)_2 \xrightarrow{heat} 2ZnO + 4NO_2 + O_2$$
*Zinc nitrate* — *Zinc oxide* — *Nitrogen dioxide* — *Oxygen*

$$2Pb(NO_3)_2 \xrightarrow{heat} 2PbO + 4NO_2 + O_2$$
*Lead(II) nitrate* — *Lead(II) oxide* — *Nitrogen dioxide* — *Oxygen*

## ACTIVITY 1.8

1 Refer to Chemistry text books or any other reference materials and investigate the formation of oxides by the thermal decomposition of

a copper hydroxide b copper carbonate c copper nitrate

2 Write the chemical equations for the reactions in this activity.

## Exercise 1.10

1 Describe some acidic oxides that can be prepared by the thermal decomposition of nitrates and carbonates.

2 Give two other examples each to acidic and basic oxides that are not mentioned above.

## 1.3.2 Acids

## ACTIVITY 1.9

Form a group and perform the following activity.

Imagine a taste experiment using orange, lemon, tomato and grape fruit. They all taste alike. In what way would they taste alike, and why? What is the name of the acid in lemon and orange?

After the discussion, present the group's opinion to the class.

**CAUTION!** *You should not taste any substance to identify the acidity or basicity unless you are told to do so.*

*Figure 1.8:* **A boy tasting lemon**

For millions of years people have known that vinegar, lemon juice and many other foods taste sour. However, only a few hundred years ago people discovered why these things taste sour.

The term *acid*, in fact, comes from the Latin term "*acidus*" which means "sour". We come across many acids each day in the food we eat, see *Figure 1.9* For example, orange juice and grape fruit juice contain citric acid. These juices, and others, also contain ascorbic acid, commonly known as Vitamin C. Salads are often flavored with vinegar, which contains dilute acetic acid. Carbonated beverages have carbonic acid in them. Sour 'Tella' contains acetic acid and milk contains lactic acid. So not all acids are harmful.

## ACTIVITY 1.10

In your group, list names of some laboratory acids you know. Among your list, select three most common laboratory acids. Then, tell your classmates what these acids are.

We also have acids in our body. For example, human stomach contains *hydrochloric acid,* which is used to digest food. Some insects use acids as a form of defense. For example, bees and ants contain formic acid in their stings which create irritating pain when they bite us.


*Figure 1.9:* **Some substances containing acids**

Acids are a group of substances that release hydrogen ions ($H^+$) when they are in aqueous solution. Acids have sour taste.

**Example:**

$$HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl^-(aq)$$

Note that (g) stands for the *gaseous state* and (aq) stands for the *aqueous* (*water*) solution.

In any chemistry laboratory, we find acids such as *hydrochloric acid*, *sulphuric acid*, and *nitric acid*. These acids are called *mineral acids*. Hydrochloric acid, nitric acid and sulphuric acids are the three common laboratory acids. You probably use mineral acids in your school laboratory.

Some more examples of acids that we commonly encounter in our lives are citric acid (from citrus fruits), carbonic acid (for the carbonation of soft drinks), methanoic acid (formic acid), and benzoic acid.

## The pH Scale

When scientists talk about how acidic or basic a solution is, they use the *pH scale*. pH is a measure of acidity or alkalinity of a solution. The pH scale ranges from 0 to 14.

- *Acids have pH value below 7. The more acidic a solution is, the lower its pH value will be.*
- *Bases have pH value above 7. The more basic a solution is the higher its pH value will be.*
- *The pH of a neutral solution is very close to 7.0.*

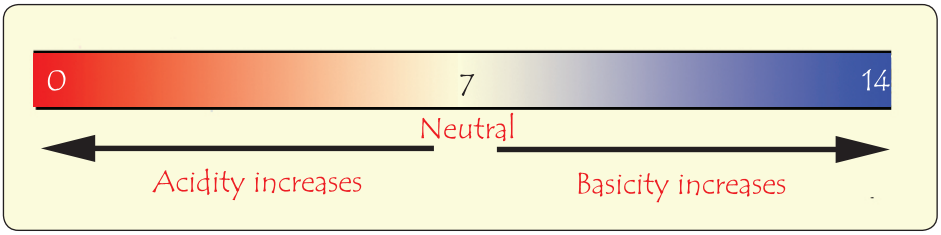



*Figure 1.10:* **The pH scale**

Almost all substances can be classified as *acidic*, *basic*, or *neutral* based on their pH values.

## ACTIVITY 1.11

Form a group and perform the following activity.

1 Predict the pH values of the following substances:

Lemon juice, solution of soap, a solution of antiacid, vitamin C and water.

2 Use *Figure 1.10* as an example, and draw a scale for the pH range between acid and base, through neutral.

Stomach acid (pH = 1), rain water (pH = 5.5), baking soda (pH = 9), and blood (pH = 7.4).

After the discussion, choose a group representative to present your group's opinion to the class.

## Preparation of Acids

There are two ways of preparing acids. These are:

i direct combination of elements

ii reaction of acidic oxides with water.

### I *Direct Combination of Elements*

Some non-metals combine with hydrogen to form binary compounds, which in turn dissolve in water to produce acids. For example, hydrogen combines with chlorine to form hydrogen chloride gas. Hydrogen chloride, mixed with water, produces hydrochloric acid.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

$$HCl(g) + H_2O(l) \rightarrow HCl(aq), (\textit{hydrochloric acid})$$

Note that (l) *stands for the liquid state*, (g) for the gaseous sate and (aq) for water solution.

## ACTIVITY 1.12

Form a group and perform the following activity.

Write the chemical equations and names of binary acids that can be formed from the reaction between hydrogen and fluorine, bromine, and sulphur.

After the discussion, choose a group representative to present the group's opinions to the class.

### II *Reaction of Acidic Oxides with Water*

Acidic oxides (*acid anhydrides*) react with water to form acids.

Acid anhydride + Water → Acid

**Examples**

$N_2O_5(g)$ + $H_2O(l)$ → $2HNO_3(aq)$

*Nitrogen pentoxide* *Water* *Nitric acid*

$SO_3(g)$ + $H_2O(l)$ → $H_2SO_4(aq)$

*Sulphur trioxide* *Water* *Sulphuric acid*

## ACTIVITY 1.13

Form a group and perform the following activity. After the discussion, choose a group representative to present the group's opinion to the class.

Write the chemical equation that represents how sulphuric acid is prepared from its acidic oxide (acid anhydride).

## Exercise 1.1

1 Name the following common laboratory acids.

a HCl

b $HNO_3$

c $H_2SO_4$

2 Indicate the pH value as pH < 7, pH = 7 or pH > 7 for each of the following substances.

a Lemon juice

b Water

c Aqueous solution of MgO

d Aqueous solution of $Na_2O$

3 Identify the compounds represented by X, Y and Z, and write the complete and balanced chemical equations. Name the reactant or product wherever necessary.

a $X + H_2O(l) \rightarrow H_2SO_3$ (*Sulphurous acid*)

b $CO_2(g) + H_2O(l) \rightarrow Y$ ( ? )

c $P_2O_3(g) + H_2O(l) \rightarrow Z$ ( ? )

## Properties of Acids

### 1 *Acids change the color of indicaters*

#### *What are acid-base indicators?*

The easiest technique to identify an acid from a base is by using acid-base indicators. *Indicators* are dyes extracted from plants that show the presence of an acid or a base by undergoing specific color changes when placed in a solution. Litmus, methyl orange phenolphthalein, and universal indicator are common indicators

### Experiment 1.3

***Title*: Effect of acids on acid-base indicators**

***Objective*:** To investigate the effect of dilute hydrochloric acid and sulphuric acid on the colors of litmus paper, phenolphthalein and methyl orange.

***Materials required*:** Blue and red litmus papers, phenolphthalein, methyl orange, test tubes, test tube rack, dilute solutions of hydrochloric acid and sulphuric acid.

***Procedure*:**

1 Pour about 5 mL of dilute HCl into three test tubes.

2 Hold the first test tube in inclined position and put blue and red litmus papers turn by turn into it and see if there is any colour change.

3 Add few drops of phenolphthalein in the second and few drops of methyl orange in the third and observe if there is colour change.

4 Repeat the above procedure using dilute $H_2SO_4$ solution.

***Observation and analysis*:**

Record your findings in the following table.

| Acid | Color of the indicator in the acid solution | | |
|---|---|---|---|
| | Litmus | Phenolphthalein | Methyl orange |
| Dilute HCl | | | |
| Dilute $H_2SO_4$ | | | |

Write a laboratory report in groups and submit it to your teacher.

## ACTIVITY 1.14

Form a group and perform the following activity. Choose a group representative to present the group's opinion to the class.

Add a small amount of lemon juice to a glass of tea. What happens to the color of the tea? Which is the indicator, the lemon juice or the tea?

## II *Reaction of Acids with metals*

Dilute acids react with active metals like zinc, magnesium, iron and aluminum to form salts and liberate hydrogen gas.

Active Metal + Dilute Acid → Salt + Hydrogen

**Example**

$$\underset{\textit{Calcium}}{Ca(s)} + \underset{\textit{Hydrochloric acid}}{2HCl(aq)\ (\textit{dilute})} \rightarrow \underset{\textit{Calcium chloride}}{CaCl_2(aq)} + \underset{\textit{Hydrogen}}{H_2(g)}$$

## Experiment 1.4

***Title:*** **Reaction of an acid with a metal**

***Objective:*** To investigate the reaction of zinc metal with hydrochloric acid.

***Materials required:*** Test tubes, test tube rack, rubber stopper, zinc metal, dilute HCl, steel wool, lighter or match, wooden splint.

***Procedure:***

1. Pour about 5 mL of dilute HCl into a test tube as shown in *Figure 1.11*.
2. Clean a piece of zinc with the steel wool until it is shiny.
3. Add zinc to the test tube containing dilute HCl, close the test tube with a rubber stopper and record your observations.

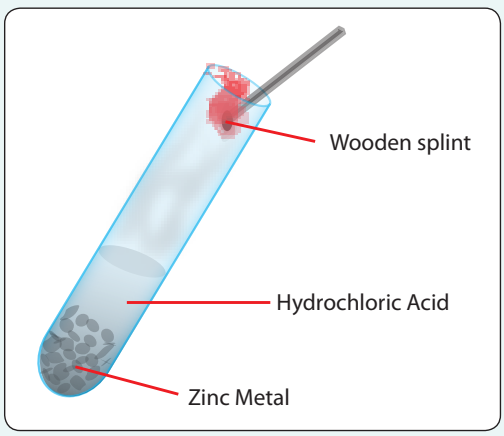



*Figure 1.11:* **Reaction of zinc with HCl**

4. Ignite a wooden splint using lighter or match, remove the rubber stopper and introduce the lighted splint in to the mouth of the test tube as shown in *Figure 1.11*.

**CAUTION!** *Note that you should hold the test tube and the lighted splint away from yourself and others!*

***Observation and analysis:***

a Why was the piece of zinc cleaned with steel wool?

b What happens when you drop zinc metal into the test tube containing dilute HCl?

c How do you know that a gas is produced in the reaction?

d What is the colour of the gas?

e What happens when the lighted splint is held inside the mouth of the test tube?

f Write the chemical equation for the reaction between zinc and hydrochloric acid.

Write a laboratory report in groups and present to the rest of the class.

## ACTIVITY 1.15

Perform the following tasks in groups, present your group's work to the rest of the class.

1 Write the balanced chemical equations for the reactions between dilute hydrochloric acid and;

a Magnesium

b Aluminium

c Iron

2 Write the balanced chemical equations representing the reactions between dilute $H_2SO_4$ and:

a Zinc

b Magnesium

c Aluminium

d Iron

## III *Reaction of Acids with Carbonates and Hydrogen Carbonates*

Acids react with carbonates and hydrogen carbonates to form salts, water and carbon dioxide gas.

Acid + Carbonate → Salt + Water + Carbon dioxide

Acid + Hydrogen carbonate → Salt + Water + Carbon dioxide

**Example**

$2HCl\,(aq) + MgCO_3(s) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$

$H_2SO_4\,(aq) + Ca(HCO_3)_2(aq) \rightarrow CaSO_4(aq) + 2H_2O\,(l) + 2CO_2(g)$

## Experiment 1.5

***Title*: Reactions of acids with carbonates and hydrogen carbonates**

***Objective*:** To investigate the reactions of carbonates and hydrogen carbonates with dilute hydrochloric acid and sulphuric acid.

***Materials required*:** Dilute hydrochloric acid, dilute sulphuric acid, calcium carbonate, sodium hydrogen carbonate, test tubes, test tube rack, lime water (calcium hydroxide solution), spatula, rubber stopper.

***Procedure*:**

1. Using a spatula, add calcium carbonate powder or a lump of calcium carbonate into the first test tube and 5 mL of lime water into the second test tube.
2. Add 5 mL of dilute hydrochloric acid into a test tube containing calcium carbonate, cover its mouth with rubber stopper immediately and hold it in inclined position.
3. Bring the mouth of the test tube containing lime water with your other hand holding it in an inclined position closer to that of the test tube which you covered with rubber stopper.
4. Remove the stopper so that the gas produced can escape into the test tube containing lime water. Shake the test tube and see if there is any colour change.
5. Repeat the above procedure using sodium hydrogen carbonate and dilute sulphuric acid.

***Observation and analysis*:**

a. Is there formation of bubbles in step 2?
b. If yes, what does the formation of bubbles indicate?
c. What happens to the lime water used in step 4? Why is that so?
d. Write the equation for the reaction:
   1. between hydrochloric acid and calcium carbonate.
   2. between sodium hydrogen carbonate and sulphuric acid.
   3. that occurs in step 4.

## IV *Acids neutralizes bases.*

Acids react with bases to form salts and water.

Acid + Base → Salt + Water.

**Example**

$$2HCl(aq) + Ca(OH)_2(aq) \rightarrow CaCl_2(aq) + 2H_2O\ (l)$$

The reaction of an acid with a base or basic oxide is called neutralisation reaction.

# Experiment 1.6

***Title:*** *Neutralising effect of an acid on a base.*

***Objective:*** To investigate the neutralising effect of sulphuric acid on sodium hydroxide.

***Materials required*:** Dilute sulphuric acid, sodium hydroxide solution, conical flask, phenolphthalein, burette, stand, clamp, measuring cylinder, blue and red litmus papers.

***Procedure*:**

1. Set up the apparatus as shown in *Figure 1.12*.
2. Fill the burette with dilute sulphuric acid.
3. Measure 20 mL of sodium hydroxide solution, pour it into a conical flask and add about five drops of phenolphthalein.
4. Open the stop cock of the burette, add sulphuric acid to the sodium hydroxide solution with your one hand, while shaking the conical flask with your other hand.
5. When the colour begins to disappear, add the acid drop by drop shaking the flask continuously.
6. When the colour disappears, completely, close the stop cock of the burette immediately and check the solution in the conical flask using blue and red litmus papers.

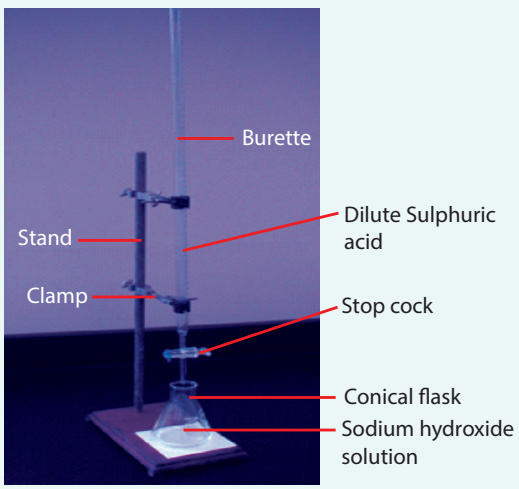



*Figure 1.12:* **Neutralization reaction of sulphuric acid with sodium hydroxide**

***Observation and analysis***

a. What colour appeared when phenolphthalein is added to the solution in the conical flask in step 3.

b. Why does the colour disappear in step 6?

c. Does the solution obtained in step 6 affect the colour of either blue or red litmus paper?

d. Write the balanced equation for the reaction that takes place in this experiment.

Write a laboratory report in groups and present your findings to the rest of the class.

## Uses of Hydrochloric Acid, Nitric Acid and Sulphuric Acid

### ACTIVITY 1.16

Perform the following task in groups.

1 Read different chemistry reference books to investigate the common uses of:

a Hydrochloric acid b Nitric acid and c Sulphuric acid

2 Prepare a table as shown below and complete it with all the required information and make a few minutes presentation.

| Name of the acid | Formula | Uses |
|---|---|---|
| Hydrochloric acid | | |
| Nitric acid | | |
| Sulphuric acid | | |

### Exercise 1.12

1 Write the colour of each of the following indicators in acidic solution.

a Litmus paper b Methyl orange c Phenolphthalein

2 Which ion is a characteristic of all acids in water solution?

3 Acids can be formed by direct combination of elements. Give one example and show the reaction using a chemical equation.

4 Which acid is produced in a small quantity in our stomach?

5 What is the acid used in the preparation of explosives?

6 What is the acid used in car batteries?

7 What is the main commercial use of $H_2SO_4$?

## 1.3.3 Bases

### ACTIVITY 1.17

Form a group and perform the following task. Choose a group representative to present your group's opinion to the class.

When plants are partly burned, ash is formed. When the ash is dissolved in water, it gives a solution which tastes bitter and feels slippery when rubbed between the fingers. Why do you think this happens?

A base is an oxide or hydroxide of a metal which neutralizes acid to form salt and water. Bases which are soluble in water are called *alkalis*. An alkali is a substance that releases hydroxide ion ($OH^-$) when dissolved in water. Sodium hydroxide, NaOH(aq), calcium hydroxide, $Ca(OH)_2$(aq), and aqueous ammonia, $NH_4OH$ are common alkalis used in the laboratory, industry and at home.

## ACTIVITY 1.18

Form a group and perform the following activity. Choose a group representative to present your group's opinion to the class.

Name some common bases that are:

a metal oxides and

b metal hydroxides, and write their formulas.

## Preparation of Bases

Bases can be prepared by the following methods.

### I *Reaction between active metals and water*

Active metals such as sodium, potassium and calcium react with water to form bases and hydrogen gas.

Active metal + Water → Base + Hydrogen

**Examples**

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

*Potassium* *Water* *Potassium hydroxide* *Hydrogen*

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

*Sodium* *Water* *Sodium hydroxide* *Hydrogen*

### II *Reaction between metal oxides and water*

When metal oxides react with water, a base is formed.

Basic anhydride + Water → Base

(Basic oxide)

**Examples**

$K_2O(s) + H_2O(l) \rightarrow 2KOH(aq)$

*Potassium oxide* *Water* *Potassium hydroxide*

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

*Sodium oxide* *Water* *Sodium hydroxide*

# Experiment 1.7

***Title*: Preparation of calcium hydroxide**

***Objective*:** To prepare calcium hydroxide by heating calcium in air and dissolving the resulting calcium oxide in water.

***Materials required*:** Evaporating dish, tripod, wire gauze, Bunsen burner, tong, water, red litmus paper

***Procedure*:**

1. Take small amount of calcium in an evaporating dish.
2. Heat it on a Bunsen burner as shown in *Figure 1.13.*
3. After it is burned, remove the evaporating dish holding it with a tong and add some drops of water to dissolve.
4. Now, put a piece of red litmus paper to the solution in the evaporating dish.
5. Observe the colour change on the indicator in the solution.


*Figure 1.13:* **Heating calcium metal in an evaporating dish**

***Observation and analysis*:**

a. When calcium is heated in air over a Bunsen burner flame, what happens to it? Write the chemical equation for the reaction that takes place.

b. When the resulting product in the evaporating dish is dissolved in water, what happens to it? Write the chemical equation for the reaction that takes place.

c. When red litmus paper is placed in the evaporating dish containing calcium hydroxide solution, what did you observe? What do you conclude from your observation?

## Properties of Bases

### I *Effect on acid-base indicators*

Alkalis change the colour of indicators. The following practical activity demonstrates the effect of a base on indicators.

# Experiment 1.8

***Title:*** The effect of a base on indicators

***Objective:*** To study the effect of a base on indicators

***Materials required:*** Red and blue litmus papers; phenolphthalein solution, methyl orange, ammonia solution ($NH_4OH$) test tubes, test tube holder and test tube rack.

***Procedure:***

1. Take four clean test tubes.
2. Add about 5 mL $NH_3$ solution in each of the test tubes and label the test tubes as 1, 2, 3, and 4 as shown in *Figure 1.14*.
3. Put red litmus paper, blue litmus paper, 2 drops of phenolphthalein solution and 2 drops of methyl orange solution in test tubes 1,2, 3 and 4, respectively.
4. Observe the colour change and record your observation.


*Figure 1.14:* **Testing the effect of a base on indicators**

***Observation and analysis:***

a. What were the colours of the ammonia solution, phenolphthalein and methyl orange before the experiment?

b. What happens to the colours of the red litmus paper, blue litmus paper, phenolphthalein and methyl orange solutions after the addition of $NH_3$ solution?

c. What do you conclude from this experiment?

Write a laboratory report in groups and present your findings to the rest of the class.

## II *Bases neutralize acids.*

Bases react with acids (acidic oxides) to form salt and water.

Base + Acid → Salt + Water

**Example**

$Ca(OH)_2$ + $H_2SO_4$ → $CaSO_4$ + $2H_2O$

*Calcium hydroxide* *sulphuric acid* *Calcium sulphate* *Water*

## Experiment 1.9

***Title:*** **Neutralising effect of a base on an acid**

***Objective:*** To investigate the neutralising effect of sodium hydroxide on hydrochloric acid.

***Materials required:*** Sodium hydroxide solution, hydrochloric acid, conical flask, phenolphthalein, burette, stand, clamp, measuring cylinder, blue and red litmus papers.

***Procedure:***

1. Set-up the apparatus as shown in *Figure 1.15*.
2. Fill the burette with sodium hydroxide.
3. Measure 20 mL of hydrochloric acid solution, pour into a conical flask and add five drops of phenolphthalein.
4. Open the stop cock of the burette, add sodium hydroxide to the acid solution with your one hand, and shaking the conical flask with the other hand.
5. When the colour begins to appear, add the base drop by drop shaking the flask continuously.
6. When the colour becomes intense, close the stop cock of the burette immediately and check the solution in the conical flask using blue and red litmus papers.

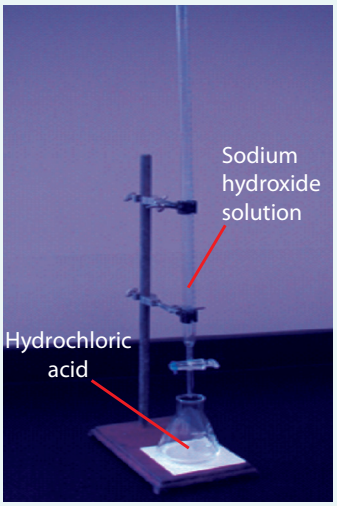



*Figure 1.15:* **Neutralisation reaction of hydrochloric acid and sodium hydroxide**

***Observation and analysis:***

a. What colour appeared when phenolphthalein is added to the solution in the conical flask in step 3?

b. Why does the colour appear in step 6?

c. Does the solution obtained in step 6 affect the colour of blue or red litmus paper?

d. Write the balanced equation for the reaction that take place in this experiment.

Write a laboratory report in groups and present your findings to the rest of the class.

## Uses of Sodium Hydroxide, Magnesium Hydroxide and Calcium Hydroxide

### ACTIVITY 1.19

Perform the following task in groups.

1 Read different chemistry reference books to investigate the common uses of:

a Sodium hydroxide

b Magnesium hydroxide

c Calcium hydroxide

2 Prepare a table as shown below, and complete it with all the required information and make a few minutes presentation.

| Name of the base | Common name | Formula | Uses |
|---|---|---|---|
| Sodium hydroxide | Caustic soda | | |
| Magnesium hydroxide | Milk of Magnesia | | |
| Calcium hydroxide | Lime water /Slaked lime | | |

### Exercise 1.13

1 Describe how you could prepare each of the following bases.

a KOH b $Ca(OH)_2$ c $Mg(OH)_2$

2 Write a least two important properties of bases.

3 Describe how you can check whether a given solution is basic or not.

4 What is the name and formula of the base which is commonly known as caustic potash?

5 What is the base used for manufacturing soap and detergents?

6 What is the base used for neutralising acidic soil?

7 What is the base used as stomach anti-acid?

## Diluted and Concentrated Acids and Alkalis

"Dilute" and "concentrated" are relative terms used to describe the amount of a substance present in a given volume of solution. The term "concentrated" indicates that a large mass of solute is dissolved in a given volume of solution. On the other hand the term "dilute" indicates that a small mass of solute is dissolved in a given volume of solution.

*A concentrated acid* contains relatively a large amount of acid dissolved in small amount of water.

*A concentrated base* (alkali) contains relatively a large amount of base dissolved in small amount of water.

*A dilute acid* solution contains relatively small amount of acid dissolved in relatively large amount of water.

*A dilute base(alkali)* solution contains relatively small amount of base dissolved in large amount of water.

Acids and alkalis may be used as concentrated and dilute solutions. For most laboratory experiments we work with dilute solutions since they are less hazardous.

## Safety Precautions while Working with Acids

Hydrochloric acid, sulphuric acid and nitric acid are poisonous and corrosive. Therefore, they must be handled with great care. The vapors of HCl and $HNO_3$ are irritating to the skin, eyes, and respiratory system. Inhalation of the vapors of these acids should be prevented. If these acids come in contact with the eyes and skin, they cause severe burn. If taken by mouth, they will cause severe internal irritation and damage.

- *If a concentrate acid is spilled or splashed on your skin, wash thoroughly the affected part with water, and then wash it with 10% $Na_2CO_3$ solution.*
- *If an acid enters your eye, wash thoroughly with water for a long time.*
- *If you accidentally drink corrosive acids, take a base such as $Mg(OH)_2$ which is available in the pharmacy to neutralize the acid.*
- *Never add water into concentrated acids. This is because the addition of water to the concentrated acid produces a vigorous reaction which often causes acid droplets to be discharged in all directions.*

## Safety Precautions while Working with Bases

NaOH and KOH are corrosive and poisonous. They are called caustic soda and caustic potash, respectively. This is because they rapidly attack the human skin. Therefore, you have to avoid contact with your skin and other parts of your body while working with bases.

The following measures are useful if a concentrated base is spilled on your skin or enters your eyes.

- *If a base is spilled on your skin, wash the affected area with plenty of water and then treat the affected part with a weak acid such as dilute acetic acid to neutralize the base.*
- *If a base comes into contact with your eyes, wash the eyes with plenty of cold water.*
- *If you drink a base by accident, neutralize it by drinking 1 – 2% dilute solution of acetic acid or lemon juice.*
- *If a base is spilled on your working table wipe the spillage immediately. Whenever bases are splashed on your cloth wash the affected part with running tap water.*

Common precautions when working with acids and bases (alkalis) include:

- ⇨ *Wearing eye protection (goggle).*
- ⇨ *Wearing protective clothing such as an apron or laboratory coat.*
- ⇨ *Keeping reagent bottles stoppered when not in use.*
- ⇨ *Wiping up all spillages straight away with a wet cloth.*

## Exercise 1.14

1 Explain how you could distinguish between a concentrated base and a dilute base?

2 What measures should you take if

a an acid enters your eyes?

b you accidentally drink a base?

## 1.3.4 Salts

### ACTIVITY 1.20

Discuss the following in groups and share your opinion to the rest of the class.

Name the salt:

a used to prepare our food.

b used to make baking powder.

c which is the constituent of limestone and marble.

d used as a fertilizer.

e used to make gun powder.

The term 'salt' does not refer only to the table salt which we use to make our food. The word 'salt' applies to a large group of compounds. These compounds are either naturally occurring or man made. A large percentage of minerals exist in the earth's crust as salts. These salts are widely used for various purposes. They are used as raw materials in chemical industries, as fertilizers, as building materials, etc.

***What is meant by neutralisation reaction? What products are obtained from this reaction?***

Salts are group of chemicals that are obtained by the reactions of acids and bases. These reactions are called neutralisation reactions. Sodium chloride (NaCl), calcium carbonate ($CaCO_3$), potassium nitrate ($KNO_3$) are examples of salts.

## Naming Salts

The group names of salts are related to the names of the acids from which they are derived. Table 1.2 shows the names of some acids and group names of the salts derived from them.

*Table 5.1* **Names of some acids and group names of their salts**

| Name of the acid | Group name of salt | Example of salt |
|---|---|---|
| Carbonic acid, $H_2CO_3$ | Carbonates | Calcium Carbonate($CaCo_3$) |
| Hydrobromic acid, HBr | Bromides | Sodium Bromide (NaBr) |
| Phosphoric acid, $H_3PO_4$ | Phosphates | Magnesium Phosphate ($Mg_3(PO_4)_2$) |
| Hydroiodic acid, HI | Iodides | Potassium Iodide (KI) |
| Hydrosulphuric acid, $H_2S$ | Sulphides | Calcium Sulphide (CaS) |

### ACTIVITY 1.21

Discuss the following points in groups and share your opinion to the rest of the class.

Name the groups of salts that are derived from:

a hydrochloric acid.

b nitric acid.

c sulphuric acid.

The name of a salt is derived from the name of the base and the acid from which it is obtained. As an illustrative example, see the following chemical equation:

Calcium hydroxide + Hydrobromic acid → Calcium bromide + Water

*Base* *Acid* *Salt* *Water*

The name of the salt calcium bromide is obtained by taking the word 'calcium' from the name of the base and '*bromide*' from the name of the acid by dropping the word '*hydro*' and changing the ending '*-ic acid*' to '*-ide*'.

It is also possible to suggest the acid and base combinations that yield a given salt from the name of the salt.

For example:

- *Magnesium chloride is the name of the salt formed by the reaction of magnesium hydroxide and hydrochloric acid.*
- *Calcium sulphate is the name of the salt obtained by the reaction of calcium hydroxide and sulphuric acid.*

## Exercise 1.15

1 Complete the following word equations and name the salt formed by the reaction.

a Barium hydroxide + Sulphuric acid →

b Calcium hydroxide + Nitric acid →

c Potassium hydroxide + Hydrochloric acid →

d Sodium hydroxide + Hydroiodic acid →

2 Name the acid and base pairs that forms each of the following salts.

a Sodium sulphate

b Potassium nitrate

c Calcium sulphate

d Lithium chloride

e Magnessium chloride

The salt sodium sulphate, $Na_2SO_4$, contains sodium ion ($Na^+$), a positive ion derived from NaOH and the sulphate ion, $SO_4^{2-}$, a negative ion derived from $H_2SO_4$.

Thus, a salt is defined as *a compound consisting of the positive ion of a base and the negative ion of an acid.* The positive ion in the salt can be that of a metal ion or ammonium ion.

## Exercise 1.16

Name the base and the acid from which the positive and the negative ions are derived in each of the following salts.

a Sodium nitrate

b Calcium chloride

c Barium chloride

d Potassium sulphate

e Ammonium nitrate

f Copper (II) sulphate

*Classification of salts:* There are different ways of classifying salts. At this level, we will classify salts only according to the number of elements they contain. They are **binary** salts and **ternary salts**.

*Binary salts* are salts which contain only two elements. For example, sodium chloride (NaCl) contains the elements sodium and chlorine, Magnesium bromide ($MgBr_2$); contains the elements magnesium and bromine. Other examples of binary salts are $PbCl_2$, CaS, $CaCl_2$, KBr, NaI, etc.

*Ternary salts* are salts which consist of three elements. For example, sodium sulphate ($Na_2SO_4$) contains three elements: sodium, sulphur and oxygen. Some other examples of ternary salts are calcium nitrate ($Ca(NO_3)_2$), magnesium carbonate ($MgCO_3$), potassium chlorate ($KClO_3$), aluminium sulphate ($Al_2(SO_4)_3$), etc.

## Exercise 1.17

Classify the following salts as binary or ternary and write their formulas.

a Aluminum chloride
b Copper sulphate
c Barium nitrate
d Calcium iodide
e Potassium chloride
f Calcium sulphide
g Silver bromide
h Calcium sulphate
i Lead (II) nitrate

## Preparation of Salts

Although, there are many ways of preparation of salts, we will discuss only two of the methods here.

### I *Direct combination of elements*

This method involves the direct combination of metals and non-metals to produce salts. It is used only to prepare binary salts such as chlorides and a few sulphides. The method cannot be used to prepare ternary salts such as nitrates and sulphates.

**Examples**

1 Sodium chloride can be prepared by burning sodium in chlorine gas.

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

2 Iron sulphide is prepared by heating a mixture of iron filings and powdered sulphur.

$$Fe(s) + S(s) \rightarrow FeS(s)$$

### II *Neutralisation reaction*

This is a more general and useful method of preparation of salts. Neutralisation reactions are the reactions of acids and bases that form salts and water. This involves either reactions of metal oxides or metal hydroxides with acids.

Metal oxide (basic oxide) + Acid → Salt + Water

Metal hydroxide + Acid → Salt + Water

**Examples**

$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O$

$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O$

$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O$

$NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O$

## ACTIVITY 1.22

Discuss in groups the reaction for the preparation of each of the following salts and share your ideas to the rest of the class.

a Calcium sulphate
b Magnesium nitrate
c Aluminum chloride
d Potassium nitrate

## Experiment 1.10

***Title:*** **Preparation of salts by neutralisation**

**Part I:** *Preparation of salt by the reaction of metal oxide and acid*

***Objective:*** To prepare copper (II) sulphate from copper (II) oxide and dilute sulphuric acid.

***Materials required:*** Copper (II) oxide, dilute sulphuric acid, glass rod, beaker, funnel, filter paper, Bunsen burner, tripod, wire gauze, evaporating dish, measuring cylinder and conical flask.

***Procedure:***

1. Measure 10 mL of dilute sulphuric acid and pour it into a beaker.
2. Warm the solution in the beaker on a Bunsen burner flame and add copper (II) oxide a little at a time and stir using a glass rod.
3. Continue adding copper (II) oxide stirring until the reaction is complete.
4. Place a funnel to which a filter paper is fitted into the mouth of a conical flask and filter the solution.
5. Pour the filtrate into an evaporating dish, and heat the solution on a Bunsen flame until a solid begins to form.
6. Put off the flame and leave the evaporating dish to cool.

***Observation and analysis:***

a What is the colour of copper (II) oxide?

b What colour change is observed when you add copper (II) oxide to the acid solution? What does this show?

c What is the colour of the solid formed? Name the solid.

d Write a balanced chemical equation for the reaction.

**Part II:** *Preparation of a salt by the reaction of metal hydroxide and acid.*

***Objective:*** To prepare sodium chloride by the reaction of sodium hydroxide and hydrochloric acid.

***Materials required:*** sodium hydroxide solution, dilute hydrochloric acid, beakers, glass rod, evaporating dish, wire guaze, tripod, Bunsen burner, blue and red litmus papers.

***Procedure:***

1 Measure 15 mL of sodium hydroxide and pour it into a beaker.

2 Measure 20 mL of dilute hydrochloric acid solution. Pour about 13 mL of it into the beaker containing sodium hydroxide solution. Stir the mixed solution with a glass rod and test it with red and blue litmus papers. Observe carefully.

3 Then continue adding the acid solution a little at a time and testing the solution using blue and red litmus paper until the colours of the blue litmus and red litmus will not change.

4 When the colours of the blue and red litmus papers remain the same, pour the solution into an evaporating dish, and heat the evaporating dish on a Bunsen flame till the liquid evaporates.

***Observation and analysis:***

a The colour of which litmus paper is changed when you test the solution in step 2?

b What volume of hydrochloric acid is added until the colours of blue and red litmus papers change?

c When do the colours of blue and red litmus papers remain the same?

d What is left in the evaporating dish after evaporation? Name the compound.

e Write a balanced equation for the reaction in this experiment.

Write a laboratory report in groups for the two parts of the experiment and submit it to your teacher

## Uses of Some Salts

### ACTIVITY 1.23

In this activity you are expected to perform the following tasks in groups by reading different chemistry reference books.

1 Prepare a table as shown below and fill in with required information.

| Name of the salt | Formula of the salt | Important uses |
|---|---|---|
| Sodium chloride | | |
| Calcium carbonate | | |
| Sodium bicarbonate | | |
| Potassium nitrate | | |
| Diammonium phosphate (DAP) | | |

2 Prepare three minutes presentation on the preparation and uses of the salts listed above.

# Unit Review

## Check List

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

| No | Can I | Yes | No |
|---|---|---|---|
| 1 | tell that compounds are classified as organic and inorganic? | | |
| 2 | define organic chemistry as the study of carbon containing compounds? | | |
| 3 | define inorganic chemistry as the study of non-carbon containing compounds? | | |
| 4 | write the general formula of alkanes, alkenes and alkynes? | | |
| 5 | write the specific chemical formulas of the first ten members of alkanes, alkenes and alkynes? | | |
| 6 | name the first ten members of alkanes, alkenes and alkynes? | | |
| 7 | list some common uses of organic compounds? | | |
| 8 | tell that inorganic compounds are classified into oxides, acids, bases and salts? | | |
| 9 | define acidic oxide and basic oxide? | | |
| 10 | give examples of acidic and basic oxides? | | |
| 11 | describe the properties of acidic oxides and basic oxides? | | |
| 12 | explain the preparation of acidic oxides and basic oxides? | | |
| 13 | prepare sulfur dioxide in the laboratory by burning sulfur in air? | | |
| 14 | use moist blue litmus paper to test the acidic nature of sulfur dioxide? | | |
| 15 | prepare magnesium oxide in the laboratory by burning magnesium ribbon in air? | | |
| 16 | use red litmus paper to test the basicity of magnesium oxide in water solution? | | |
| 17 | define acid as a substance that releases hydrogen ions in water solution? | | |
| 18 | give common examples of acids? | | |
| 19 | define pH as the measure of acidity or alkalinity of a solution? | | |

| | | | |
|---|---|---|---|
| 20 | describe pH scale? | | |
| 21 | explain preparation of acids by direct combination of elements and reaction of acidic oxide with water? | | |
| 21 | describe the properties of acids? | | |
| 22 | conduct experiments on the properties of acids? | | |
| 23 | list some common uses of hydrochloric acid, nitric acid and sulphuric acid? | | |
| 23 | define base as a substance that neutralizes an acid? | | |
| 25 | describe the properties of alkalis? | | |
| 26 | investigate properties of bases experimentally? | | |
| 27 | list some common uses of sodium hydroxide, magnesium hydroxide and calcium hydroxide? | | |
| 28 | define dilute and concentrated acid and base? | | |
| 29 | describe concentrated acidic and alkaline solutions? | | |
| 30 | describe dilute acidic and alkaline solutions? | | |
| 31 | explain the safety precautions while working with acids and bases? | | |
| 32 | give some common examples of salts? | | |
| 33 | name some common salts? | | |
| 34 | define salts as compounds that are composed of the positive ions of a base and the negative ions of an acid? | | |
| 35 | define oxides? | | |
| 36 | classify oxides into metallic and non-metallic oxides? | | |
| 37 | give examples of metallic and non-metallic oxides? | | |

## Key Terms

- Acid
- Acidic oxide
- Alkali
- Alkane
- Alkene
- Alkyne
- Base
- Basic oxide
- Binary salt
- Concentrated acid and base
- Dilute acid and base
- Hydrocarbon
- Indicator
- Inorganic compound
- Metallic oxide
- Non-metallic oxide
- Organic compound
- Oxide
- pH scale
- Salt
- Ternary salt

# UNIT SUMMARY

- ✓ Organic compounds are carbon-containing compounds except the oxides of carbon, carbonates, and hydrogen carbonates.
- ✓ Organic compounds are largely classified as hydrocarbons and hydrocarbon derivatives.
- ✓ Hydrocarbons are organic compounds that contain only carbon and hydrogen.
- ✓ Hydrocarbons are classified as alkanes, alkenes and alkynes.
- ✓ Alkanes are hydrocarbons with the general formula $C_nH_{2n+2}$ where n is the number of carbon atoms in the molecule.
- ✓ Alkenes are hydrocarbons with the general formula $C_nH_{2n}$ where n is the number of carbon atoms in the molecule.
- ✓ Alkynes are hydrocarbons with the general formula $C_nH_{2n-2}$ where n is the number of carbon atoms in the molecule.
- ✓ Inorganic compounds are classified as oxides, acids, bases, and salts.
- ✓ Oxides are binary inorganic compounds formed when oxygen combines with other elements.
- ✓ Oxides are classified as acidic and basic oxides depending on their properties.
- ✓ Oxides can be prepared by the direct combination of elements and by thermal decomposition of some compounds.
- ✓ Acids are compounds that release hydrogen ions in water solution.
- ✓ Bases are compounds that neutralise acids.
- ✓ An alkali is a substance that releases hydroxide ions in aqueous solution.
- ✓ Salts are compounds that contain positive ions derived from bases and negative ions derived from acids.
- ✓ Salts can be classified based on their properties and sources.
- ✓ Binary and ternary salts are classes of salts based on the number of elements they contain.
  - *Binary salts consist of only two types of elements.*
  - *Ternary salts consist of three types of elements.*
- ✓ Salts are prepared by direct combination of elements or by neutralization reactions.
- ✓ Salts are used as raw materials to manufacture building materials, medicines, to make food, etc.

# REVIEW EXERCISE ON UNIT 1

## I *Match the items under column 'A' with those under column 'B'.*

| Column A | | Column B | |
|---|---|---|---|
| 1 | Butane | A | Car fuel |
| 2 | Ethene | B | Stove fuel |
| 3 | Formalin | C | One of the components in butagas |
| 4 | Ethanol | D | Alcoholic beverages |
| 5 | Ethanoic acid | E | Pickling |
| 6 | Octane | F | Used to preserve biological specimens |
| 7 | Decane | G | Used to prepare polyethylene plastics |

## II *Choose the correct answer from the given alternatives for each of the following questions.*

8 Which one of the following formula represents an alkane containing ten carbon atoms?

A $C_{10}H_{10}$ C $C_{10}H_{22}$

B $C_{10}H_{20}$ D $C_{10}H_{18}$

9 The name of the alkane in question number 8 is:

A decene C decyne

B decane D decanol

10 The correct formula of nonene is:

A $C_9H_9$ C $C_9H_{18}$

B $C_9H_{20}$ D $C_9H_{22}$

11 All of the following compounds are hydrocarbons *except:*

A ethane C ethyne

B ethene D ethanol

12 Which one of the following compounds can be used for preserving biological specimens?

A Formalin C Ethanol

B Vinegar D Decane

13 The characteristic property of an acid is due to the presence of:

A hydride ions C hydrogen ions

B hydroxide ions D oxide ions

14 A carbonated drink contains carbonic acid. Its pH is:

A less than 7 C equal to 7

B more than 7 D approximately 7.8

15 Which of the following is an alkali?

A $Fe(OH)_3$ C $Zn(OH)_2$

B $Cu(OH)_2$ D $NaOH$

16 When the following equation representing a reaction, is completed, the products are:

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow$

A NaCl and $H_2O$ C NaCl, $CO_2$ and $H_2O$

B $H_2O$ and $CO_2$ D NaCl, $CO_2$ and $H_2$

17 What is the missing product 'X' in the following equation?

$2NH_3(aq) + H_2SO_4(aq) \rightarrow X$

A $NH_4NO_3$ C $(NH_4)_3PO_4$

B $(NH_4)_2SO_4$ D $(NH_4)_2S$

18 The formula of sodium carbonate is:

A $Na_2CO_3$ C $NaHCO_3$

B $Na_2SO_4$ D $NaHPO_4$

19 Which of the following salts is used as a baking powder?

A $(NH_4)_2HPO_4$ C $CaCO_3$

B $NaHCO_3$ D $KNO_3$

20 The salt used as a fertilizer with the commercial name 'DAP' is represented by the formula:

A $Ca_3(PO_4)_2$ C $(NH_4)_2HPO_4$

B $KNO_3$ D $CaSO_4$

21 Which one of the following pairs of compounds produces calcium sulphate?

A Calcium oxide and hydrochloric acid.

B Calcium hydroxide and nitric acid.

C Calcium oxide and water.

D Calcium hydroxide and sulphuric acid.

22 Identify a binary salt among the following.

A $KNO_3$ C $MgSO_4$

B $NaClO_3$ D $CaCl_2$

23 Which of the following group of salts can be prepared by direct combination of elements?

A Sulphates C Chlorides

B Nitrates D Phosphates

24 Sulphates are salts of:

A Hydrochloric acid
B Sulphuric acid
C Phosphoric acid
D Nitric acid

25 Sodium nitrate is not:

A formed by direct combination
B a ternary salt
C a salt of nitric acid
D formed by the reaction of NaOH and $HNO_3$

## III *Give short answers for each of the following questions.*

26 Give the name of:

a an alkane containing 4 carbon atoms.
b an alkene containing 7 carbon atoms.
c an alkyne containing 2 carbon atoms.

27 Deduce the molecular formula of:

a Butane b Propene c Hexyne

28 Write the names and formulas of the acids and bases required to prepare each of the following salts.

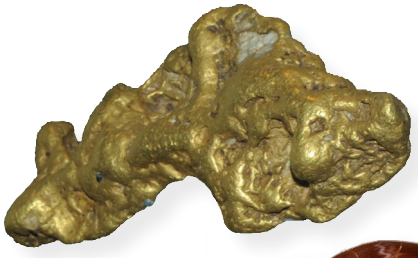
a Potassium phosphate
b Sodium sulphate
c Calcium bromide
d Copper (II) Chloride

29 Write the name and the formula of a salt used in:

a our diet.
b making construction materials.
c making gun powder.

# UNIT 2

# SOME IMPORTANT METALS



## MAIN CONTENTS



## UNIT OUTCOMES

***After completing this unit, you will be able to:***

- ✓ Know the general properties of metals.
- ✓ Explain the occurrence and uses of sodium, potassium, magnesium, calcium, aluminum, iron, copper, silver, gold, platinum, and tantalum.
- ✓ Recognize common and important ores of sodium, potassium, magnesium, calcium, aluminum, iron, copper, silver, gold, platinum, and tantalum.
- ✓ Describe some of the common properties of alloys and explain their uses.
- ✓ Describe scientific enquiry skills along this unit: observing, comparing and contrasting, communicating, asking questions, drawing conclusions, applying concepts, problem solving.

## START-UP ACTIVITY

In Grade 7 chemistry, you learned about periodic table. Perform the following activity in group.

Copy the table below which is assumed to represent part of a blank Periodic Table representing some of the main group elements. The numbers in each cell of the table are for the atomic numbers of the elements. In your table, write

'A' in the space which the alkali metals would occupy

'N' in the space which would be occupied by noble gases

'P' in the space which the most active non-metal would occupy

'C' in the space which could be occupied by an element capable of forming a compound $CP_2$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | 2 |
| 3 | | | | | | | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |

After the group discussion, give the chance for the group representative to present the group's opinion to the rest of the class.

# 2.1 GENERAL PROPERTIES OF METALS

***After completing this section, you will be able to:***

- ✓ mention general properties of metals;
- ✓ investigate general properties of metals practically; and
- ✓ present a report of your project work on the properties of Fe, Ag, and Au after visiting the works of blacksmith and goldsmith.

## HISTORICAL NOTE

The use of metals is said to be the thing that makes people different from animals. Before they used metals, people made tools from stones, wood, and animal bones. This period is known as the stone age. No one knows when the first metal was found and used.

## ACTIVITY 2.1

Form a group and in your group name some common metals you know and discuss the uses of these metals. After the group discussion, present the group's opinion to the class by the assigned group representative.

This section is devoted primarily in describing various properties and characteristics of metals. The general properties of metals include thermal and electrical conductivity, physical state, hardness, malleability, ductility, luster, sonorous, high melting and boiling points.

Metals generally have the following properties

1 *Thermal and Electrical Conductivity:* Conductivity is the property that enables a metal to carry heat or electricity. Thermal conductivity is the property of a metal's ability to conduct heat. Metals are good conductors of heat and electricity. Silver and copper are the two best conductors of heat and electricity.

2 *Physical State:* Metals are solids at room temperature with the exception of mercury which is a liquid.

3 *Hardness:* Hardness refers to the ability of a metal to resist abrasion (scratch), penetration, cutting action, or permanent distortion. All metals are hard except sodium and potassium, which are soft and can be cut with a knife.

4 *Malleability:* Metals have the ability to be made into thin sheets known as foils. A metal that can be hammered, rolled, or pressed into various shapes without cracking or breaking is said to be malleable. This property is necessary in sheet metal that is to be worked into curved shapes. Copper is one example of a malleable metal.

5 *Ductility:* Ductility is the property of a metal that permits it to be permanently drawn, bent, or twisted into various shapes without breaking. Therefore metals can be drawn into wires. For example, 100 g of silver can be drawn into a thin wire about 200 m long.

6 *Luster:* Metals have the quality of reflecting light from their surfaces and can be polished. Most metal have characteristic luster or shiny appearance. For example, gold, silver and copper.

7 *Sonorous:* Sonorous is a physical property of a metal by which sound is produced when a metal is struck. For example, aluminum produces a high pitch sound when struck. Many metals are used to make musical instruments in order to exploit their sonorous properties.

8 *Melting and Boiling points:* Metals have high melting and boiling point. Tungsten has the highest melting point. Sodium and potassium have low melting points.

The physical properties of different metals make them useful for different purposes. For example, aluminium conducts heat, which makes it a useful material for making cooking utensils and gold is shiny, which makes it an attractive material for jeweler.

## Experiment 2.1

***Title:*** **Physical properties of metals**

***Objective:*** To investigate some of the physical properties of common metals

***Materials required:*** Iron, copper, aluminum, zinc, lead, bulb, DC source and Bunsen burner.

***Procedure:***

1. Connect the various substances given into the circuit below (*Figure 2.1*) one at a time, and find out if they are conductors or non - conductors of electricity.
2. Take 10 cm long wire or foil of each metal, heat at one end on a Bunsen burner flame holding the other end turn by turn. Record what you feel.
3. Observe each metal and identify whether or not it is lustrous.
4. Hit the foil or rod of each metal with a ruler or stick and record whether or not it is sonorous.

***Observation and analysis:***

a Draw and complete the following table. Indicate the properties that each metal shows by putting a tick (√) mark where it is appropriate.

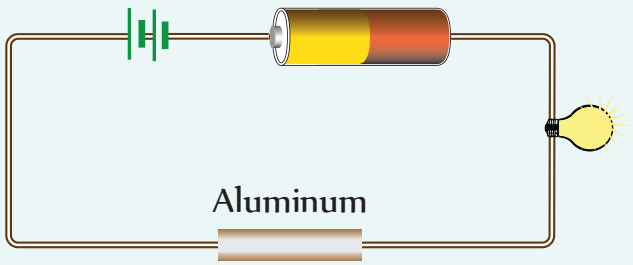



*Figure 2.1:* **An electric circuit**

| Metal | Properties | | | |
|---|---|---|---|---|
| | Electrical conductor | Thermal conductor | Lustrous | Sonorous |
| Iron | | | | |
| Copper | | | | |
| Aluminium | | | | |
| Lead | | | | |
| Zinc | | | | |

b Which of these metals are electrical and thermal conductors?

c Are all the metals sonorous?

d Which of these metals are lustrous?

e Write a laboratory report in groups and present your observation to the rest of the class.

## Project Work

Visit the works of a metal worker who makes and repairs things made of iron like horse shoes (blacksmiths) and goldsmiths and present the properties of Fe, Ag and Au to your class.

## Exercise 2.1

1. State the physical properties of metals.
2. Which metal has the highest melting point?
3. Name the only liquid metal at room temperature.
4. Mention three most malleable and ductile metals.

# 2.2 SODIUM AND POTASSIUM

***After completing this section, you will be able to:***

- ✓ explain the occurrence of sodium and potassium;
- ✓ list common ores of sodium and potassium; and
- ✓ discuss the uses of sodium and potassium.

## 2.2.1 Occurrence

The elements of Group I are commonly referred to as the alkali metals. They are, the most metallic elements. These metals occur chiefly as the chloride compounds. For example, sodium occurs mainly as sodium chloride (common salt) and potassium as potassium chloride. They are never found in free elemental form in nature. Sodium is the sixth most abundant element and the fourth most abundant metal in the earth's crust.

Potassium is the seventh most abundant element and the fifth most abundant metal.

### ACTIVITY 2.2

1 Discuss what would happen if metallic sodium or potassium was kept in soil for any length of time.

2 Discuss in class the reason why sodium and potassium were not extracted (isolated) until the early nineteenth century while metals like gold, silver and copper have been known and used for various purposes since ancient times. Present your group's opinion to the rest of the class.

## 2.2.2 Important Ores

Ores are naturally occurring rocks that contain metals or metal compounds in sufficient amounts.

Sodium is an important element in our diet in the form of NaCl. The principal ore of sodium is halite (NaCl) or table salt. It also occurs in ores such as soda ash ($Na_2CO_3$), Chile saltpeter ($NaNO_3$), and borax ($Na_2B_4O_7.10H_2O$).

Sylvite (KCl), is the chief source of potassium. It is not found abundantly like halite (sodium chloride). Other ores of potassium are nitrates and carbonates.

## 2.2.3 Uses

Since sodium (Na) and potassium (K) are extremely reactive; they rapidly tarnish when exposed to air, because they react with moisture and oxygen in the atmosphere. Both sodium and potassium are stored in bottles covered with liquid hydrocarbons such as kerosene and toluene. Due to this and other reasons these metals are not commonly used in their metallic forms.

## ACTIVITY 2.3

Use any reference material and the internet to perform the following activity. First do it independently and then in a group. Share your opinion with your group members.

1 Search the uses of the following compounds of sodium and potassium from any chemistry literature.

a Sodium chloride
b Sodium hydroxide
c Sodium carbonate
d Sodium sulphate
e Potassium nitrate
f Potassium chlorate
g Potassium permanganate (VII)
h Potassium chloride

2 Which potassium salts listed in question number 1 are used as fertilizers and why?

Sodium is mainly used in the manufacture of sodium peroxide ($Na_2O_2$) which in turn is used in bleaching. A more known use of sodium is in street lights. The orange-yellowish lights which can be seen on most highways in cities are made of sodium. Sodium cyanide (NaCN) and sodium amide ($NaNH_2$) are used in the extraction of gold and silver. Because of its low melting point and high heat conductivity, sodium – potassium alloy is used to cool the fuel in nuclear reactors.

Another compound of potassium, potassium bisulfate ($KHSO_4$), is used to preserve foods (except meats), wine and beer. It can also be used to bleach textiles and straw and can tan leather.

Although the compounds of potassium are used in a number of ways, the metal itself is not widely used. Almost all of the pure metal produced is used to prepare potassium superoxide ($KO_2$) which in turn is used by submarines and spacecraft. This supplies oxygen to the inhabitants of the submarine or spacecraft.

## Exercise 2.2

1 Which is the most abundant alkali metal in the Earth's crust?

2 Name some naturally occurring compounds of Na and K.

3 Why are sodium and potassium stored under liquid hydrocarbons?

4 List some uses of metallic sodium and potassium.

5 What are the components of sodium chloride (rock salt)? In which regions of Ethiopia do we find huge deposits of rock salt?

# 2.3 MAGNESIUM AND CALCIUM

***After completing this section, you will be able to:***

- ✓ explain the occurrence of magnesium and calcium;
- ✓ list common ores of magnesium and calcium; and
- ✓ discuss the uses of magnesium and calcium.

## 2.3.1 Occurrence

The elements Mg and Ca are members of Group IIA which are commonly referred to as the alkaline earth metals. They are metallic elements. Metals of Group IIA are reactive and do not occur as free elements in nature.

### ACTIVITY 2.4

Form a group and perform the following activity. Share your opinion with your group members.

Discuss possible reasons why magnesium and calcium were not isolated until the early nineteenth century while other metals like gold and silver have been known since ancient times.

### Experiment 2.2

***Title: Effects of soil on a piece of magnesium or calcium***

***Objective:*** To investigate the observed changes of magnesium or calcium metals placed in soil.

***Materials required:*** Magnesium or Calcium metals

***Procedure:*** Place a piece of magnesium or calcium in a soil for a couple of weeks.

***Observation and analysis:*** Observe the effects of the soil on the metals and present your findings to the class.

## 2.3.2 Important Ores

Magnesium does not occur in nature as a free element. Important ores (natural sources) of magnesium are the minerals such as magnesite, dolomite, and carnalite. Magnesium chloride ($MgCl_2$) is found in seawater, brines, and salt wells. In the terrestrial crust, magnesium is found as magnesite ($MgCO_3$), and dolomite ($CaCO_3.MgCO_3$) and many common silicates. Mineral waters often contain salts of magnesium.

Almost all natural waters, including seawater, contain either or both calcium carbonate and calcium sulphate.

Many organisms concentrate calcium compounds in their shells or skeletons. For example calcium carbonate is formed in the shells of oysters and in the skeletons of coral (a stone like substance formed from the bones of very small sea animals). Calcium is present in the earth's crust in the forms of carbonate, sulphate, fluoride, silicate and borate. The calcium carbonate ($CaCO_3$) occurs in marble, chalk (limestone) and calcite. Calcium sulphate ($CaSO_4$) occurs in anhydrite and gypsum, calcium fluoride in fluorspar or fluorite ($CaF_2$) and calcium phosphate, $Ca_3(PO_4)_2$ occurs in apatite. Calcium also occurs in numerous silicates and aluminosilicates.

## 2.3.3 Uses

Magnesium is used in producing several light alloys with metals such as aluminium. Magnesium is also used (in powder form) in flares and fireworks (*Figure 2.2*). Although most cameras now use electronic flashes, magnesium metal is often contained in cameras that use flash bulbs. A thin strip of magnesium metal is found in the bulb. When the flash is ignited, the magnesium strip catches fire. It burns with a very bright white light. The light from the bulb illuminates a scene for the photograph.

*Figure 2.2:* **Magnesium burns with a blinding white light at high temperatures**

Because of its low density alloys of magnesium is extensively used in an aerospace industry.

Calcium has limited use of a pure metal. It is used in the manufacture of other metals like thorium, chromium, uranium, etc and in the production of alloys. Calcium has large uses in the form of its compounds such as calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), calcium carbonate ($CaCO_3$), gypsum ($CaSO_4.2H_2O$), etc.

### ACTIVITY 2.5

Form a group and perform the following activity. Share your opinion with your group members.

Use any possible reference like books and the internet and research the uses of the following magnesium and calcium compounds.

a Magnesium oxide
b Magnesium hydroxide
c Magnesium chloride
d Magnesium sulphate
e Magnesium citrate
f Calcium hydroxide
g Calcium oxide
h Calcium compounds in building materials such as cement, mortar, gypsum and marble.

## Exercise 2.3

1 What calcium compounds are constituents of cement?

2 When magnesium is left in moist air for several hours, the metal surface tarnishes. Why? Explain.

3 What is the color of the flame when magnesium burns in air?

4 Which alkaline earth metal is the component of the following materials?

a Lime stone

b Slaked lime

c Quick lime

d Gypsum

e Epsom salt

# 2.4 ALUMINUM

***After completing this section, you will be able to:***

- ✓ explain the occurrence of aluminum;
- ✓ list common ores of aluminum; and
- ✓ discuss the uses of aluminum.

## 2.4.1 Occurrence

The most important metal of Group IIIA is aluminum. Like metals of Group IA and Group IIA, aluminum is not found free in nature. Rather it exists in compound form because it is a reactive metal. Aluminum is the first most abundant metal and the third most abundant element in the earth's crust.

### ACTIVITY 2.6

Form a group and perform the following activity. Share your opinion with your group members.

1 Aluminum is extensively used today, and yet there was a time when it was more expensive than gold. Discuss in class why aluminum was more expensive than gold when first discovered.

2 Discuss any possible reasons why aluminum was not isolated until the early nineteenth century while other metals like gold and silver have been known since ancient times.

## 2.4.2 Important Ores

Aluminum is abundantly distributed in nature in the form of aluminosilicate minerals. However, the metal is not extracted from these sources at present. Some of the chief ores of aluminium are: mica (feldspar), kaolin (china clay), corundum ($Al_2O_3$), cryolite ($Na_3AlF_6$) and bauxite ($Al_2O_3.2H_2O$). Bauxite is the principal ore used for the extraction of aluminium.

## 2.4.3 Uses

Aluminum is a constituent of several alloys. They combine high tensile strength with lightness (low density), and have been much used in aircraft constructions.

Its availability, low density, good looking appearance, good conductivity of heat, and resistance to attack by cooking stuff (except alkali solutions) made it widely applicable in making household cooking utensils such as pots, kettles, and pans.

Aluminum is resistant to corrosion. The resistance to corrosion is due to a coherent oxide film formed on the metal surface. This is one of the reasons why Aluminum is used in making door and window frames and aluminum roofing as well.

The low density of aluminum is very favorable in making high tension line electric cables (*Figure 2.3*). Aluminum is used in the extraction of chromium, manganese, and vanadium from their ores.

*Figure 2.3:* **Aluminum cables for electric power transmis sion**

### ACTIVITY 2.7

Form a group and perform the following activity. Share your opinion with your group members.

What is thermite process? Discuss in group.

## Exercise 2.4

1 Write four uses of aluminum metal.

2 Explain why aluminum is often used for long distance overhead electric cables (high voltage wires).

3 What is the principal ore of aluminum?

4 Even though aluminum is active, it is highly resistant to air. Explain the reason for this.

5 What properties of aluminum make it particularly useful for each of the following applications?

a Drinking cans b Aircraft construction

6 Name key elements found in the following materials.

a Corundum b Kaolin c Cryolite

7 Aluminum cookwar cannot be used in cooking acidic foods why? Is it possible to clean an aluminium pot using an oven cleaner containing sodium hydroxide, NaOH? Explain.

## 2.5 IRON

***After completing this section, you will be able to:***

- ✓ explain the occurrence of iron;
- ✓ list common ores of iron; and
- ✓ discuss the uses of iron.

### 2.5.1 Occurrence

The Stone, Bronze and Iron ages are historical periods named after the most common material that was used for making tools during each time. The Bronze age came before an Iron age because copper and tin, the elements that are melted together to form Bronze, were both widely available and easily accessible metals. Broze is stronger than copper or tin alone.

Iron is the second most abundant metal and the fourth most abundant element in the earth's crust. It is a transition metal. Iron is seldom found as a free metal.

**ACTIVITY 2.8**

Form a group and perform the following activity. Share your opinion with your group members.

Using your common sense, deduce why iron was used to make tools and weapons than the metals discussed in the previous sections. Share your opinion with the class.

### 2.5.2 Important Ores

The main ores of iron are: Haematite ($Fe_2O_3$), Magnetite ($Fe_3O_4$), Iron pyrite ($FeS_2$), and Siderite ($FeCO_3$). Haematite and magnetite are the principal ores from which iron is extracted.

### 2.5.3 Uses

The impure form of iron known as pig iron contains impurities like silicon, manganese, phosphorus, carbon and sulphur. The high carbon content in pig iron is particularly undesirable since it makes the metal extremely brittle. The conversion of pig iron to a more useful form is essential. This form of iron is known as steel. The mechanical property of steel is determined by its carbon content and other chemical compositions. Steel is stronger and corrosion resistant than pure iron.

## ACTIVITY 2.9

Iron in the form of steel has extensive and well known uses. Discuss in your class the wide uses of iron/steel mainly in the fields of building constructions, fabrications of machineries and common household items.

## Exercise 2.5

1 Give the names and formulas of the most important ores of iron.

2 Define ore.

3 List three common uses of iron.

4 What are the elements constituting

a Heamatite b Magnetite c Siderite

# 2.6 COPPER AND SILVER

***After completing this section, you will be able to:***

- ✓ explain the occurrence of copper and silver;
- ✓ list common ores of copper and silver; and
- ✓ list the uses of copper and silver.

## 2.6.1 Occurrence

Copper and silver can be obtained freely (native or uncombined) in nature. Both copper and silver have been known since ancient times. The earliest coins were made of copper, silver and gold. This use which continues today is based on the durability and corrosion resistance of the metals. These metals are prized metals in the decorative arts and for making jewellery.

## ACTIVITY 2.10

Why is that copper and silver are easy to be extracted from their ores? Discuss the possible reasons in your class.

## 2.6.2 Important Ores

Though copper and silver can be found as native metals i.e. as metal in the ground, compounds of copper are also many in number.

*Figure 2.4:* **Silver coins**

*Figure 2.5:* **Copper wire for household electric system**

The principal ores of copper are chalcopyrites ($CuFeS_2$),chalcocite ($Cu_2S$), covelline (CuS), cuprite ($Cu_2O$), and malachite ($CuCO_3.Cu(OH)_2$).There are also extensive deposits of the native metal in certain places. Silver is a rather rare element occurring as native silver. The common ore of silver is argentite, $Ag_2S$.

### 2.6.3 Uses

**ACTIVITY 2.11**

Form a group and discuss the main uses of copper and silver. After the discussion, present your opinion to the class by the group representative.

## Exercise 2.6

1 Give the name and formula of the common ores of copper.

2 Why is copper not usually used in overhead electric cables?

3 List three common uses of copper and three common uses of silver.

4 Indicate the chemical composition of the material known as basic copper carbonate (Malachite green).

5 Give the name and formula of the common ore of silver.

## 2.7 GOLD, PLATINUM AND TANTALUM

***After completing this section, you will be able to:***

- ✓ explain the occurrence of gold, platinum and tantalum;
- ✓ list common ores of gold, platinum and tantalum; and
- ✓ list the uses of gold, platinum and tantalum.

### 2.7.1 Occurrence

Gold and platinum have been known since ancient times although very little attention was given to platinum as it was neither prized nor used in the same way as gold.

Gold is resistant to attack by air, similar to silver. Gold is more inert to attack by acids than silver. Therefore, gold is obtained native in nature.

Platinum is an extremely rare metal in the earth's crust. Platinum is often found chemically uncombined as native platinum. Platinum is noble like gold.

Tantalum is one of the most inert metals known. An inert material is one that does not react with most other chemicals. Tantalum is discovered about two hundred years ago.

Note that gold, platinum and tantalum are so unreactive. They are found as the native metals and not as compounds. So they do not need to be chemically separated.

## 2.7.2 Important Ores

The primary mineral of gold is the native metal and electrum (a gold-silver alloy). Some tellurides are also important mineral ores such as calaverite (gold telluride), sylvanite, and petzite.

Platinum arsenide (sperrylite) is a major source of platinum associated with nickel ores.

The main tantalum ore is tantalite. It is also possible to find this element in smaller amounts in samarskite, pyrochlore, fergusonite and euxenite.

Ethiopia's known tantalum deposits are currently in Kenticha, Shakiso and Seba weredas, Guji Zone, Oromia Regional State which is 600 km south of Addis Ababa.

## 2.7.3 Uses

Gold's primary use is a rather unusual one: as a monetary reserve for individuals and nations of the world. It is also used as jewellery and electrical wiring.

*Figure 2.6:* **A massive gold sample**

Platinum is mainly used in the free metal form, as catalyst in hydrogenation reactions performed in organic chemistry. It is also used in the preparation of gasoline to increase its yield and in the purification of gases for catalytic oxidation. The alloy of platinum and iridium is used in jewellery, laboratory utensils, electrodes and electric contacts. Alloyed with palladium, platinum is used in dentistry.

The primary use of tantalum metal is in making capacitors. A capacitor is an electrical device similar to a battery. Tantalum is one of the best metals for this purpose. Different kinds of capacitors are made for many different applications. They are used in military weapons systems, aircraft, space vehicles, communication systems, computers, and medical applications. For example, the smallest hearing aids are likely to have a tantalum capacitor.

Tantalum is also used in many different alloys. Tantalum alloys are used in laboratory equipment, weights for very precise balances, fountain and ball point pen points, and tools that have to operate at high speeds and temperatures.

Tantalum has no effect on body tissues. It is used in artificial hips and knees. Tantalum alloys are used to make artificial joints. Most metals, dissolve in acids, but tantalum is not affected by acids or other strong chemicals. For this reason, tantalum is used to make chemical, medical, and dental equipments.

## Exercise 2.7

1 Explain why gold is not attacked by oxygen, moisture and acids.

2 Which three transition metals are the best electric and thermal conductors of all the metals?

3 What are the common ores of gold, platinum and tantalum?

4 What are the uses of gold, platinum and tantalum?

# 2.8 ALLOYS

***After completing this section, you will be able to:***

- ✓ define the term alloy;
- ✓ give examples of some common alloys;
- ✓ describe the importance of alloying;
- ✓ identify the components of some common alloys;
- ✓ describe some of the common properties of alloys; and
- ✓ explain the uses of some common alloys.

### ACTIVITY 2.12

Form a group and discuss what an alloy is? After the discussion, present your opinion to the class by the group representative.

## 2.8.1 Advantages of Alloying Metals

Alloys are solid solutions that contain different metals and sometimes non-metallic elements. Alloys are homogeneous mixtures of two or more metallic elements or metallic and non-metallic elements.

***Why do metallurgists (people who work with metals) mix two or more elements together?***

The main idea with alloying is that the combinations work better together than any of the metals alone. **Metallurgists** sometimes add chromium (Cr) and/or nickel (Ni) to steel. While steel is already an alloy that is a very strong, the addition of small amounts of other metals help steel resist rusting. Depending on what element is added, you could create stainless steel or galvanized steel. It is always about improving specific qualities of the original. Another good example improving an alloy is addition of carbon to steel. A tiny amount of carbon (a non-metallic element) makes steel stronger. These special carbon-steel alloys are used in armor plating and weapons.

The use of alloys by humans started with the use of meteoric iron, a naturally occurring alloy of nickel and iron. As no metallurgic processes were used to separate iron from nickel, the alloy was used as it was because people had no means of separating the metals.

Ancient civilizations took into account the mixture and the various properties it produced, such as hardness, toughness and melting point. Even today, people make alloys for the following reasons.

- *To modify color, e.g. the color of copper is changed by additions of tin in variable amounts.*
- *To increase the elasticity, tensile strength and toughness.*
- *To get good castings.*
- *To modify electrical properties. The electrical properties of alloys are different from their component elements.*
- *To modify chemical reactivity. The chemical reactivity may increase or decrease by alloying. Alloys are more stable and are less affected by air and water and*
- *To make metal more resistant to corrosion.*

*Steel* is produced from iron by carefully controlling the amount of carbon present. Most steels contain between 0.1 percent and 1.0 percent carbon. By mixing steel with certain metals, alloys which are resistant to corrosion can be produced.

These alloys are called *stainless steel.* Steel alloyed with chromium or with nickel will produce corrosion resistant stainless steels.

*Bronze* is an alloy of copper and tin, was the first alloy discovered, during the prehistoric period now known as the Bronze Age. It was harder than pure copper and originally used to make tools and weapons, but was later superseded by metals and alloys with better properties. In later times bronze has been used for ornaments, bells, statues, and bearings.

*Brass* is an alloy made from copper and zinc. Brass has differing properties including strength, machinability, ductility, wear-resistance, hardness, colour, electrical and thermal conductivity, and corrosion-resistance. Brass also has excellent thermal conductivity making it a first choice for heat exchangers (radiators).

*Cupronickel* is an alloy of copper and nickel. The Cu-Ni alloys are single-phase throughout the full range of compositions and many standard alloys exist within this range, usually with small additions of other elements for special purposes.

*Electrum* is a naturally occurring alloy of gold and silver, with trace amounts of copper and other metals. It has also been produced artificially, and is often known as ‘green

gold'. The ancient Greeks called it 'gold' or 'white gold' as opposed to 'refined gold'. Its color ranges from pale to bright yellow, depending on the proportions of gold and silver. Electrum was used for the earliest metal coins and ancient drinking vessels.

### ACTIVITY 2.13

Form a group and perform the following activity. Share your opinion with your group members.

1 Discuss how the purity of gold is expressed.

2 How do you trace the difference between 14 – carat gold and 18 – carat gold?

3 Discuss the reason why 24 – carat gold is not used for making jewellery.

## 2.8.2 Some Common Alloys and Their Use

Alloying is of great importance because it is one of the primary ways of modifying the properties of pure metals. Today there are many alloys known and they are used in various ways for different purposes.

### ACTIVITY 2.14

Form a group and perform the following activity. Share your opinion with your group members.

1 List some alloys using different sources, the components of these alloys, and their uses related to their properties. Include the following alloys in your discussion: Amalgams, duralumin, type metal, stainless steel, solder, bronze, and brass. After the group discussion, present your findings to the rest of the class.

2 Alloying is of great importance because it is of the primary ways of modifying the properties of pure metallic elements. What are these properties?

3 Are there only metal-metal alloys? How about metal-non-metal and non-metal-non-metal? Explain.

# Unit Review

## Check List

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

| № | Can I | Yes | No |
|---|---|---|---|
| 1 | explain the occurrence of sodium and potassium? | | |
| 2 | list common ores of sodium and potassium? | | |
| 3 | discuss the uses of sodium and potassium? | | |
| 4 | explain the occurrence of magnesium and calcium? | | |
| 5 | list common ores of magnesium and calcium? | | |
| 6 | discuss the uses of magnesium and calcium? | | |
| 7 | explain the occurrence of aluminum? | | |
| 8 | list common ores of aluminum? | | |
| 9 | discuss the uses of aluminum? | | |
| 10 | explain the occurrence of iron? | | |
| 11 | list common ores of iron? | | |
| 12 | discuss the uses of iron? | | |
| 13 | explain the occurrence of copper and silver? | | |
| 14 | list common ores of copper and silver? | | |
| 15 | list the uses of copper and silver? | | |
| 16 | explain the occurrence of gold, platinum and tantalum? | | |
| 17 | list common ores of gold, platinum and tantalum? | | |

| | | | |
|---|---|---|---|
| 18 | list the uses of gold, platinum and tantalum? | | |
| 19 | define the term alloy? | | |
| 20 | give examples of some common alloys? | | |
| 21 | describe the importance of alloying? | | |
| 22 | identify the components of some common alloys? | | |
| 23 | describe some of the common properties of alloys? | | |
| 24 | explain the uses of some common alloys? | | |

## Key Terms

- Abundance
- Alloys
- Ductile
- Electrical conductivity
- Extraction /Isolation
- Malleable /malleability
- Occurrence
- Ore
- Physical state
- Sonorous
- Thermal conductivity

# UNIT SUMMARY

- ✓ Most metals exhibit a characteristic metallic luster. Metals are good conductors of heat and electricity. They are malleable and ductile. All metals except mercury are solids at room temperature. Most metals have high melting points. Metal are sonorous.
- ✓ Of all the metals, the Group IA metals known as the alkali metals have low densities and low melting points. These metals are never found native in nature.
- ✓ The alkali metals have a few important uses. Liquid sodium is used as a heat transfer medium in some types of nuclear reactors. Small quantities of sodium, as sodium vapor, are used in lamps for outdoor lighting. Sodium and potassium are essential to living organisms, and many Group IA compounds have medical value.
- ✓ Magnesium and calcium are found in many minerals, for example, in lime stone ($CaCO_3$), and dolomite ($CaCO_3.MgCO_3$). Among the important Group IIA compounds are the carbonates, chlorides, hydroxides, oxides, and sulphates of magnesium and calcium.

- ✓ The most important metal of group IIIA is aluminum. Aluminum, an active metal, is protected against corrosion by a film of aluminum oxide ($Al_2O_3$). One interesting reaction of aluminum is the highly exothermic thermite reaction. The heat produced by this reaction can be used to produce molten iron metal that is used to weld large iron objects such as pipes and rails.Perhaps most familiar is aluminum's use in beverage cans, cookware, and as foil for wrapping foods. The greatest quantity of aluminum is consumed in structural materials, usually alloyed with other metals to impart greater strength.

- ✓ Iron is seldom found native in nature. Iron occurs mainly in the form of iron oxide, iron carbonate and iron sulfide ores. Steel is an alloy of iron and carbon. Alloy steel contains carbon plus other metals such as chromium, cobalt, nickel, manganese, tungsten and molybdenum. Stainless steel, for example, contains iron, carbon, chromium and nickel.

- ✓ Copper and silver are among the coinage metals. They are much less active metals. Most technological uses of copper and silver are based on their inertness toward air oxidation (rust) and their exceptional abilities to conduct heat and electricity.

- ✓ Silver is used in jewellery, silverware, high-capacity batteries, coinage and photography.

- ✓ Gold is very rare element. It is very dense having a density of 19.3 $g/cm^3$. Its texture is soft, its color is yellow and has high luster. Gold is probably the earliest known metal. This is because it occurs naturally as native gold.

- ✓ Platinum can occur free in nature and is sometimes found in deposits of gold. Platinum is a soft, dense, ductile metal that is very resistant to corrosion. Platinum is used to make jewellery, wire, electrical contacts and laboratory vessels. Platinum is widely used as a catalyst.

- ✓ Tantalum is found in nature as native metal. Tantalum is discovered very recently. Tantalum is widely used in making capacitors. Tantalum alloys are used in medical and dental applications because the metal has no side effect on body tissues.

- ✓ An alloy is a material that contains more than one element. Alloys are harder, resistant to corrosion, poor conductors of heat and electricity, lower in density as compared to the component metals.

# REVIEW EXERCISE ON UNIT 2

## I *Choose the correct answer from the given alternatives for each of the following questions.*

1 A metal which has a very high self protective property from corrosion is possibly:

A Fe
B Mg
C Na
D Al

2 Which of the following ore doesn't contain iron?

A Magnetite
B Chalcopyrite
C Siderite
D Heamatite

3 Which one of the following metallic elements is most likely found native (free or uncombined)?

A Zn
B Au
C Al
D Fe

4 Which of the following is not the use of sodium?

A Manufacture of sodium cyanide.
B Manufacture of sodium hydroxide.
C Making sodium amalgam alloy.
D Jewelry.

5 Which one of the following statements does not describe gold?

A It exists as free element in nature.
B It is an excellent conductor.
C It has a yellow color.
D It reacts with oxygen in the presence of moist air.

6 Which of the following alloys contain chromium?

A Brass
B Stainless steel
C Bronze
D Solder

7 The corrosion of iron possibly occurs in the presence of:

A Helium
B Carbon dioxide
C Nitrogen
D Oxygen

## II *Give short Answers for each of the following questions.*

8 Name the following:

a A molten metal that catches fire in chlorine gas and gives off white fumes.

b A metal that forms two types of oxides and rusts in moisture; write their formulas.

c A metal used in hot water systems.

d A metal used in long distance cable wires.

e A metal added to gold to harden it.

9 Give the names and formulas of the most important ores of iron.

10 Which metal best fits each of the following descriptions?

a Suitable to be used in artificial body joints.

b Used in fireworks.

c Popular in manufacturing door and window frames.

# UNIT 3

# SOME IMPORTANT NON-METALS

## MAIN CONTENTS



## UNIT OUTCOMES

***After completing this unit, you will be able to:***

- ✓ Know the general properties of non-metals and how to differentiate non-metals from metals.
- ✓ Explain the occurrence and uses of carbon, nitrogen, phosphorus, oxygen and sulphur.
- ✓ Explain the uses of some common compounds of non-metals like carbon dioxide, sodium carbonate, nitric acid, phosphoric acid, calcium phosphate, sulphur dioxide and sulphuric acid.
- ✓ Describe scientific inquiry skills along this unit: observing, comparing and contrasting, communicating, asking questions, drawing conclusions, applying concepts, and problem solving.

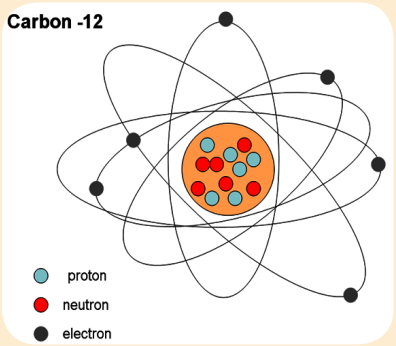
## START-UP ACTIVITY

1 To which of the following categories (Monoatomic, Diatomic, Polyatomic) does oxygen molecule belong?

2 As you know water and air have a major role in supporting life. What are their constituents? Are these constituents metals or non-metals?

3 Which component of air is essential for respiration?

## HISTORICAL NOTE




In 1961 the International Union of Pure and Applied Chemistry (IUPAC) adopted the isotope C-12 as the basis for atomic weights. Isotopes are atoms of the same element which possess the same atomic number but different mass numbers. Carbon-14, isotope is used to determine the age of such materials as wood, archeological specimens, etc.

# 3.1 GENERAL PROPERTIES OF NON-METALS

***After completing this section, you will be able to:***

- ✓ mention the general properties of non-metals.

All non-metals except hydrogen are found on the right hand side of the periodic table (p-block). This block includes the metalloids and few metals such as aluminum, tin and lead.

The number of non-metals as compared to metals in the periodic table are few. Only eighteen elements of the periodic table are classified as non-metals. Non-metals contribute a great deal to the growth of a country's development. Non-metals are used in the manufacture of fertilizers, medicines, fabrics, plastics, building materials and other significant chemical substances. The main components of food items are also made of non-metals.

## ACTIVITY 3.1

Discuss in groups and present your opinion to the class.

1 List some common non-metals and discuss their uses in industries and environment.

2 What is the role of plants in providing oxygen and food? Do you know the chemical process behind this?

3 What are the ways in which trees support human life?

Non-metals generally have the following properties:

1 **Non-malleable and non-ductile:** Non-metals are generally brittle and hence cannot be beaten into sheets or drawn into wires. In other words, non-metals are non-malleable and non-ductile. When stress is applied to non-metals, they shatter into pieces.

2 **Poor conductors of heat and electricity**: Non-metals are generally poor conductors of heat and non-conductors of electricity. Carbon (graphite) is an exception. It is a good conductor of electricity.

3 **Physical state**: Non-metals exist in solid, liquid or gaseous state at room temperature. For example, carbon, sulphur, iodine and phosphorus are solids at room temperature; bromine is a liquid and hydrogen, oxygen, fluorine, chlorine, nitrogen are gaseous non-metals.

4 **Non-lustrous**: Non-metals are generally non-lustrous and dull. Iodine and graphite are the only lustrous non-metals.

5 **Tensile strength**: Non-metals have low tensile strength. Tensile strength is the ability to be stretched or the amount of weight it can hold without breaking. Therefore, non-metals are not strong and get easily broken.

6 **Density**: Non-metals possess low densities. They are light as compared to metals.

7 **Texture**: Non-metals are generally soft. However, carbon (diamond) is an exception. Diamond is very hard. In fact, diamond is the hardest natural substance known.

8 **Melting and boiling points**: All non-metals (except carbon in the form of graphite) posses low melting and boiling points. Carbon (graphite) is a non-metal but possesses high melting point.

## Exercise 3.1

1 Three of the elements in the right wing of the periodic table are the most abundant elements in earth's crust. What are they?

2 Write two most active non-metals and two most active metals among the right wing elements in the periodic table?

3 Which two non-metals are fortunately lustrous?

# 3.2 CARBON

***After completing this section, you will be able to:***

- ✓ explain the occurrence of carbon;
- ✓ discuss the uses of elemental carbon.

## 3.2.1 Occurrence

You have been already introduced in **Unit 1** that hydrocarbons contain carbon. Carbon is the basis of all forms of life on earth. Carbon is also a major component in very large masses of carbonate rock (limestone, dolomite, marble, etc). Coal is the largest commercial source of mineral carbon. For example; anthracite contains 92 – 98% carbon.

Carbon is a Group IVA element and is distributed widely in nature. Carbon is present as carbon dioxide in the atmosphere and dissolved in all natural waters.

Carbon exists mainly in three allotropic forms. **Allotropy** is the property of some chemical elements to exist in two or more different forms under the same physical state. The different forms of these elements are known as **allotropes**. For example, the allotropes of carbon are diamond, graphite and fullerenes.

Graphite is one of the softest known materials while diamond is one of the hardest. The discovery of fullerenes, $C_{60}$, is more recent. As of the early twenty-first century, this new form of carbon is the subject of great interest. The chemical and physical properties of fullerenes are still under study, in both pure and applied research laboratories.

## 3.2.2 Uses

Carbon as charcoal, soot and coal has been used since prehistoric times.

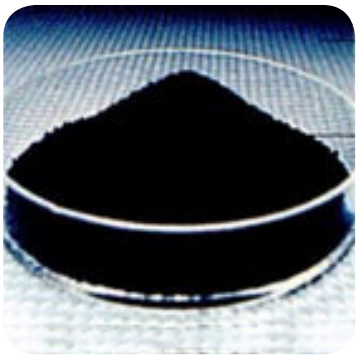


*Figure 3.1* **Carbon black**

Carbon as diamond has also been known since very ancient times. Diamonds have attractive appearance and hence are used in jewelry, but they also have industrial uses. Because they have a high heat conductivity (they dissipate heat quickly) and are extremely hard. Diamonds are used as abrasives and in drilling bits for cutting steel and other hard materials. Diamonds are also used as gemstones.

*Figure 3.2* **Dimond Jewelry**

Graphite is perhaps most familiar as the "lead" in pencils. Graphite is used for electrodes in dry cells and in industrial electrolysis reactions. It can also withstand high temperature leading to its use in furnaces, and other high temperature devices.

Graphite is quite soft and cleaves easily between its layers; hence it has lubricating properties (graphite greases) which contrast with the abrasive properties of diamond.

*Figure 3.3* **Graphite**

## Exercise 3.2

1 What is carbon black? How is it prepared, and what are some of its uses?

2 Explain why graphite can conduct electricity but diamond cannot.

3 Give three contrasting properties of diamond and graphite.

4 Name three crystalline forms of carbon.

## 3.3 NITROGEN

***After completing this section, you will be able to:***

- ✓ explain the occurrence of nitrogen;
- ✓ conduct an experiment to estimate the nitrogen content;
- ✓ discuss the uses of elemental nitrogen;

### 3.3.1 Occurrence

Nitrogen ($N_2$) is the most abundant element in the atmospheric air. About four-fifths of the atmospheric air is free nitrogen. The most important gases present in dry atmospheric air are oxygen about 21%, carbon dioxide about 0.03% and nitrogen about 78% by volume.

Nitrogen does not react easily because the element is composed of diatomic molecules, the atoms of which are held together very strongly by triple bonds. Only when sufficient energy is supplied to break these bonds does nitrogen react. Nitrogen is much less reactive than oxygen and when substances are burnt in air they react with oxygen much more than nitrogen.

### Experiment 3.1

***Title: The bell jar experiment***

***Objective:*** To investigate the nitrogen content of air by removing oxygen and carbon dioxide.

***Materials required:*** White phosphorus, scissors or knife, tongs, glass rod, one-holed rubber stopper bell-jar, two rubber bands, match, Bunsen burner, water, trough, graduated cylinder, crucible, calcium oxide or calcium hydroxide.

***Procedure:***

**CAUTION!** *white phosphorus is dangerous because it catches fire very easily. Always store and cut it under water.*

1 Fill a trough with water to three-fourth of its total volume and add a spatula full of calcium oxide or calcium hydroxide.

2 Float a crucible in water in a trough.

3 Cut a piece of white phosphorus (about the size of a pea) with scissors, hold the piece of phosphorus with forceps, take it out off the container, dry it on a tissue paper and put it in a crucible.

4 Place a bell-jar, with its stopper removed, over the crucible as shown in *Figure 3.4*.

5 Mark the level of the water in the jar with a rubber band.

6 Insert a glass rod through the hole of the rubber stopper and heat one of its ends with a Bunsen burner flame.

7 Push the rubber stopper into the neck of the bell-jar, making it air tight, push the glass rod down until the hot end touches the phosphorus in the crucible and raise it immediately. Observe what is happening.

8 Leave the apparatus until the fumes dissolve in water and mark the final water level with the other rubber band.

9 Remove the bell-jar, fill it with water to the first rubber band, and measure the volume of water with a graduated cylinder to get the initial volume of air and record volume of air before the experiment.

10 Again, fill the bell-jar with water to the second rubber band and measure the volume of this water to get the final volume of air (volume of air after the experiment).

***Observation and analysis:***

a How do you remove oxygen and carbon dioxide?

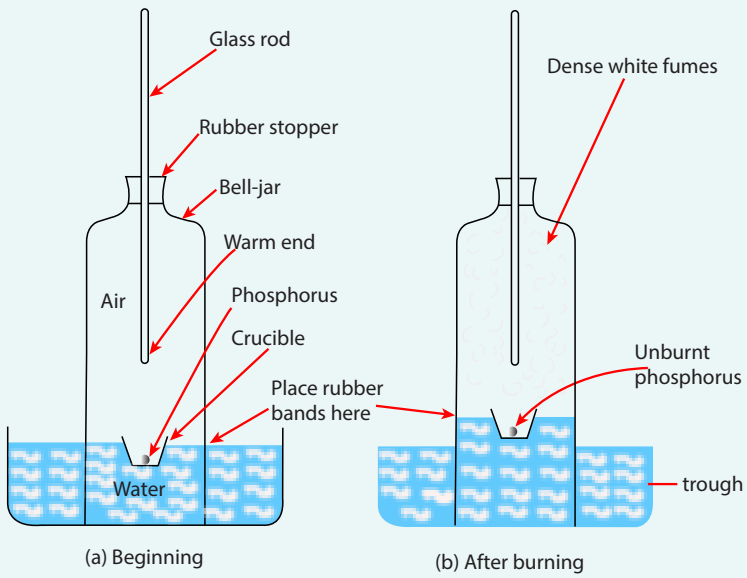



*Figure 3.4* **Bell-Jar Experiment**

b How can dry nitrogen be collected?

c What is the volume of air before the experiment?

d What is the volume of air after the experiment?

e Calculate the fractional part of nitrogen from the data you collected in the experiment using the relation:

$$\text{Fractional part of } N_2 = \frac{\text{Final volume of air}}{\text{Initial volume of air}}$$

f What fractional part of air is oxygen?

$$\text{Fractional part of } O_2 = \frac{\text{Initial volume of air - Final volume of air}}{\text{Initial volume of air}}$$

Write a laboratory report about your findings in groups and present to the class.

Note: From the above experiment you may not get the actual fractional part of nitrogen in air. This is due to the limitations of accuracy of this method as it doesn't remove argon that exists in air either physically or chemically.

## 3.3.2 Uses

Nitrogen is an essential element to living organisms; it occurs in all proteins and in many other biologically important molecules. Animals get nitrogen through food.

### *What about plants?*

Nitrogen, phosphorus and potassium (NPK) are the major elements (macronutrients) that plants should get through fertilizers. Among these, nitrogen is the most important one. Although nitrogen exists in large quantities in the atmosphere, it cannot be used directly by most plants and animals. The $N_2$ molecule first must be "fixed", that is, converted to compounds that are more readily usable by living organisms. Plants take up nitrogen in the form of soluble nitrate ion ($NO_3^-$) or ammonium ion ($NH_4^+$) from the soil.

Nitrogen is used to produce ammonia by reacting it with hydrogen by the process called Haber process.

### ACTIVITY 3.2

Form a group and perform the following activity. Share your opinion with your group members and finally present to your classmates.

1 The role of nitrogen-fixing and denitrifying bacteria in the root nodules of leguminous plants – plants of the bean family (like beans, clover, peas, etc) and in the soil.

2 What are the micro-organisms that are able to convert atmospheric nitrogen to ammonia and ammonium salts?

Plants get only a very small amount of nitrogen through microorganisms, whereas the decomposition and decay of dead plants and animals provide large quantities of nitrogen to plants.

### ACTIVITY 3.3

Form a group and perform the following activity. Share your opinion with your group members and finally present to your classmates.

1 What are the organic wastes generally supplied to plants for their growth?

2 What is the importance of organic fertilizers in agriculture?

3 What are the limitations of organic fertilizers? How can this be overcome?

## Exercise 3.3

1 Explain how nitrogen is used to produce ammonia and write the balanced chemical equation.

2 What do plants use nitrogen for?

3 How is atmospheric nitrogen made available to plants?

# 3.4 PHOSPHORUS

***After completing this section, you will be able to:***

- ✓ explain the occurrence of phosphorus;
- ✓ discuss the uses of elemental phosphorus.

## 3.4.1 Occurrence

Phosphorus (P) is a reactive element which does not occur freely in nature. It occurs mainly in the form of phosphate minerals. The principal source of phosphorus is phosphate rock (ground rock phosphate) which contains phosphate mainly in the form of $Ca_3(PO_4)_2$.

Phosporus exists in two allotropic forms known as *red phosphorus* and *white phosphorus*. They have different fundamental structural units. The two allotropes differ appreciably in their properties; red phosphorus, for example, is less reactive than white phosphorus. If white phosphorus is left exposed to air, it bursts into flame. Because of its reactivity with oxygen, white phosphorus is stored under water. White phosphorus is soluble in carbon disulphide ($CS_2$), benzene ($C_6H_6$) and ether ($CH_3 - O - CH_3$). White phosphorus exists in the form of $P_4$ molecules.

When white phosphorus is heated to about $300^0$C in the absence of air, it is transformed to red phosphorus.

## 3.4.2 Uses

### ACTIVITY 3.4

Use any available reference material to investigate the main uses of phosphorus. Form a group and share your opinion with your group members. Discuss with the rest of the class after your group discussions.

1 Phosphorus has extensive and well known uses. Discuss in your class the wide uses of phosphorus mainly in the fields of producing acids, producing fertilizers, in the growth of animals, manufacturing insecticides, matches, pesticides, military applications and the like.

2 Are there alloys made of non-metals and metals? If your answer is 'yes', what is the name of the alloy composed of phosphorus, copper and tin?

There are large quantities of phosphorus compounds which are used in agriculture and chemical industries. Some of these compounds are: phosphoric acid, two important oxides of phosphorus ($P_4O_6$ and $P_4O_{10}$), phosphine ($PH_3$), phosphates, and organophosphorus compounds.

## ACTIVITY 3.5

Form a group and share your opinion with your group members. Discuss with the rest of the class after your group discussions.

1 Use reference books and/or internet (if possible) to research the uses of some important compounds of phosphorus including phosphoric acids, oxides of phosphorus ($P_4O_6$ and $P_4O_{10}$), phosphine ($PH_3$), phosphates (sodium tripolyphosphate ($Na_3PO_4$) and calcium phosphate ($Ca_3(PO_4)_2$) and organophosphorus compounds.

2 Investigate and discuss the importance of phosphorus in plants and animals.

## Exercise 3.4

1 What are the two allotropic forms of phosphorus?
2 Which form of phosphorus is more reactive?
3 Which allotrope of phosphorus has less ignition temperature?
4 Which allotrope of phosphorus is soluble in $CS_2$?
5 What are the formulas of the oxides in which phosphorus has valences of 3 and 5, respectively?

# 3.5 OXYGEN

***After completing this section, you will be able to:***

- ✓ explain the occurrence of oxygen;
- ✓ discuss the uses of elemental oxygen.

## 3.5.1 Occurrence

Free oxygen exists in the air, forming about 21% by volume. Nitrogen is far more abundant than oxygen in the atmosphere by volume, but the situation is reversed in earth's solid crust. Nitrogen compounds occur only in trace amounts in the crust, but sources of oxygen are so numerous that oxygen is the most abundant element. Nearly half the mass of earth's crust consists of oxygen in a combined state in the form of water, silicates, and many metallic and non-metallic oxides and in the form of salts. The main reason for this difference is that nitrogen gas is rather inert, and oxygen gas is quite reactive.

Oxygen forms compounds with all the elements except the lighter noble gases (He, Ne, and Ar) and noble metals such as Au, Ag, and Pt under normal conditions.

Two allotropes of oxygen are known. These are oxygen ($O_2$) and ozone ($O_3$). Ozone occurs naturally in the upper atmosphere where it acts as a protecting blanket shielding the earth's biosphere from ultraviolet rays (UV). Ozone, $O_3$, is less stable than $O_2$.

Oxygen can be prepared by using electrical energy. The process by which electrical energy is used to produce a chemical change is known as electrolysis. Therefore, a quantity of oxygen can be prepared by the electrolysis of water after additions of drops of acids or alkalis.

$$2H_2O(l) \xrightarrow{electricity} 2H_2(g) + O_2(g)$$

### 3.5.2 Uses

Oxygen can be used:

- ✓ In the production of steel and some metals. Most commercially produced oxygen is used to convert iron ore into steel.
- ✓ With acetylene in the oxyacetylene flame, oxygen can be used for welding and cutting metals.
- ✓ To support life as an aid to breathing where the natural supply of oxygen is insufficient, for example, in high altitude flying or climbing, in air and space travel, and in submarines and mines.
- ✓ As bleaching agent for pulp and paper, in the production of oxygen-containing compounds, and in biological treatment of wastewater.
- ✓ Rockets use liquid oxygen to burn fuel and launch the rocket.

## Exercise 3.5

1 What is the name of the gas which supports combustion?
2 Is oxygen soluble in water?
3 Explain the occurrence of oxygen.
4 What is the common use of ozone?
5 What is liquid oxygen used for?

## 3.6 SULPHUR

***After completing this section, you will be able to:***

- ✓ explain the occurrence of sulphur;
- ✓ discuss the uses of elemental sulphur.

### 3.6.1 Occurrence

Sulphur belongs to Group VIA of the periodic table. It is widely distributed in nature. It occurs both in free elemental state and in combined states. Elemental sulphur exists in molecular form as $S_8$. The major source of sulphur is underground deposit of elemental sulphur. Sulphur occurs in the form of compounds mainly as sulphides and sulphates. It is found in many minerals and ores, such as iron pyrites ($FeS_2$), galena (PbS), cinnabar (HgS), zinc blende (ZnS), gypsum ($CaSO_4.2H_2O$), epsom salt ($MgSO_4$) and in mineral springs and other waters. It is found uncombined in some volcanic regions (for example, Afar region in Ethiopia). Sulphur deposits are found in Dallol located in the Danakil depression (Afar regional state) in north-east Ethiopia, in an area

*Figure 3.5* **Sample of pure sulphur**

subject to the highest average temperature on the planet. Native sulphur is reported in sediments of the Danakil depression. Sulphur often occurs with coal, petroleum, and natural gas. Sulphur is a component of all living cells.

Sulphur sometimes occurs in bright yellow layers on the top of the earth. It has a sharp, offensive odor. When it burns, it gives off a strong, suffocating smell. The odor is like that produced when a match is struck.

Sulphur exists in three allotropic forms known as ***rhombic sulphur, monoclinic sulphur*** and ***plastic sulphur***. Rhombic sulphur is a yellow translucent crystal. It is the most stable form of sulphur at room temperature. If rhombic sulphur is heated until it melts and then cooled, it is converted to monoclinic sulphur. Monoclinic sulphur is amber crystal. When sulphur is heated to about 200$^{O}$C and then poured into cold water, a red-brown rubbery material, called plastic sulphur is obtained.

Sulphur must have been well known to ancient people. But ancient people certainly did not think about sulphur the way modern chemists do.

### ACTIVITY 3.6

Use the school library or public library to research the countries in the world which are the main providers of elemental sulphur. Bring a written material on the result of your findings to the class.

## 3.6.2 Uses

### ACTIVITY 3.7

Form a group and share your opinion with your group members. Discuss with the rest of the class after your group discussions.

Recycling materials help preserving our environment for the future. Discuss in groups after independently referring to available literature of chemistry about the advantages of recycling elemental sulphur on the subject of reducing demand on resources and reducing atmospheric pollution resulting from one of the oxides of sulphur – $SO_2$.

Sulphur is used in textiles, rubber products such as tyres and boots, daily household products such as detergents, paints, paper and carpets. Sulphur is also used in the manufacture of matches, insecticides, fungicides and gun powder. It is also used in many life-saving medicines. Sulphur has found applications in the manufacture of skin ointments and drugs. Sulphur is essential to life. It is a minor constituent of fats, body fluids and skeletal minerals.

Sulphur is used in the vulcanization of natural rubber. Vulcanization is the process of hardening rubber by heating natural rubber in the presence of sulphur.

A tremendous amount of sulphur is used to make sulphuric acid, the most important manufactured chemical.

## Exercise 3.6

1 What are the three allotropes of sulphur?
2 What are the two classes of compounds considered as mineral ores of sulhur?
3 What is the chemical symbol of sulphur?
4 Name the elements that are contained in sulphur dioxide.
5 Give two large scale uses of sulphur?

## 3.7 Uses of Common Compounds of Non-Metals

***After completing this section, you will be able to:***

- ✓ explain the uses of some common compounds of non-metals.

A number of non-metal compounds contribute a great deal to the economic development of a country. They are used in the manufacture of medicines, fertilizers, building materials and other important materials. The following are examples of non-metal compounds.

1 Carbon disulphide ($CS_2$) is a flammable, volatile liquid that is a good solvent for sulphur, bromine, iodine, fats, and oils. However, its toxicity somewhat limits this use. Carbon disulphide is an important intermediate in the manufacture of rayon and cellophane.

2 Carbon tetrachloride ($CCl_4$) have been extensively used as a solvent, dry-cleaning agent, and fire extinguisher. $CCl_4$ is declining in importance because it causes liver and kidney damage and it is suspected human carcinogen.

3 Salts of sulphuric acid are known as sulphates. Sulphates have many important use. Calcium sulphate hydrate ($CaSO_4.2H_2O$) is known as gypsum. Gypsum is the primary material used for wall board in the construction industry. As the hydrate $2CaSO_4.H_2O$, calcium sulphate is known as plaster of pairs, a substance used to make casts and molds.

4 Aluminum sulphate ($Al_2(SO_4)_3$) is used in water treatment purifying the water by removing suspended matter.

5 Calcium carbide ($CaC_2$), a binary compound of carbon is a convenient solid reagent that can be transported and then generate the gaseous fuel acetylene ($C_2H_2$) simply by adding water. Acetylene is used in oxyacetylene flame for welding.

### Activity 3.8

Form groups and research the uses of the compounds listed below and prepare a brief summary in your group that could be shared with the rest of the class. Only one compound for a group.

- ✓ Carbon dioxide
- ✓ Sodium carbonate
- ✓ Nitric acid
- ✓ Phosphoric acid
- ✓ Calcium phosphate
- ✓ Sulphur dioxide
- ✓ Sulphuric acid

# Unit Review

## CHECK LIST

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

| № | Can I | Yes | No |
|---|---|---|---|
| 1. | Mention the general properties of Non metals? | | |
| 2. | Explain the occurrence of carbon? | | |
| 3. | Discuss the uses of elemental carbon? | | |
| 4. | Explain the occurrence of nitrogen? | | |
| 5. | Conduct an experiment to estimate the nitrogen content? | | |
| 6. | Discuss the uses of elemental nitrogen? | | |
| 7. | Explain the occurrence of phosphorous? | | |
| 8. | Discuss the uses of elemental phosphorus? | | |
| 9. | Explain the occurrence of oxygen? | | |
| 10. | Discuss the uses of elemental oxygen? | | |
| 11. | Explain the occurrence of sulphur? | | |
| 12. | Discuss the uses of elemental sulphur? | | |
| 13. | Explain the uses of some common compounds of non-metals? | | |

## Key Terms

- Allotropes
- Allotropy
- Electrodes
- Non-ductile
- Non-lustrous
- Non-malleable
- Physical state
- Rocket fuel
- Refractory
- Vulcanization

## UNIT SUMMARY

- ✓ Carbon is the key element of organic compounds. The three allotropes of carbon are diamond, graphite and fullerenes. Diamond is valued for hardness and thermal conductivity, graphite for electrical conductivity and refractory properties.

- ✓ The chief components of dry air are $N_2$, $O_2$ and Ar. Nitrogen must be "fixed" for use by plants, animals and humans.
- ✓ Phosphorus occurs mainly in phosphate bearing rock, produced in nature from the remains of marine animals deposited millions of years ago. Ground phosphate rock is a member of the class of minerals called apatites.
- ✓ Phosphorus exists in two common allotropic forms – white phosphorus and red phosphorus. The stable form of phosphorus is red phosphorus.
- ✓ Phosphorus forms two important oxides. These are $P_4O_6$ and $P_4O_{10}$.
- ✓ The principal compounds of phosphorus are the phosphates.
- ✓ Oxygen forms compounds with all elements except with the lighter noble gases and noble metals such as Au, Ag and Pt. The two allotropic forms of oxygen are $O_2$ and $O_3$. $O_3$ in the stratosphere protects living organisms by absorbing ultraviolet radiation (UV),
- ✓ Sulphur occurs in nature as a free element and in the form of compounds such as sulphides and sulphates.
- ✓ The allotropes of sulphur are rhombic sulphur, monoclinic sulphur and plastic sulphur.
- ✓ The important compounds of sulphur are the oxides and the sulphates.

## REVIEW EXERCISE ON UNIT 3

### I *Choose the correct answer from the given alternatives for each of the following questions.*

1 Which of the following elements does not have an allotropic forms?

A Sulphur C Phosphorus

B Carbon D Nitrogen

2 Which one of the following does not contain sulphur?

A Iron pyrite C Gypsum

B Dolomite D Cinnabar

3 What is the major source of elemental sulphur?

A Sea water

B Sulphides

C Sulphates

D Underground deposits of elemental sulphur

4 The major use of carbon dioxide is in

A refrigeration.

B the production of carbonated beverages.

C the manufacturing of baking soda.

D the manufacturing of washing soda.

5 The most abundant element in the earth's crust is

A oxygen.
C nitrogen.
B silicon.
D aluminum.

6 Which of the following are not allotropes?

A Graphite and diamond.
B Ozone and oxygen.
C Carbon dioxide and carbon monoxide.
D Red phosphorus and white phosphorus.

7 Which one of the following elements form compounds that can be used in the production of cement?

A Potassium
C Carbon
B Sodium
D Calcium

8 Which one of the following is stored in water?

A Sodium
C Potassium
B Phosphorus
D Calcium

9 A compound which is used as a fertiliser is

A NaCl
C $CaCO_3$
B $KNO_3$
D $NO_2$

10 One of the main uses of phosphorus is in making of

A cemen
C glass
B paint
D fertilizer

11 Which of the following statement is not correct?

A Nitrogen is one of the main constituents of air.
B Nitrogen is slightly reactive.
C Nitrogen cannot be taken directly from the air by humans and animals.
D Nitrogen is one of the main nutrients of plants.

12 Which one of the following is not a use of sulphur dioxide?

A As a cooling agent in refrigrators.
B Manufacture of sulphuric acid.
C It is used as a fumigant
D Preserving canned foods.

13 The element that doesn't occur in elemental state in nature is

A phosphorus. C nitrogen.

B sulphur. D carbon.

14 Which non-metallic element has an allotrope that is used in jewellery?

A Sulphur C Phosphorus

B Carbon D Nitrogen

## II *Give short answers for each of the following questions.*

15 Write the common properties of white phosphorus and red phosphorus.

16 Which side of the periodic table contains non-metals?

17 Which allotrope of sulphur is the most stable form at room temperature?

18 Which non-metallic element is an essential constituent of nervous and muscular tissue?

19 What is the name of the chemical used to bleach sugar in sugar industries?

20 What is the name of the compound constituting limestone?

21 Which non-metallic element is very useful in making matches at present?

# Unit 4

# Environmental Chemistry

## Main Contents



## Unit Outcomes

***After completing this unit, you will be able to:***

- ✓ Know the composition of air;
- ✓ Understand air pollution, causes of air pollution and effects of air pollutants;
- ✓ Understand global warming, causes and effects of global warming;
- ✓ Describe the hardness and softness of water;
- ✓ Demonstrate the effect of hardness of water and describe the methods of softening of temporary and permanent hard water;
- ✓ Understand water pollution and water pollutants;
- ✓ Understand water purification;
- ✓ Describe the composition of soil and differentiate acidic, alkaline or neutral soils;
- ✓ Know the major plant nutrients, explain methods of improving soil fertility and suggest some methods of correcting soil acidity and alkalinity;
- ✓ Describe elemental composition of coal, natural gas and crude oil and explain their physical properties and uses;
- ✓ Demonstrate scientific inquiry skills along this unit: observing, classifying, comparing and contrasting, communicating, asking questions, designing experiments, drawing conclusions, applying concepts and problem- solving.

## START-UP ACTIVITY

In your group, discuss the following points. When you complete, elect a group representative to present the group's opinion to the rest of the class.

1 Define the term Environment.

2 What is environmental chemistry? List down the concerns of environmental chemistry.

## HISTORICAL NOTE

Dr. Tewolde Berhan Gebre Egziabher

Dr. Tewolde Berhan Gebre Egziabher (born in 1940 in Adwa, Tigray) is an Ethiopian scholar who won the Right Livelihood Award (often referred as the "Alternative Nobel Prize") in 2000 "for his exemplary work to safeguard biodiversity and the traditional rights of farmers and communities to their genetic resources."

Tewolde Berhan is also named one of the 2006 winners of the top United Nations Environmental Prize (UNEP), which honored him as **a Champion of the Earth**. In addition with many other international recognitions and awards, Tewolde Berhan is a recipient of National Green Award from the presidant of the Federal Democratic Republic of Ethiopia in 2008.

# 4.1 AIR

***After completing this section, you will be able to:***

- ✓ describe the percentage of nitrogen, oxygen and carbon dioxide in the air;
- ✓ list air pollutants;
- ✓ discuss sources of $SO_2$, CO and $NO_x$ (NO, $NO_2$);
- ✓ explain effects of $SO_2$, CO and $NO_2$ in the air
- ✓ define global warming;
- ✓ discuss the causes of global warming;
- ✓ discuss the effects of global warming.

## 4.1.1 Composition of Air

### ACTIVITY 4.1

Discuss on the following points and present your opinion to the rest of the class.

1 Is the composition of air the same at all places in the world? Explain.

2 Is clean air a homogeneous or a heterogeneous mixture?

Air is not a pure substance. It is a mixture of several gases. It cosists of 78% nitrogen, 21% oxygen, 1% argon and 0.04% carbon dioxide by volume.

## ACTIVITY 4.2

Draw a pie chart to illustrate the composition of air using the values given above in groups. Compare the pie chart you have drawn with others.

### 4.1.2 Air Pollution

## ACTIVITY 4.3

Discuss in groups on the following points and present your findings to the rest of the class.

Based on the objective reality of your locality;

1 What are the human activities that release gasesous contaminants to atmospheric air ?

2 What are the gaseous contaminants that are released to the atmosphere due to these human activities?

Air is a mixture. Its composition varies from place to place. One of the causes for this variation is pollution. **Air pollution** refers to the contamination of atmospheric air due to gaseous substances and tiny solid particles entering into it that are not normally present in air. Air pollution can also be caused by the emission of gaseous substances like carbon dioxide which results in an increase in its concentration. Substances that contaminate air are called *air pollutants.*

Some of the common air pollutants are **sulphur dioxide ($SO_2$), carbon monoxide (CO), nitrogen oxides, particulates** and **pollen**. In air, there are more than one kind of oxides of nitrogen. The most common oxides of nitrogen available in air are nitrogen monoxide (NO) and nitrogen dioxide ($NO_2$).

Air Pollutants do not orginate from the same source. For example, particulates may escape to the air during road construction, from different factories and other human activities.

## ACTIVITY 4.4

In your group, discuss the sources of the following air pollutants and present your conclusion to the rest of the class.

a Sulphur dioxide ($SO_2$)

b Nitrogen oxides (NO and $NO_2$)

c Carbon monoxide (CO)

### 4.1.3 Effects of Air Pollutants

Air pollutants produce different effects on the environment. They can harm the lives of animals and plants directly or indirectly. Some air pollutants are responsible for acid rain, while others affect breathing, cause caughing and irritation to the lungs, bring about ozone depletion and many other effects.

## ACTIVITY 4.5

By reading different reference materials from your school library or any other sources, investigate in groups the effects of the following air pollutants.

a Sulphur dioxide ($SO_2$)
b Nitrogen oxides (NO and $NO_2$)
c Carbon monoxide (CO)

After completing your investigation, explain the effects of each air pollutant you discovered to the rest of the class.

## 4.1.4 Global Warming

***What is global warming? Can you tell what it is to your nearby friend?***

Carbon dioxide occurs in the air as a result of natural processes such as respiration, decay and decomposition of organic matter. Besides this, human activities that involve the combusion of mineral coal and petroleum have resulted in a significant increase in concentration of carbon dioxide in atmospheric air. Thus, this increase in the amount of carbon dioxide in atmospheric air resulted in global warming. Global warming is an increase in the average temperature of our planet.

***What is the relationship between amount of carbon dioxide in the atmosphere and global warming?***

Our planet, the earth, gets heat from radiation of the sun. The earth absorbs some part of the radiation from the sun and reflect some part of it back into space. However, certain gaseous substances in the upper atmosphere like carbon dioxide and water vapour, absorb the reflected radiation of heat from the earth, behaving like the glass in a green-house. Thus, carbon dioxide and water vapour are called ***green-house gases***. The absorption of the reflected radiation by carbon dioxide and water vapour is called the ***green-house effect***. This effect was essential for raising the temperature of the earth to a level where life is able to live. However, in the past few decades, there has been a significant increase in green-house gases, especially carbon dioxide, in the atmosphere, which has led to an enhanced green house effect. This situation is now resulting in global warming.

## ACTIVITY 4.6

Discuss in groups the following points and present your findings to the class.

1 What are the effects of global warming including Climate change, Melting polar caps, Rising sea levels ?
2 What are the effects of global warming
   a on the world as a whole?  b on Ethiopia?
3 What solutions do you recommend to overcome global warming?

## Exercise 4.1

**I** ***Write 'True' if the statement is correct and 'False' if it is wrong.***

1 The composition of atmospheric air is the same at all places in the world.

2 Global warming is caused by the increased amount of carbon dioxide in atmospheric air.

3 Nitrogen constitutes nearly 21% by volume of atmospheric air.

4 The green-house effect has no role in creating favourable condition for life on earth even when it is not enhanced.

5 Air pollutants have harmful effects on the lives of animals and plants.

**II** ***Answer the following questions.***

6 Why do we say air is a mixture?

7 What is the percentage of nitrogen, oxygen, argon and carbon dioxide in air?

8 Define air pollution and air pollutants; and give examples of air pollutants?

9 What human activities release sulphur dioxide, carbon monoxide and oxides of nitrogen to the atmosphere?

10 What are the effects of $SO_2$, CO and $NO_2$ when present in air?

11 What is global warming?

12 What are the causes and effects of global warming?

## 4.2 WATER

***After completing this section, you will be able to:***

- ✓ define hard water as a a water that does not form lather with soap;
- ✓ state soluble salts of calcium and magnesium as the causes of hardness of water;
- ✓ conduct an experiment to demonstrate the effect of hardness of water by taking rain water, tap water and ground water;
- ✓ describe boiling of water and adding washing soda as methods of softening hard water;
- ✓ perform an experiment to soften hard water by boiling and adding washing soda;
- ✓ describe the improper ways of disposing domestic and industrial wastes and excessive use of agricultural chemicals as the causes of water pollution;
- ✓ write a report on the causes, effects and prevention of water pollution;
- ✓ describe the physical, biological and chemical water treatments;
- ✓ conduct simple experiment to purify dirty water.

## 4.2.1 Hardness of Water

### ACTIVITY 4.7

Discuss on the following points in groups and share your idea with the class.

1 From what sources do people of your locality get water?

2 Do people of your locality prefer rain water or ground water for washing clothes with soap? What is the reason for their preference?

***Do you have any idea about soft water and hard water? How can water be either soft or hard?***

Softness of water and hardness of water is related to the ability of the water to form lather with soap.The water that forms a lather, readily with soap is **soft water**. When soap dissolves in soft water lather may form immediately. The water that doesn't readily form a lather with soap is called **hard water**. When soap dissolves in hard water, a lather may not form immediately. For a hard water to form a lather, enough soap must be dissolved in it. Hardness of water is caused by the presence of certain calcium and magnesium salts dissolved in it. Salts dissolve in water as rain water collects on the ground and flows through rocks such as limestone ($CaCO_3$) and dolomite ($CaCO_3.MgCO_3$).

Hard water doesn't form a lather more readily with soap due to the reaction of calcium ions ($Ca^{2+}$) and/or magnesium ions ($Mg^{2+}$) with the soap to form an insoluble scum. Hard water can form lather after the reaction between the ions and the soap is complete.

### Experiment 4.1

***Title: The Effect of Hardness of Water***

***Objective:*** To investigate the effect of hardness of water on the formation of a lather with soap.

***Materials required:*** Rain water, distilled water, ground water, soap, scissors, three test tubes and measuring cylinder.

***Procedure:***

1 Pour about 20 mL of rain water in the first test tube, 20 mL of distilled water in the second and 20 mL of ground water in the third test tube.

2 Cut pieces of soap with scissors and add into the water in each test tube.

3 Shake each of the test tubes by closing their mouth with your thumb turn by turn as shown in *Figure 4.1*

*Figure 4.1:* **Dissolving soap in water**

***Observation and analysis:***

a In which test tube does the water form a lather more rapidly?

b In which test tube does the water form a lather slowly?

c Which water sample is (i) soft water? (ii) hard water?

Write a laboratory report about your observation in groups and present your findings to the class.

**Is the hardness in all samples of hard water of the same type?** In reality it is not. Water hardness can be classified as temporary hardness and permanent hardness.

Temporary hardness of water is caused by the presence of dissolved calcium hydrogencarbonate, $Ca(HCO_3)_2$ and/or magnesium hydrogencarbonate, $Mg(HCO_3)_2$.

Permanent hardness of water is caused by dissolved calcium chloride, $CaCl_2$, magnesium chloride, $MgCl_2$, and/or sulphate of calcium, $CaSO_4$, and sulphate of magnesium, $MgSO_4$.

## ACTIVITY 4.8

Discuss in groups the formation of calcium hydrogencarbonate that causes temporary hardness by writing word equation and formula equation to each of the suggested steps.

Step 1: Rain water dissolves carbon dioxide to form carbonic acid.

Step 2: Carbonic acid reacts with limestone (calcium carbonate) to form calcium hydrogencarbonate.

## Experiment 4.2

***Title: Formation of Calcium Hydrogencarbonate***

***Objective:*** To observe the formation of calcium hydrogen carbonate by blowing carbon dioxide through lime water.

***Materials required:*** Conical flask, rubber stopper with one hole, beaker, glass tube (delivery tube), distilled water or rain water, graduated cylinder, test tube, calcium oxide or calcium hydroxide, and beam balance.

***Procedure:***

1 Measure 100 mL of distilled or rain water and pour it in to a beaker.

2 Dissolve about 6 - 8 g calcium oxide or calcium hydroxide to produce limewater.

3 Pour 100 mL of limewater into the conical flask, fit it with a rubber stopper to which a delivery tube is inserted.

4 Blow carbon dioxide through the delivery tube into the limewater until the clear solution turns milky (See *Figure 4.2*).

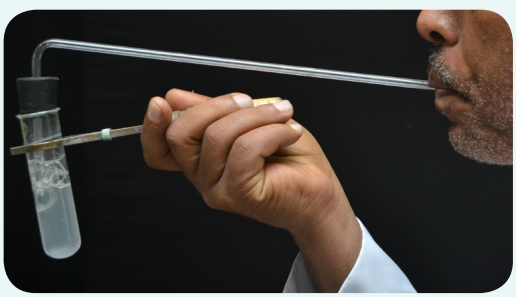


*Figure 4.2:* **Blowing $CO_2$ through lime water**

5 Continue blowing carbon dioxide gas until the milky solution becomes clear again.

6 Pour about 20 mL of the solution obtained in step 5 in a test tube, add a piece of soap and shake well. (Keep the remaining solution for experment 4.3).

***Observation and analysis:***

a Why did the solution in step 4 turn milky? Explain using chemical equation that represents the reaction.

b Why did the solution turn clear again in step 5? Explain using chemical equation that represents the reaction.

c Is the formation of lather in step 6 as rapid as it was in distilled or rain water? If not, what is the reason?

Write a laboratory report in groups and present your findings to the class.

## 4.2.2 Softening of Water

***Is it possible to remove hardness of water? How can this task be accomplished?***

The process of removing hardness of water is called **softening of water**. The process primarily involves the removal of calcium ions and/or magnesium ions from water that are the causes of hardness.

Temporary hardness can be removed by boiling. When temporary hard water is boiled, carbon dioxide gas is given off and the soluble calcium hydrogencarbonate ($Ca(HCO_3)_2$) is converted to insoluble solid calcium carbonate, $CaCO_3$. This can be shown using chemical equation as:

$$Ca(HCO_3)_2(aq) \xrightarrow{heat} CaCO_3(s) + CO_2(g) + H_2O(\ell)$$

### Experiment 4.3

***Title: Softening Temporary Hard Water***

***Objective:*** To investigate that boiling removes temporary hardness.

***Materials required:*** Temporary hard water, beaker, test tube, wire gauze, tripod, Bunsen burner and soap.

***Procedure:***

1 Take the temporary hard water you reserved after Experiment 4.2, and pour 50 mL of it in to a beaker and about 20 mL of it into a test tube.

2 Put the water in a beaker on a wire gauze placed on a tripod and heat it using a Bunsen burner flame until it boils.

3 Pour about 20 mL of the boiled water into an empty test tube.

4 Add a slice of soap into each of the test tubes containing boiled and cold water samples and shake well.

***Observation and analysis:***

a Which water sample forms lather with soap (i) slowly (ii) rapidly?

b What makes them differ in the duration of time they form lather?

Write a laboratory report in groups and submit it to your teacher.

When temporary hard water is boiled, the soluble calcium hydrogencarbonate changes to an insoluble solid calcium carbonate. The insoluble solid calcium carbonate settles down to the bottom of the material into which the water is boiled. It forms a layer on the interior surface called ***lime scale***. This layer is moslty formed in kettles, pans and boilers. The lime scale is a bad conductor of heat and wastes fuel.

## ACTIVITY 4.9

Read different chemistry reference books from your school library or any other sources about the formation of stalactites and stalagmites. Write a short note on the formations individually. Then, bring your notes and discuss in groups the information you gathered about the formation of stalactites and stalagmites. Finally, present your findings to the rest of the class.

### *Does boiling permanent hard water remove its hardness?*

## Experiment 4.4

***Title: Boiling Hard Water***

***Objective:*** To prove whether or not boiling removes permanent hardness of water.

***Materials required:*** Hard water, soap, two beakers, graduated cylinder, wire gauze, tripod, Bunsen burner, glass rod and match.

***Procedure:***

1 Measure and pour about 30 mL of hard water into each of the two beakers.

2 Place one of the two beakers on a wire gauze and heat it until the water boils using Bunsen burner flame.

3 When the water boils, stop heating and remove the beaker and place it on your working bench to the side of the beaker containing cold water.

4 Add a piece of soap, into the water in each beaker, stir using a glass rod and observe.

***Observation and analysis:***

a What did you observe when you dissolve soap in the water samples of the two beakers?

b Is there formation of an insoluble solid in step 4?

c What is your conclusion?

Write a laboratory report in groups and present your findings to the class.

Boiling doesn't remove permanent hardness of water. Whenever we dissolve soap into hard water, there is a formation of an insoluble solid called ***scum***.

***How can scum form when soap dissolves in hard water?*** Soap contains a compound called sodium stearate, $C_{17}H_{35}COONa$. When soap dissolves in water, it split apart into stearate ion, $C_{17}H_{35}COO^-$ and sodium ion, $Na^+$. The stearate ion reacts with calcium or magnesium ions in hard water to form scum. The ***scum*** is thus the result of formation of an insoluble ***calcium stearate*** or ***magnesium stearate***. For hard water containing calcium ions, the formation of scum is shown by the equation;

$$Ca^{2+}(aq) + 2C_{17}H_{35}COO^-(aq) \longrightarrow Ca(C_{17}H_{35}COO)_2(s)$$

Stearate ion Scum (Calcium stearate)

In order to remove permanent hardness, the calcium or magnesium ions must be removed by precipitation using washing soda or sodium carbonate, $Na_2CO_3$. Here precipitation refers to the formation of an insoluble solid substance that settles down to the bottom of the container.

When sodium carbonate, $Na_2CO_3$, dissolves in water, it splits apart into sodium, $Na^+$ ions and carbonate, ions $CO_3^{2-}$. The carbonate ions react with calcium or magnesium ions in hard water to form an insoluble calcium carbonate or magnesium carbonate. The precipitation of calcium ions from hard water by their reaction with carbonate ions is given by the following equation:

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3)(s)$$

## Experiment 4.5

***Title:*** ***Removing Permanent Hardness of Water***

***Objective:*** To prove that addition of sodium carbonate or washing soda removes permanent hardness of water.

***Material required:*** Hard water, graduated cylinder, two beakers, washing soda, soap, glass rod and spatula.

***Procedure:***

1 Measure and pour about 30 mL of hard water into each of the two beakers.

2 Add a spatula full sodium carbonate only in one of the beakers and stir until all the sodium carbonate dissolves.

3 Add pieces of soap into both beakers and stir.

***Observation and analysis:***

a What did you observe as sodium carbonate dissolve in the water in step 2?

b Did the two water samples form lather with soap at the same speed? If not, explain why this happened?

Write a laboratory report about your observations in groups and submit it to your teacher.

## 4.2.3 Water Pollution

***Water pollution*** is the decrease in the quality of water caused by the discharge of solid or liquid waste into it. Polluted water contains substances that affect the lives of animals and plants or damage property. These harmful substances that affect the lives of animals and plants are called ***water pollutants***. The major water pollutants are ***domestic wastes***, ***agricultural chemicals*** and ***industrial wastes***.

Domestic waste refers to solid or liquid materials we discharge into water of rivers, streams, lakes and oceans. The water (**sewage**) we discharge into water sources is not pure. For example, **sewage** that originate from washing clothes contain detergents and a variety of dirts.

### ACTIVITY 4.10

Discuss in groups and make a list of sources of wastewater from your homes. Present the list you made in your group to the rest of the class.

Other sources of water pollution include water run off from fields carrying fertilizers that have not been absorbed by plants together with other agricultural chemicals such as herbicides (weed killers) and pesticides which exist as residues on and in the soil. Thus, excessive use of chemical fertilizers in agriculture is one of the causes of water pollution. Industrial wastes such as liquid wastes from factories are other sources of water pollution. This liquid wastes from factories may contain acid residues, heavy metal ions and other harmful chemicals.

### ACTIVITY 4.11

In your group, investigate the effects of water pollution using the Internet or any other resources such as books from your school library, newspapers or science magazines. Choose only one aspect of water pollution; for example, domestic waste or agricultural chemicals or industrial wastes. Write a group report outlining:

- the causes and effects of water pollution, and
- how it can be controlled or prevented.

In your report, you may use the key words; sewage, eutrophication, effluent, acid rain, agricultral pollution and detergent pollution.

After completing your group report, present your report to the rest of the class.

## Field trip

Your teacher will arrange a field trip to enable you visit a local body of polluted water. During the visit, you should try to ascertain::

- the causes of pollution,
- the effects that the pollution have on the organisms living in the water and in the surrounding area.

Finally, write in groups a report about the causes, effects and a solution you suggest to overcome the problem of pollution. Present your group report to the rest of the class after the visit.

## Experiment 4.6

***Title: Analysing Sample of Polluted Water***

***Objective:*** To carry out a simple analysis of a sample of polluted water by comparing its properties with that of pure water such as pH, clarity, smell and amount of dissolved solids.

***Materials required:*** A bottle of polluted water, a bottle of pure water, pH indicator paper, two evaporating dishes, graduated cylinder and beam balance.

***Procedure:***

1. Compare the clarity and smell of the pure and polluted water and record your observation.
2. Insert a pH indicator paper into the sample of pure water and record the pH. Repeat the same procedure for the polluted water.
3. Weigh the evaporating dishes separately, record their masses and label them 1 and 2.
4. Pour 100 mL of pure water into the first evaporating dish and the same volume of polluted water into the second evaporating dish 2.
5. Place the two evaporating dishes in sunlight until all the water evaporates.
6. Weigh the two evaporating dishes after dryness and compare their masses with those you recorded in step 3. To get the mass of dissolved solids in each sample use the relation:

Mass of dissolved solid = Mass measured in step 6 − Mass measured in step 3

***Observation and analysis:***

a. Do the two water samples have the same clarity, smell and pH?

b. Which water sample contains a larger amount of dissolved solids?

Write a laboratory report in groups and submit it to your teacher.

## 4.2.4 Water Purification

### ACTIVITY 4.12

Discuss in groups on the following points and present your groups opinion to the rest of the class.

1 In your locality, do people get water from pipe lines, rivers, streams or wells?

2 If people of your locality get water from pipe lines, what water purification techniques does the water supply authority use? (you can consult a person from the authority to get information).

***Water purification*** is the removal of contaminants from untreated water to produce water that is pure enough for an intended use. ***Water treatment describes*** those processes used to make water fit for a desired use. These can include uses such as *drinking water, industrial process*, *medical* and many other.

Substances that are removed during the process of drinking water treatment include **suspended solids, bacteria, algae, viruses, fungi, minerals, sulphur** and other chemical pollutants such as **fertilizers**.

The treatments used in water purification are:

a Physical treatment

b Chemical treatment

c Biological treatment

**a** **Physical treatment** involves processes that are carried out causing no chemical or biological changes. The most common methods of physical treatment are **screening** and **filtration**.

**Screening** is a physical treatment method used to remove larger pieces of solid waste.

**Filtration** is also a physical treatment method mostly used to remove fine suspended particles. In this process, the water is passed through a filter medium to remove very small solid particles.

**b** **Chemical treatment** is the addition of chemicals to water to improve its quality. The most common chemical treatment methods are **chlorination** and addition of aluminium sulphate ($Al_2(SO_4)_3$).

**Chlorination** is the addition of chlorine to water to kill bacteria and other harmful micro-organisms.

Addition of aluminium sulphate causes chemical reactions to occur that form insoluble soilds. This helps to remove dissolved harmful substances and also to improve the clarity of water.

**c** **Biological Treatment** is a method that uses micro-organisms, mostly bacteria to decompose waste substances in water. Due to the action of bacteria,

the waste substance can be converted to carbon dioxide, water and other products. This method is moslty used in wastewater treatment. Physical and chemical treatments can be used to treat drinking water as well as wastewater.

### *Why is it necessary to treat wastewater or raw sewage before releasing it into lakes and rivers?*

A very good disposal of wastewater is dependent on its treatment prior to disposal. Adequate treatment is necessary to prevent contamination of receiving waters (lakes or rivers). Wastewater treatment consisits of applying known technology to imporve or upgrade the quality of wastewater. Most commonly, wastewater treatment will involve collecting the wastewater in a central, segregated location (The Wastewater Treatment Plant). Then, subjecting it to physical, chemical and biological treatments.

## Field trip

Your teacher will arrange a field trip for you to visit a local water treatment plant. During your visit to the plant, ask the expertise working at the plant to find out:

a the processes necesary to turn raw sewage into water that is safe to release into lakes or rivers, and

b the purpose of each process.

After your visit, write a report about the processes you observed at the plant and the purpose of each process. Present your report to the rest of the class.

## Project Work

1 Construct a model of water treatment plant in which water is filtered and chlorinated.

2 After you complete making the model plant, bring the model and a bottle of dirty water to your class.

3 Filter the dirty water using your plant, collect the filtered water and chlorinate it.

4 Test whether or not each of the procedures you used to purify the water, removed micro-organisms using agar gel plates to grow colonies of organisms.

(You should take one water sample after filtration only and another after chlorination). Write a report about what you discovered in groups and present it to the class.

## Exercise 4.2

**I** ***Write 'True' if the statement is correct and 'False' if it is wrong.***

1 Permanent hardness of water is removed by boiling.

2 Temporary hardness of water is caused by dissolved calcium and magnesium chorides or sulphates.

3 Soft water forms an insoluble solid called scum when soap dissolves in it.

4 Boiling temporary hard water changes the soluble calcium or magnesium hydrogencarbonates into insoluble calcium or magnesium carbonates.

5 Softening of water involves the removal of calcium and magnesium ions from hard water.

6 Physical treatment of water involves the removal of waste substances without causing chemical or biological changes.

7 It is not harmful to discharge wastewater or sewage into rivers and lakes without treatment.

8 Permanent hard water doesn't form a lather with soap due to the reaction of magnesium and/or calcium ions with soap.

9 Stalactites and stalagmites are formed in caves due to deposition of carbonates when temporary hard water evaporates.

10 Heating soft water in kettles, pans and boilers results in the formation of coating in their interior surfaces.

## II *Fill in the blanks with the appropriate words or phrases.*

11 Hardness of water is classified as _____ and _____.

12 The type of hardness of water that is removed by the addition of washing soda is_____.

13 Harmful substances which contaminate water are collectively called _____.

14 Treatments carried out in water purification are _____ , _____ and _____.

15 The process of removing calcium and magnesium ions from hard water is _____.

## III *Give short answer for each of the following questions.*

16 Explain how lime scale forms in kettles, pans and boilers.

17 When carbon dioxide is bubbled through lime water (calcium hydroxide solution), the solution first turns milky and then to colourless. Explain why these changes occur.

18 Explain how stalactites and stalagmites are formed.

19 What is the difference between permanent hardness and temporary hardness of water?

20 What treatments are carried out in water purification?

21 What are the sources of water pollutants?

22 Explain what is meant by

a sewage. b eutrophication. c effluent.

23 What are the effects of water pollution?

24 Explain how water pollution is prevented.

# 4.3 SOIL

***After completing this section, you should be able to:***

- ✓ define soil as a thin layer of natural material covering the surface of the earth;
- ✓ list the percentage composition of the solid, the liquid and the gaseous portions of soil;
- ✓ describe the composition of the solid, the liquid and the gaseous portions of the soil;
- ✓ conduct an experiment to show the compositon of soil;
- ✓ tell that the soil can be acidic, alkaline or neutral;
- ✓ list the major plant nutrients;
- ✓ explain methods of improving soil fertility;
- ✓ prepare ammonium nitrate;
- ✓ prepare compost in the school compound;
- ✓ apply the compost in the school garden;
- ✓ tell the type of soil that is favourable for crop production;
- ✓ Suggest some methods of correcting soil acidity and alkalinity.

## ACTIVITY 4.13

In your group, discuss the following points. When you complete, present your group's opinion to the rest of the class.

1 What are the parent materials from which soil is formed?

2 What process is responsible to the formation of soil?

3 Define soil?

## 4.3.1 The Solid, Liquid and Gas Components of Soil

Soil is the top layer of the earth in which plants grow. It is the growing medium for the growth of plants. The soil provides a plant with stability as well as, water and minerals essential for the growth of plants.

Soil consists of components existing in three physical states. These are the **solid component**, the **liquid component** and the **gas component.**

**The solid component of soil** consists of minerals and organic matter or humus. This component make up about 50% of the total soil volume.

**The liquid component of the soil** consist of water and dissolved minerals. It make up about 25% of the total volume of soil.

The **gas component** of the soil consists of air. The composition of soil air is 78% nitrogen, 21% oxygen and about 0.05% carbon dioxide by volume. The composition of soil air is nearly the same as that of atmospheric air. However, the percentage of carbon dioxide is slightly higher in soil air than that of atmospheric air.

## ACTIVITY 4.14

Discuss the following points in groups. When you complete, present your group's opinion to the rest of the class.

1 Why is the percentage of carbon dioxide higher in soil than that of atmospheric air?

2 Is the percentage of the liquid and the gas component of the soil the same when it is wet and dry? Why?

## Experiment 4.7

***Title: The Composition of Soil***

***Objective:*** To investigate the composition of soil and see the gradation of particles.

***Materials required:*** 400 mL beaker, water and soil

***Procedure:***

1 Half-fill the beaker with water.

2 Add some soil in the water and shake well.

3 Leave the soil and water mixture to stand for sometimes and observe.

***Observation and analysis:***

a Did you observe particles that settle to the bottom of the beaker?

b Did the largest or the finest particles sink to the bottom of the the beaker? In what order did they settle?

c Did you observe any component of the soil floating on the surface of the water? What is that?

Write a report about your observation in groups and present your findings to the rest of the class.

## Experiment 4.8

***Title: Characteristics of Soil***

***Objective:*** To investigate different characteristics such as water, air, humus content and particle size distirubiton of soil.

***Materials required:*** Soil, oven, tin lid, Bunsen burner, two graduated cylinders, water, two sieves of different hole size, test tube, beam balance, evaporating dish, wire gauze, tripod

***Procedure:***

1. Weigh an evaporating dish and record its mass.
2. Add soil to the evaporating dish until the mass of the soil is 100 g and record the total mass (Total mass = 100 g + mass of the dish).
3. Place the evaporating dish containing the soil in an oven at $100^0$C and wait for about 25 minutes.
4. Take the evaporating dish out of the oven, cool it, measure the total mass and record it.
5. Take a tin lid, measure the mass using a balance and record its mass.
6. Place the dry soil from step 4 on a tin lid until the mass of the soil is 20 g, place the tin lid on a wire gauze and heat it on a Bunsen burner flame for about 20 minutes. (Total mass = 20 g + mass of tin lid).
7. Put off the Bunsen burner flame, leave the tin lid for some time to cool, weigh the total mass of the tin lid and soil and record the mass.
8. Measure 50 mL of soil in one graduated cylinder and 50 mL of water with the other. Pour the water into the graduated cylinder containing the soil, wait for few minutes, read the total volume and record. (The soil you use in this procedure should not be heated).
9. Measure 100 mL of dry powdered soil (the soil should not be heated) and place it onto the sieve with larger holes, try to pass as much soil as you can through it. After that, place the soil that passed through this sieve onto the other with holes of smaller size. Try to pass the soil again through this sieve. Compare the size of particles left on the first and second sieves and those passed through the sieve of smaller-holes.
10. Take a test tube, add soil into it to one-half of its total volume. Pour water into the test tube and measure the time it takes for the water to reach the bottom of the test tube. That is from the start of pouring up to the time you see water reaching the bottom.

***Observation and analysis:***

a. What is the water content of the soil?

(Total mass in step 2 − Total mass in step 4)

b. What is the humus content of the soil? Calculate its percentage?

$$\left(\frac{\text{Total mass in step 6 - Total mass in step 7}}{20\text{ g}}\right)\times 100$$

c. What is the air content of the soil? (Volume of air = Total volume of soil and water before mixing - Total volume of water and soil after mixing.)

d. How do you describe the particles of the soil obtained in step 9.

e. What is the water retention of the soil? (The time recorded in step 10)

Write a laboratory report in groups and present your findings to the rest of the class.

## 4.3.2 Acidic and Alkaline Soil

***Is the soil at all places the same in nature? Can we grow the same crop on the soil at all places?***

The nature of soil depends on the material from which it is developed, the minerals it contains and many other factors. Naturally, a soil can be acidic, alkaline or neutral.

***How can we know whether or not a soil is acidic, alkaline or neutral?***

Acidity or alkalinity of a substance is measured interms of pH. pH is the measure of acidity or alkalinity of substances including soil. The pH of substances and that of soil depends on the concentrations of hydrogen ion, $H^+$, and that of hydroxide ion, $OH^-$.

For an acidic solution and soil the concentration of $H^+$ is greater than that of $OH^-$. For an alkaline solution and soil, the concentration of $H^+$ is smaller than that of hydroxide ion. A solution is said to be neutral when the concentration of hydrogen ion is equal to that of hydroxide ion. The acidity or alkalinity of solutions and soil is expressed interms of pH scale. The pH scale ranges between 0 and 14. pH is measured using pH indicator paper or pH meter.

For an acidic solution and soil, the pH is **less than 7,** for an alkaline solution and soil the pH is **greater than 7** and pH of a neutral solution and soil is **equal to 7**. However, it is unusual to find soil with pH values less than 3.5 and greater than 11. Generally, soils of humid regions are acidic, soils of arid regions are alkaline and regions where desert conditions predominate are neutral. All types of soil are not suitable to grow a specific crop plant. Each kind of plant can grow in a soil of specific pH range. Thus, pH of a soil is an important factor in determinig its suitability for growing different crops.

### Experiment 4.9

***Title: Determining pH of soil samples***

***Objective:*** To determine whether or not soil is acidic, alkaline or neutral by measuring its pH .

***Materials required:*** Different soil samples, water, funnels, two conical flasks, filter paper, two beakers, pH indicator paper and glass rod.

1. In your group, bring two soil samples from different localities.
2. Add some amount of one of the soil samples in the first beaker and the other in the second beaker.
3. Pour some amount of water in each beaker containing the soil samples and stir the mixture with glass rod.
4. Leave the mixtures to stand until the solid settles.
5. Soak filter paper into each of the funnels, place one funnel into the mouth of each conical flask and filter the mixture.
6. Take two pieces of pH indicator paper and insert one each into the filtrate in each of the flasks.

7 Compare the colours developed by the pH indicator papers with standard pH colour chart.

***Observation and analysis:***

a Is the colour developed by the pH indicator paper in the filtrates of both soil samples the same?

b What colour developed by the pH indicator in each conical flask?

c What is the pH of each soil sample?

Write a laboratory report about your observation in groups and present it to the rest of the class.

## 4.3.3 Plant Nutrients and Soil Improvement

### ACTIVITY 4.15

Discuss in groups on the following points. When you complete, present your group's opinion to the rest of the class.

1 What is a fertile soil?

2 Why do farmers add fertilizers to agricultural soil?

**Plant nutrients** are minerals required by plants for their growth and to stay healthy. Plants get these minerals from the soil. For a soil to produce good crop yield, it shoud contain all the necessary plant nutrients. In adition to this, the nutrients should be present in the soil in the amounts needed by plants. Plants do not need all the nutrients in the same amount for their growth. They require some nutrients in a large amount and others only in a very small amount.

## 4.3.4 Major Plant Nutrients

The major plant nutrients are the elements required by plants in large amounts. These elements are also called **macronutrients**. The major plant nutrients are **nitrogen, potassium**, **phosphorus, magnesium, calcium** and **sulphur**. The elements carbon, hydrogen and oxygen are also major plant nutrients. But, they are not considered as mineral nutrients. Because, they are obtained by plants from air and water.

### ACTIVITY 4.16

Refer diffent books from your school library or any other sources and write the importance of each of the major nutrients for the growth of plants.

a Nitrogen
b Potassium
c Phosphorus
d Magnesium
e Calcium
f Sulphur

When you complete, first discuss the findings of each student in your group. Then, choose one student from your group and present what you discussed to the rest of the class.

## 4.3.5 Methods of Improving Soil Fertility

A soil can be either fertile or infertile. A fertile soil contains the major plant nutrients as well as other elements required by plants in small amounts in sufficient quantitites. An infertile soil lacks some of the plant nutrients or may not contain them in sufficient quantities. When the plant nutrients are not present in sufficient quantities in a soil, it is very important to add **fertilizers** to improve its fertility.

Fertilizers are materials that are added to soils to increase the growth, crop yield and nutrient value of crops. Fertilizers are classified as **organic (natural) fertilizers** and **chemical** (**synthetic** or **artificial) fertilizers**.

**Organic (natural) fertilizers** are those derived from animals and plants. These include animal dung, urine and materials obtained from the decay and decomposition of plants residues such as leaves, roots, straw and stalks. **Green-manures** or **green-fertilizers** also belong to this group. These are plants cut down and decayed when they are still green for the purpose of imporving soil fertility. That is why they are named **green-fertilizers**.

### ACTIVITY 4.17

By asking farmers from your locality or other people, investigate the efectiveness of different types of dung as a fertiliser. These are the dung from:

a Cows
b Donkeys and horses
c Sheep and goats
d Pigs
e Chickens

**Chemical (synthetic or artificial) fertilizers** are those fertilizers manufactured by chemical industries. They are classified as **nitrogen, phosphorus** and **potash fertilizers**.

Some examples of chemical fertilizers are urea, $((NH_2)_2CO)$, diammonium phosphate, DAP, $((NH_4)_2HPO_4)$, ammonium nitrate $(NH_4NO_3)$, potassium sulphate $(K_2SO_4)$, ammonium sulphate $((NH_4)_2SO_4)$, etc.

In most cases, commercial fertilizers are complete fertilizers. They contain the three essential elements: nitrogen (N), phosphorus (P) and potassium (K). Thus, they are called NPK fertilizers. For exmaple, **NPK fertilizer** may be described as 6:6:6 indicating that it contains 6% of each element.

### Experiment 4.10

***Title: Preparation of Ammonium Nitrate***

***Objective:*** To prepare ammonium nitrate fertilizer by mixing equivalent amounts of ammonia and nitric acid.

***Materials required:*** Ammonia solution, dilute nitric acid, a beaker, a conical flask, graduated cylinder, phenolphthalein, dropper, evaporating dish, a burette, wire gauze, tripod, Bunsen burner, stand and clamp.

***Procedure:***

1 Measure 10 mL of ammonia solution, pour it into a conical flask and add few drops of phenolphalein using dropper.

2 Fix the a burette to the stand with a clamp as shown in *Figure 4.3*.

3 Pour dilute nitric acid into a beaker and then transfer it to the burette.

4 Place the conical flask containing ammonia solution below the burette, open the stop cock of the burette so that nitric acid can flow into the flask. Pour the acid slowly, shaking the concical flask until the colour of the solution in the flask disappears.

5 When the colour disappears, close the stop cock and transfer the solution in the flask into an evaporating dish.

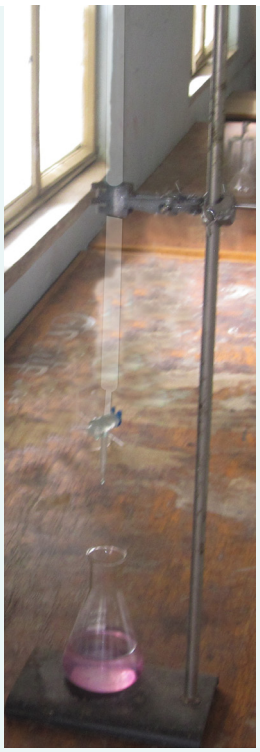


*Figure 4.3:* **Neutralizing ammonia with Nitric acid**

6 Put the evaporating dish on the wire gauze placed on the tripod and heat it gently on Bunsen burner flame to dryness (Do not heat it strongly) and observe.

**CAUTION!** ***1. Wear gloves and goggles while performing this experiment.***

***2. Avoid contact of ammonia and nitric acid with any of your body parts.***

***Observation and analysis:***

a What colour did you observe when you add phenolphthalein in step 1?

b What colour change did you observe in step 4?

c Is there any substance left in the evaporating dish when the solution was heated to dryness? What is that?

d Write a chemical equation to show the reaction that took place in this experiment.

e Write a laboratory report in groups and submit it to your teacher.

## ACTIVITY 4.18

Discuss in groups on the following points. When you complete, present your group's opinion to the rest of the class.

1 What are the advantages and disadvantages of organic fertilizers and chemical fertilizers in relation to their:

a speed to supply plant nutrients?

b effects on the soil?

c effects on water pollution?

## Project Work

You should consult experts from agricultural development agencies of your locality to do this project work. During your discussion with the expert, you should investigate:

- the materials required to produce compost;
- the importance of ensuring aeration of compost;
- why it is important to water the compost and
- the function of compost accelerators.

Based on the information you gathered, prepare compost in groups and apply it in your school garden.

### 4.3.6 Acidity and Alkalinity

Acidity and alkalinity of soil is associated with the amount of hydrogen ion, $H^+$, and that of hydroxide ion, $OH^-$, concentration. Acidic soils contain greater amount of $H^+$ than $OH^-$. Alkaline soil contain a higher amount of $OH^-$ than $H^+$ ions and neutral soil contains equal amounts of $H^+$ and $OH^-$.

Since acidity and alkalinity of a soil is expressed interms of pH, the higher the amount of hydrogen ions in a soil, the lower is its pH and the more acidic it will be. On the contrary, the higher the concentration of hydroxide ions in the soil, the higher its pH and the more basic it will be.

Different crops require different nutrients in different proportions and as a consequence, each crop grows best in soil within a particular pH range. *Table 4.1* shows the pH range of soil suitable for the growth of some crops.

*Table 4.1* **pH range of soil suitable for the growth of some crop.**

| Crop | pH range |
|---|---|
| Potatoes | 5.5 - 6.5 |
| Oats | 5.5 - 7.0 |
| Beans | 6.0 - 7.5 |

## Activity 4.19

Read different reference materials from your school library or any other sources and find the best pH range of soil for growing the following crops.

Discuss in groups and present your findings to the rest of the class.

a Barley b Wheat c Sorghum d Maize

The decay and decomposition of organic materials such as leaves, animal wastes, etc, produce organic acid in the soil. This situation in turn increases the acidity of the soil, and lower the soil pH. When the condition continues over years, the soil naturally becomes more and more acidic.

In order to prepare an acidic soil to produce good yield of a specific crop, it is necessary to adjust its pH to a pH range suitable for the growth of the plant.

The acidity of a soil can be reduced or its pH can be raised by spreading limestone ($CaCO_3$), quick lime (CaO) or slaked lime, $Ca(OH)_2$. However, the amount of limestone, quick lime or slaked lime that should be added to the soil depends on the acidity of the soil. The more acidic the soil is, the higher the amount of limestone, quick lime or slaked lime that will be added to it.

## ACTIVITY 4.20

Discuss in groups and share your group's opinion with the rest of the class.

Suppose that the pH values of soils of two farm places A and B are 3 and 4, respectively.

1 The soil of which farm place is more acidic?

2 If both owners of the farm places want to raise the pH of their farm soil to 5, the owner of which farm place should add (a) more lime to the soil (b) less lime to the soil?

## Experiment 4.11

***Title:*** ***Preparation of slaked lime***

***Objective:*** To prepare slaked lime from quick lime obtained by heating limestone.

***Materials required:*** Limestone, crucible, beam balance, water, wire gauze, tripod, litmus, beaker, Bunsen burner, tong

***Procedure:***

1 Weigh 10 g limestone and add it to a crucible.

2 Put the crucible on the wire gauze placed on the tripod and heat it for about 20 minutes with Bunsen burner flame.

3 Put off the flame and leave the crucible to cool on the gauze.

4 After few minutes, hold the crucible with a tong and transfer the heated substance into a beaker.

5 Add water into the beaker, shake well and test the solution using blue and red litmus papers and observe if there is any colour change.

***Observation and analysis:***

a To what substances does the limestone change up on heating? Write a chemical equation representing the change.

b What substance was formed when the compound obtained after heating limestone is dissolved in water? Show what has happened by writing an equation.

c Does the red or blue litmus show colour change in procedure 5? What does this change show?

Write a laboratory report in groups and present your observation to the rest of the class.

***How can the addition of limestone ($CaCO_3$), quick lime (CaO) or slaked lime ($Ca(OH)_2$) decrease the acidity of soil or increase its pH?***

In unit 1, you have learned that acidity is associated with the presence of hydrogen ion, $H^+$. The same is true for soil acidity. Thus, to reduce soil acidity or to increase its pH, it is important to decrease the amount of hydrogen ions in the soil. This is usually achieved by adding $CaCO_3$, CaO or $Ca(OH)_2$. When these substances are added to the soil, they react with water in the soil. The reaction releases hydroxide ion, $OH^-$, in the soil. So, the hydroxide ion, $OH^-$, in turn reacts with $H^+$ present in the soil to form water. As a result, the amount of $H^+$ decreases and the pH of the soil increases.

## ACTIVITY 4.21

Read different reference books from your school library or any other sources to see how it is possible to increase the acidity of soil or reduce its pH by using;

a Sulphur b Irrigation

Discuss the information you collected first in your group and then present your group's opinion to the rest of the class.

## Exercise 4.3

### I *Write 'True' if the statement is correct and 'False' if it is wrong.*

1 Soil is a thin layer of natural material covering the surface of the earth.

2 Soil consists of only solid component.

3 A neutral soil contains equal concentration of $H^+$ and $OH^-$.

4 A soil can be acidic, alkaline or neutral in nature.

5 A soil with pH = 5 is more basic than a soil with pH = 7.

6 The higher the concentration of $H^+$ in a soil, the higher is its pH.

7 Crops can grow best in a soil of any pH range.

8 One of the disadvantages of chemical fertilizers is that their excessive use causes water pollution.

9 Animal dung and green fertilizers are synthetic fertilizers.

10 NPK fertiliser contains all the major plant nutrients (elements).

### II *Give short answer for each of the following questions.*

11 What is the percentage of the solid, liquid and gaseous portions of the soil?

12 What are the constituents of the solid, liquid and gaseous portions of soil?

13 Which elements are considered as major plant nutrients?

14 What methods are useful to improve soil fertility?

# 4.4 FUELS

***After completing this section, you will be able to:***

- ✓ define fuel as a substance which releases heat energy when it is burnt (combusted);
- ✓ describe elemental composition of coal, natural gas and crude oil;
- ✓ explain uses of coal, natural gas and crude oil.

## 4.4.1 Coal, Natural Gas and Crude Oil

### ACTIVITY 4.22

Discuss the following points in groups. When you complete, present your group's opinion to the rest of the class.

1 In your locality, what materials do peoples use to get energy to:

a cook their foods? b derive their cars?

2 What do you call these materials?

There are a variety of solid, liquid and gaseous substances that serve as sources of energy. Some examples are wood, charcoal, kerosene, bottled gas, mineral coal, etc.

These substances are called fuels. **Fuel** is any substance that is capable of burning to produce heat energy and light.

C***oal, natural gas*** and ***crude*** oil are the major sources of energy. They are collectively called ***fossil fuels***.

**Coal** is a rock like material or solid formed by the slow decomposition of plant remains for several millions of years in the absence of air.

**Crude oil** and **natural gas** are formed by the decay of huge deposits of plant and animal remains in the sea for about some hundred millions of years in the absence of air.

## 4.4.2 Composition of Coal, Crude Oil and Natural Gas

**Coal** is an impure form of carbon. It consists of carbon, moisture, volatile organic compounds and sulphur compounds.

***Do you remember what hydrocarbons are from the lessons you have learnt in Unit 1? What are the principal sources of hydrocarbons?***

***Natural gas*** and ***crude oil*** are mixtures of hydrocarbons. ***Natural gas*** consists of mainly ***methane*** (about 90%) and small proportions of other gases such as ethane, higher alkanes and carbon dioxide. ***Crude oil*** consists of many different small and complex hydrocarbons.

## ACTIVITY 4.23

Refer different books from your school library or any other sources individually to identify those areas of the world where large deposits of fossil fuels are found. Your work should indicate the areas of:

a Coal b Crude oil c Natural gas.

You can locate the areas using a map. After you complete your work, first discuss in groups and present your group's findings to the rest of the class. Finally, submit your individual work to your teacher.

The presence of deposits of crude oil, natural gas and coal is proved in different parts of Ethiopia. For example, deposits of natural gas and crude oil are discovered in Somali and Gambella regions. Where as deposits of coal are found in Oromia Regional State (Wollega) and Amhara Regional State (around Chilga).

### 4.4.3 Uses of Coal, Natural Gas and Crude Oil

#### Coal

Coal is a solid fuel. It can be used as domestic and industrial fuel. Relatively larger pieces of coal are used as domestic fuel. Coal is used as a fuel in power stations after it is powdered (pulverized) into fine dust. This makes it easier to move within the power stations and ensures a more efficient combustion. Coal can be converted into another type of fuel called **coke** by destructive distillation or coking of coal that involves heating coal in the absence of air. When coal is destructively distilled, it gives **coke, ammonical liquor, coal tar** and **coal gas**.

Coke is used in the manufacture of iron and other metals. It is also used to produce gaseous fuels. Ammonical liquor is used to produce fertilizers, coal tar is used as a source of organic compounds and coal gas is used as fuel.

## ACTIVITY 4.24

Form a group. In your group, discuss the environmental problems associated with burning of coal giving emphasis to the effects of;

a incomplete combustion of coal to carbon monoxide.

b oxidation of sulphur or sulphur compounds present in coal to form acidic sulphur dioxide.

Fossil fuels contain some amount of sulphur or sulphur compounds. Although, refining processes are carried out to remove sulphur and sulphur compounds prior to their use, some will remain in the fuels. During combustion of these fossil fuels, sulphur and sulphur compounds oxidize to form **sulphur dioxide**. This oxide is air pollutant and one of the causes of ***acid rain***. So, it is important to remove this oxide from exhaust gases or flue gases of power stations.

**Flue-gas desulphurisation (FGD)** is a set of technologies used to remove sulphur dioxide ($SO_2$) from exhaust flue gases of fossil fuel power plants. For example, in a typical coal-fired power station, flue-gas desulphurisation will remove 95% or more of the $SO_2$ in the flue gas.

## Natural Gas

Natural gas is a fossil fuel. It is found in underground deposits in nature. It consists of mainly methane and small amounts of ethane, propane, butane and carbon dioxide. It can be transported from place to place along pipes.

### ACTIVITY 4.25

Form a group. In your group, discuss on the following points. When you complete, present your group's opinion to the rest of the class.

What is the importance of natural gas as a;

a domestic fuel ? b industrial fuel?

## Crude Oil

It is a complex mixture of many different hydrocarbons. It can not be used as a fuel in the form in which it appears out of the ground.

The crude oil must undergo a number of different processes such as removing impurities like sulphur compounds and others. The process of removing, impurities from crude oil and separating it, into different fractions is called **refining of crude oil**. Crude oil is separated into different fuels and other useful products by a process called **fractional distillation**. The different fuels and other products are separated based on their differences in boiling point range. *Table 4.2* shows some of the fuels and other products obtained by fractional distillation of crude oil.

*Table 4.2* **Some Petroleum Products.**

| Fraction | Boiling point range ( °C) |
|---|---|
| Bottled gas | below 30 |
| Gasoline (petrol) | 30 - 200 |
| Kerosene | 175 - 275 |
| Fuel oils | 250 - 400 |
| Lubricating oils | >350 |
| Bitumen | 400 |

The term ***petroleum*** is often used to describe the products obtained after refining crude oil.

## ACTIVITY 4.26

Refer to different chemistry books from your school library or any other sources and find out the uses of the different petroleum products listed in *Table 4.2*, individually. After you complete, first discuss your individual work in groups. Then, select one student from your group and present your group's opinion to the rest of the class. Submit your individual work to your teacher.

As mentioned above, refining crude oil includes the removal of sulphur compounds from it. The importance of removing sulphur compounds from the fuels is to prevent the formation of sulphur dioxide when the fuels are burnt in engines. This situation reduces the emission of $SO_2$ and decreases air pollution when the exhaust gases are released into the atmosphere.

## Exercise 4.4

Give short answer to each questions.

1 Define the term fuel.

2 What is meant by fossil fuels?

3 Explain the formation of coal, natural gas and crude oil?

4 What are the principal consitituent elements of coal, crude oil and natual gas?

5 Explain the uses of coal, natural gas and crude oil.

6 What is meant by flue-gas desulphurisation? What is its importance?

# Unit Review

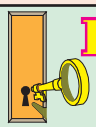
## Check List

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

| № | Can I | Yes | No |
|---|---|---|---|
| 1 | describe the percentage of nitrogen, oxygen and carbon dioxide in the air? | | |
| 2 | list air pollutants? | | |
| 3 | discuss sources of $SO_2$, CO and $NO_x$ (NO, $NO_2$)? | | |
| 4 | explain effects of $SO_2$, CO and $NO_2$ in the air? | | |
| 5 | define global warming? | | |
| 6 | discuss the causes of global warming? | | |
| 7 | discuss the effects of global warming? | | |
| 8 | define hard water as a a water that does not form lather with soap? | | |
| 9 | state soluble salts of calcium and magnesium as the causes of hardness of water? | | |
| 10 | conduct an experiment to demonstrate the effect of hardness of water by taking rain water, tap water and ground water? | | |
| 11 | describe boiling of water and adding washing soda as methods of softening hard water? | | |
| 12 | perform an experiment to soften hard water by boiling and adding washing soda? | | |
| 13 | describe the improper ways of disposing domestic and industrial wastes and excessive use of agricultural chemicals as the causes of water pollution? | | |
| 14 | write a report on the causes, effects and prevention of water pollution? | | |
| 15 | describe the physical, biological and chemical water treatments? | | |
| 16 | conduct simple experiment to purify dirty water? | | |
| 17 | define soil as a thin layer of natural material covering the surface of the earth? | | |
| 18 | list the percentage composition of the solid, the liquid and the gaseous portions of soil? | | |
| 19 | describe the composition of the solid, the liquid and the gaseous portions of the soil? | | |

| | | | |
|---|---|---|---|
| 20 | conduct an experiment to show the compositon of soil? | | |
| 21 | tell that the soil can be acidic, alkaline or neutral? | | |
| 22 | list the major plant nutrients? | | |
| 23 | explain methods of improving soil fertility? | | |
| 24 | prepare ammonium nitrate? | | |
| 25 | prepare compost in the school compound? | | |
| 26 | apply the compost in the school garden? | | |
| 27 | tell the type of soil that is favourable for crop production? | | |
| 28 | Suggest some methods of correcting soil acidity and alkalinity? | | |
| 29 | define fuel as a substance which releases heat energy when it is burnt (combusted)? | | |
| 30 | describe elemental composition of coal, natural gas and crude oil? | | |
| 31 | explain uses of coal, natural gas and crude oil? | | |



## Key Terms

- Acid rain
- Acidic soil
- Agricultural chemicals
- Air
- Air pollutant
- Air pollution
- Alkaline Soil
- Asphyxia
- Biological treatment
- Chemical fertilizer
- Chemical treatment
- Chlorination
- Coal
- Coke
- Crude oil
- Detergent
- Domestic waste
- Effluent
- Fertiliser
- Filtration
- Flue-gas sulphurization
- Fractional distillation
- Fuel
- Global warming
- Green house effect
- Hydrocarbons
- Industrial waste
- Natural (organic) fertiliser
- Natural gas
- Neutral soil
- Permanent hard water
- Petroleum
- pH
- Physical treatment
- Plant nutrients
- Screening
- Scum
- Sewage
- Sodium stearate
- Soft water
- Softening of water
- Soil
- Stalacties
- Stalagmites
- Temporary hard water
- Washing soda
- Water pollutant
- Water pollution
- Water purification
- Water treatment

## UNIT SUMMARY

- ✓ Atmospheric air is a mixture of different gases. It consists of 78% nitrogen, 21% oxygen, 1% argon and 0.04% carbon dioxide.
- ✓ Air pollution is the contamination of atmospheric air caused by gaseous and tiny solid substances entering into it.
- ✓ Air pollutants are substances that enter into atmospheric air and cause harmful effects on the lives of animals and plants.
- ✓ Air pollutants originate from combustion of fossil fuels and many other human activities such as metal extraction, construction, etc.
- ✓ Global warming is an increase in the average temperature of the earth due to an enhanced green house effect.
- ✓ Global warming is caused by an increase in the amount of carbon dioxide in atmospheric air.
- ✓ The effects of global warming are climate change, melting of polar ice caps, rising of sea and ocean water levels.
- ✓ Soft water is the water that forms a lather immediately when soap is dissolved in it.
- ✓ Hard water is the water that doesn't form a lather rapidly when soap is dissolved in it.
- ✓ Hardness of water is caused by dissolved calcium and/or magnesium compounds.
- ✓ Temporary hardness of water is caused by dissolved calcium and/or magnesium hydrogencarbonates (bicarbonates).
- ✓ Permanent hardness of water is caused by dissolved calcium and/or magnesium chlorides and/or sulphates.
- ✓ The process of removing calcium and magnesium ions from hard water is called softening of water.
- ✓ Temporary hardness of water is removed by boiling.
- ✓ Permanent hardness of water is removed by adding washing soda (sodium carbonate).
- ✓ Water pollution refers to the process by which substances that harm the lives of animals, and plants or bring about damage to property when they enter into water bodies.
- ✓ Substances that cause harmful effects on animals and plants when entering into water bodies are called water pollutants.
- ✓ The major water pollutants are domestic wastes, agricultural chemicals and industrial wastes.
- ✓ Water purification is the process of removing contaminants from water.
- ✓ Water purification involves physical treatment, chemical treatment and biological treatment.
- ✓ Soil is a thin layer of natural material covering the surface of the earth.

- ✓ Soil consists of solid component (50%), liquid component (25%) and gas component (25%).
- ✓ Naturally soil can be acidic, basic (alkaline) and neutral.
- ✓ Acidity and alkalinity of soil is expressed in terms of pH.
- ✓ The pH of acidic soil is less than 7, that of alkaline soil is greater than 7 and pH of a neutral soil is 7.
- ✓ Plant nutrients are minerals required for the growth of plants.
- ✓ The major plant nutrients are nitrogen, postassium, phosphorus, calcium, magnesium and sulphur.
- ✓ Soil fertility is improved by the addition of fertilizers and adjusting its pH to make it suitable for the growth of a specific crop.
- ✓ Fertilizers are substances that can be added to the soil to improve its fertility, growth of crop and yield.
- ✓ Fertilizers are classified as: natural (organic) and chemical (artificial or synthetic) fertilizers.
- ✓ Every crop grows best in a soil within a particular pH range.
- ✓ Soil acidity is reduced or its pH increased by the addition of limestone, quick lime or slaked lime.
- ✓ Fuel is any substance which is capable of burning to release heat and light energy.
- ✓ Coal, natural gas and crude oil are collectively called fossil fuels.
- ✓ Coal is formed by the decay of plant remains in the absence of air for hundred millions of years.
- ✓ Natural gas and crude oil are formed by the slow decomposition of huge deposits of animal and plant remians in the absence of air for some hundred millions of years.
- ✓ Coal is used as a solid fuel for domestic or industrial energy source.
- ✓ Natural gas is a gaseous fuel used at home or in industries consisting of mainly methane.
- ✓ Crude oil is a mixture of hydrocarbons that can be separated into different petroleum fractions used as a fuel or other purposes.

## REVIEW EXERCISE ON UNIT 4

***Choose the correct answer from the given alternatives for each of the following questions.***

1 The air pollutant that leads to asphyxia when absorbed into the blood is:

A carbon monoxide
C carbon dioxide
B sulphur dioxide
D nitrogen

2 Tiny solid particles that pollute atmospheric air are collectively called:

A nitrogen oxides
C oxides
B particulates
D green-house gases

3 Which one of the following is not the effect of global warming?

A Climate change.

B Melting of polar ice capes.

C Rising of sea and ocean water levels.

D Creating more favourable conditions for life.

4 Which pair of gaseous substances is responsible for acid-rain?

A Carbon monoxide and nitrogen monoxide.

B Carbon dioxide and water vapour.

C Sulphur dioxide and nitrogen dioxide.

D Nitrogen and argon.

5 Which gas is considered as a green-house gas?

A Carbon dioxide

B Sulphur dioxide

C Carbon monoxide

D Oxygen

6 One of the following is a chemical water treatment method. Which one is it?

A Screening

B Filtration

C Chlorination

D Bacterial decomposition

7 The formation of scum when soap dissolves in hard water is due to the reaction of stearate ion of the soap with:

A hydrogen carbonate ion

B calcium and/or magnesium ions

C carbonate ions

D sodium ions

8 The presence of which compound in water causes temporary hardness?

A Magnesium sulphate

B Calcium chloride

C Magnesium hydrogencarbonate

D Calcium sulphate

9 Which one of the following hard water containing compounds can be softened by boiling?

A Calcium hydrogencarbonate

B Calcium sulphate

C Magnesium chloride

D Calcium chloride

10 Softness and hardness of water is related to its ability to:

A form scum with soap

B form lather with soap

C be used for drinking.

D be absorbed by plants.

11 When carbon dioxide is bubbled through lime water, it turns milky due to the formation of

A calcium hydrogencarbonate.
B magnesium chloride.
C calcium carbonate.
D calcium hydroxide.

12 The chemical that should be added to remove permanent hardness of water is

A soap.
B calcium carbonate.
C sodium carbonate.
D carbon dioxide.

13 A very good example of soft water is

A distilled water.
B sea water.
C underground water.
D polluted water.

14 A water treatment method that uses bacteria to decompose waste substances is

A physical treatment.
B biological treatment.
C chemical treatment.
D screening.

15 The percentage of the solid component of soil is

A 5%
B 25%
C 50%
D 75%

16 Which one of the following is not a major plant nutrient?

A Nitrogen
B Iron
C Sulphur
D Phosphorus

17 50 mL of soil was mixed with 50 mL of water. If the total volume of the mixture is found to be 77 mL, what would the volume of air in the soil?

A 23%
B 50%
C 25%
D 75%

18 The substance that can not be added to soil to reduce its acidity is

A $CaCO_3$
B CaO
C $Ca(OH)_2$
D $NH_4NO_3$

19 NPK fertiliser is the one containing the major plant nutrients:

A nitrogen, potassium and calcium.
B nitrogen, phosphorus and sulphur.
C nitrogen, potassium and magnesium.
D nitrogen, phosporus and potassium.

20 Which of the following is not a fossil fuel?

A Charcoal
B Petroleum
C Coal
D Natural gas

21 Crude oil is separated into different components by:

A filtration.
B decantation.
C fractional distillation.
D destructive distillation.

22 The major consituent elements of petroleum are:

A nitrogen and phosphorus
B carbon and hydrogen
C carbon and sulphur
D sulphur and phosphorus.

23 The method of removing sulphur dioxide from exhaust gases is known as:

A destructive distillation.
B fractional distillation.
C screening.
D flue-gas desulphurisation.

24 Which product is not obtained during the separation of crude oil into different components?

A Ammonical liquor
B Bitumen
C Bottled gas
D Kerosene

25 The solid fuel that can be obtained by destructive distillation of coal is:

A lubricating oil
B coke
C coal tar
D charcoal

26 One of the following is not the effect of acid rain. Which one is it?

A Lowering the pH of water of rivers and lakes.
B Tree defoliation.
C Erosion of buildings.
D Improving the crop producing potential of soil.

# UNIT 5

# CALCULATIONS BASED ON FORMULAS

$$\% \text{ composition} = \frac{\text{Mass of element in the compound}}{\text{Formula (molar) mass of a compound}} \times 100$$

## MAIN CONTENTS



## UNIT OUTCOMES

***After completing this unit, you will be able to:***

- ✓ Understand atomic mass, molecular mass, formula mass, the concept of mole, molar mass, percentage composition of compounds, empirical formula and molecular formula;
- ✓ Know how to determine molecular mass or formula mass from a given atomic mass of elements;
- ✓ Know how to determine percentage composition, empirical formula and molecular formula of a compound;
- ✓ Demonstrate scientific inquiry skills along this unit: observing, classifying, comparing and contrasting, communicating, asking questions, designing experiments, drawing conclusions, applying concepts and problem- solving.

## START-UP ACTIVITY

Discuss the following points in groups. When you complete, select one student and present your group's opinion to the rest of the class.

1. Can you determine what the mass of a single "Teff" seed is by putting it on the pan of a balance?
2. Counting the number of "Teff" seeds in one 'quintal' may take some years. But it is possible to count the number of seeds in 1.0 g in a day or some hours. If we know the number of seeds in one gram of 'Teff; how can we calculate:
   a. the mass of a single "Teff" seed?
   b. the approximate number of "Teff" seeds in one quintal (1 quintal = 100 kg)?
3. Atoms and molecules are so small compared to "Teff" seed. Then, how can the mass of atoms and molecules be determined?
4. How do you associate the number of seeds in a 'quintal' of "Teff" to the number of particles in one mole?

## HISTORICAL NOTE

**Amedo Avogadro (1776-1856)**

Amedeo Avogadro (1776 - 1856). He was born and died in Turin, Italy. Amedeo Avogadro was born into a family of distinguished lawyers. Following in his family's footsteps, he graduated in ecclesiastical law (age 20) and began to practice law. However, Avogadro also was interested in the natural sciences and in 1800 he began private studies in physics and mathematics. Avogadro wrote a memoria (concise note) in which he declared the hypothesis that is now known as Avogadro's law. Avogadro believed that particles could be composed of molecules and that molecules could be composed of still simpler units, atoms. The number of molecules in a mole was termed Avogadro's number (sometimes called Avogadro's constant) in honor of Avogadro's theories. Avogadro's number has been experimentally determined to be $6.023 \times 10^{23}$ molecules per gram-mole.

## 5.1 INTRODUCTION

***After completing this section, you will be able to:***

- ✓ describe what information a chemical formula of a compound can provide.

***Do you recall what you have learnt in Grade 7 about chemical formulas? What does a chemical formula represent?***

***A chemical formula*** is a short hand representation of the composition of a molecule or a compound. It can be a combination of chemical symbols and numbers. A chemical formula of a compound always contains chemical symbols of two or more different elements.

### *What information does a chemical formula of a compound provide?*

A chemical formula of a compound provides information about:

a what the compound is.

b the types of elements that make up the compound.

c the proportion by which atoms of the constituent elements combined to form the compound interms of number of atoms or interms of mass of each element.

d what the molecular mass or formula mass of the compound would be.

For example, the chemical formula; NaCl:

a represents the compound sodium chloride.

b tells that the compound is formed from the combination of sodium and chlorine.

c indicates that the ratio of atoms of sodium to chlorine is 1:1 or the mass ratio of sodium to chlorine is 23:35.5.

d tells the formula mass of sodium chloride to be 58.5 a.m.u or its molar mass 58.5 g.

The information that we get from a chemical formula enables us to carry out different calculations. These calculations may include determining molecular mass, formula mass, molar mass and the percentage by mass of each element in the compound. In addition to this, we can also get information about how much of the compound is used up in a particular reaction from the equation representing the reaction.

## ACTIVITY 5.1

Discuss the following points in groups. After you complete, present your group's conclusion to the rest of the class.

Explain what information each of the following formulas of compounds can provide.

a $H_2O$ b CaO c $C_6H_{12}O_6$

## Exercise 5.1

1 From the following list, identify those which are chemical formulas of compounds.

a $P_4$ c $O_3$ e $CaCO_3$ g $CuSO_4$

b $CO_2$ d $HNO_3$ f $H_2$ h $NH_4Cl$

2 Do the chemical formulas NO, $NO_2$ and $N_2O$ provide the same information in all aspects? Explain.

# 5.2 ATOMIC MASS, MOLECULAR MASS AND FORMULA MASS

***After completing this section, you will be able to:***

- ✓ describe atomic mass;
- ✓ define the terms molecular mass and formula mass;
- ✓ describe the steps of calculating molecular mass and formula mass;
- ✓ calculate molecular mass and formula mass using formula of a compound and atomic masses.

## 5.2.1 Atomic Mass

### ACTIVITY 5.2

Discuss the following points in groups. When you complete, present your group's opinion to the rest of the class.

1. Recall what you have learnt in Grade 7 Unit 4 about atomic structure. Based on what you know, suggest from what the mass of an atom arises?
2. What numerical information can you get about an element in the box where its symbol is found on the periodic table?

In Grade 7, you have learnt that an atom is the smallest neutral particle of an element. Since an atom is very small, its actual mass is also too small. For example, the mass of one atom of oxygen is $2.657 \times 10^{-23}$ g while the mass of one atom of carbon is $2.0 \times 10^{-23}$ g. These very small atomic masses are incovenient for use in chemical calculations. Because of this incovenience, the actual (real) atomic mass is replaced by ***relative atomic mass***. Relative atomic masses of all other atoms have been determined in relation to a defined standard. The ***carbon -12*** atom has been chosen as a standard by the international organization of scientists. A single atom of carbon-12 is arbitrarily assigned a mass of ***12 atomic mass units***. The ***atomic mass unit*** is symbolized by ***a.m.u. One atomic mass unit*** is exactly $\frac{1}{12}$ the mass of a carbon -12 atom. ***The mass of an atom expressed in atomic mass unit is the atomic mass of the atom***. Due to the very small size of atoms, atomic masses are not measured in grams or kilograms, but in atomic mass units. Conventionally, scientists do not assign a unit to atomic masses, molecular masses or formula masses.

### ACTIVITY 5.3

Discuss the following points in groups. After the discussion, present your group's findings to the rest of the class.

1. Using the information given in a periodic table, find the atomic masses of elements whose atomic numbers are 3 to 18.
2. Are the atomic masses of all these elements whole numbers? If not, explain why this happened?
3. Do all atoms of the same element have equal mass? Explain.

Most elements occur naturally as mixtures of isotopes. The percentage of each isotope in the naturally occurring element is nearly always the same, no matter where the element is found. Atomic masses for the elements, which are included in the periodic table are average for those naturally occuring mixtures of isotopes.

***Average atomic mass is the weighted average of the atomic masses of the naturally occurring isotopes*** of an element. Calculation of average atomic mass depends on the mass and the relative abundance of each isotope.

Example 5.1

Naturally occurring copper consists of two isotopes with atomic mass of 63 a.m.u and 65 a.m.u which have a relative abundance of 69.17% and 30.83%, respectively. What is the average atomic mass of copper?

*Solution:*

To calculate the average atomic mass of copper, multiply the mass of each isotope by its relative abundance and add the products. Thus;

$$\text{Average atomic mass of copper} = \left(63 \times \frac{69.17}{100}\right) + \left(65 \times \frac{30.83}{100}\right)$$

$$= 43.577 + 20.03 = \mathbf{63.6\ a.m.u}$$

## 5.2.2 Molecular Mass and Formula Mass

***Molecular mass*** is the sum of the relative atomic masses of the individual atoms it contains. The term molecular mass refers to the mass of a molecule of an element or a compound. It is used to describe the masses of molecules of elements and covalent compounds.

Ionic compounds do not exist as molecules. Thus, we do not use the term molecular mass to describe the mass of an ionic compound. Instead, we use the term ***formula mass.*** ***Formula mass*** *is the sum of the mass of each kind of atoms (ions) of elements in the formula of the compound.* It is the mass of the ions present in thier lowest possible ratio of whole numbers.

## 5.2.3 Calculating Molecular Mass and Formula Mass

Inorder to calculate molecular mass or formula mass, we use the following steps.

Steps:

1. Identify each kind of atom present in the formula of the compound or molecule.
2. Decide the number of each kind of atom per formula.
3. Multiply the number of atoms with their respective atomic masses to get the total mass of each element in the molecule or compound.
4. Add all the products obtained in step 3 to get the molecular mass or formula mass.

**Example 5.2**

Calculate the molecular mass of a molecule of white phosphorus, $P_4$. (Atomic mass: P = 31).

*Solution:*

***Step 1*** The only atom present in the molecule is phosphorus (P).

***Step 2*** Number of P atoms = 4

***Step 3*** Total mass = 4 × 31 = 124

***Step 4*** Molecular mass = **124 a.m.u**

**Example 5.3**

What is the formula mass of aluminium sulphate, $Al_2(SO_4)_3$? (Atomic mass: Al = 27, S = 32, O = 16)

*Solution:*

***Step 1*** Elements present: Aluminium, sulphur and oxygen.

***Step 2*** Number of atoms: Al = 2, S = 3, O = 4 × 3 = 12

***Step 3*** Total mass of each element: Al = 2 × 27 = 54, S = 3 × 32 = 96, O = 12 × 16 = 192

***Step 4*** Formula mass of $Al_2(SO_4)_3$ = 54 + 96 + 192 = 342 a.m.u

## Exercise 5.2

1 The two naturally occurring isotopes of chlorine have masses of 35 a.m.u and 37 a.m.u. If the average atomic mass of chlorine is 35.5 a.m.u, what would be the percent abundance of each isotope of the element?

2 Calculate the molecular mass of each of the following:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a | $O_3$ | c | $C_4H_{10}$ | e | $C_6H_{12}O_6$ | g | $N_2O_4$ |
| b | $NH_3$ | d | $C_2H_2O_4$ | f | $SO_3$ | h | $H_2CO_3$ |

3 Calculate the formula mass of the following compounds.

| | | | | | |
|---|---|---|---|---|---|
| a | $KNO_3$ | d | $Ca_3(PO_4)_2$ | g | $Ba(NO_3)_2$ |
| b | $MgBr_2$ | e | $Mg(HCO_3)_2$ | h | $NH_4NO_3$ |
| c | $Na_2SO_4$ | f | $NaHSO_4$ | | |

# 5.3 THE MOLE CONCEPT

***After completing this section, you will be able to:***

- ✓ define mole and molar mass;
- ✓ calculate number of moles of atoms, molecules or formula units from a given mass or number of particles and *vise versa*;
- ✓ convert a given number of moles of atoms, molecules or formula units to number of atoms, molecules or formula units and *vise versa*.

## ACTIVITY 5.4

Discuss the following points in groups and present your group's opinion to the rest of the class.

1 Suppose you have one million eggs. Would it be simpler for you to sell them by counting from one to million or by grouping them in boxes containing one hundred eggs each? Why?

2 Tablets are also sold in containers or boxes containing specific numbers. Why is that so?

We may group different items in dozens or grosses. Analogous to the grouping of items, particles like atoms and molecules are grouped in moles in chemistry. Since atoms and molecules are very small, scaling factor called **mole** is used to convert their small masses into masses in grams. The mole provides the basis for relating masses in grams to number of atoms, molecules or formula units.

***The mole is the amount of a substance that contains the same number of particles as the number of atoms in exactly 12 g of carbon-12***. 12 g of carbon-12 contains an Avogadro's number of carbon-12 atoms.

Avogadro's number = $6.022 \times 10^{23}$

***A mole of any substance is a group containing $6.022 \times 10^{23}$ particles of that substance whether the particles are atoms, molecules or ions***. Thus, one mole of atoms contains $6.022 \times 10^{23}$ atoms. One mole of molecules contains $6.022 \times 10^{23}$ molecules. One mole of an ionic compound contains $6.022 \times 10^{23}$ formula units. The mass of one mole of atoms, one mole of molecules and one mole of an ionic compound is equal to the atomic mass, molecular mass and formula mass expressed in grams, respectively.

For example:

One mole of carbon atoms has a mass of 12 g.

One mole of water molecules has a mass of 18 g.

One mole of sodium chloride has a mass of 58.5 g.

The mass of one mole of atoms, molecules or a compound is called ***molar mass.*** It is denoted by 'M' and expressed by the unit gram per mole (g/mol).

It is possible to calculate the mass of moles of a substance in grams. This can be done by multiplying the number of moles by the molar mass.

Mass of the substance = Given number of moles × Molar mass (g/mol).

**Example 5.4**

Calculate the mass of 2.5 mol of sodium atom (Atomic mass: Na = 23)

*Solution:*

You can also proceed to calculate the mass as follows.

1 mol of sodium = 23 g/mol

2.5 mol of sodium = x

Cross multiplying and solving for 'x' gives.

$$x = \frac{2.5 \text{ mol of sodium} \times 23\ g}{1 \text{ mol of sodium}} = 57.5\ g$$

**Example 5.5**

What is the mass of 5 mol of sodium hydroxide, NaOH?

(Atomic mass: Na = 23, O = 16, H = 1 )

*Solution:*

First, calculate the molar mass of NaOH or formula mass of NaOH in grams.

Molar mass of NaOH = (1 × 23) + (1 × 16) + (1 × 1) = 40 g/mol

Thus, mass in grams of 5 mol NaOH = 5 mol × 40 g/mol

**= 200 g**

It is possible to calculate the number of moles of a substance from a given mass or number of particles.

To calculate the number of moles of a substances from a given mass, we use the relation:

$$\text{Number of moles (n)} = \frac{\text{Given mass in grams}}{\text{Molar mass of the substance in grams per mole}} = \frac{m}{M}$$

In short, we can write this relation as:

$$n = m/M$$

Where n = number of moles

m = given mass

M = molar mass.

**Example 5.6**

How many moles are there in 81 g of aluminium, Al? Atomic mass: Al = 27

*Solution:*

Molar mass of Al (M) = Atomic mass of Al = 27 g/mol.

Given mass of Al (m) = 81 g.

$$\text{The number of mole of Al (n)} = \frac{\text{Given mass}}{\text{Molar mass}}$$

$$= \frac{81\ g}{27\ g/mol} = \mathbf{3\ mol\ of\ Al}$$

## ACTIVITY 5.5

Solve the following problems in groups. Present how you solved the problems to the rest of the class. How many moles are contained in:

a 20 g of $CaCO_3$ (Atomic mass: Ca = 40, C = 12, O = 16)

b 147 g of $H_2SO_4$? (Atomic mass: H = 1, S = 32, O = 16)

The number of moles of a substance from a given number of particles is calculated using the relation:

$$\text{Number of moles (n)} = \frac{\text{Given number of particles}}{6.022 \times 10^{23} \text{ particles/mol}}$$

**Example 5.7**

How many moles are $9.033 \times 10^{23}$ molecules of ammonia, $NH_3$?

*Solution:*

Given number of molecules = $9.033 \times 10^{23}$ $NH_3$ molecules.

$$\text{Number of moles of } NH_3 = \frac{\text{Given number of molecules}}{6.022 \times 10^{23} \text{molecules/mol}}$$

$$= \frac{9.033 \times 10^{23} \text{ } NH_3 \text{ molecules}}{6.022 \times 10^{23} \text{ } NH_3 \text{ molecules / mol}}$$

$$= 1.5 \text{ mol of } NH_3.$$

You can also proceed as follows:

$1 \text{ mol} = 6.022 \times 10^{23}$ molecules

$x = 9.033 \times 10^{23}$ molecules

Cross multiplying and solving for 'x' gives you 1.5 mol again.

Generally, when the number of particles (atoms, molecules or formula units) is given, simply divide the given number of particles by Avogadro's number to calculate the number of moles.

To calculate the number of particles in a given mass (amount) of a substance, first calculate the number of moles of the substance and then multiply by Avogadro's number.

$$\text{Number of particles} = \frac{m}{M} \times 6.022 \times 10^{23} \text{ particles/mol}$$

or

$$\text{Number of particle} = \frac{\text{Give mass}}{\text{Molar mass}} \times 6.022 \times 10^{23} \text{ particles/mol}$$

**Example 5.8**

What is the number of molecules of water in 27 g of water?

(Atomic mass: H = 1, O = 16)

*Solution:*

Molar mass of $H_2O = (2 \times 1) + (1 \times 16) = 18$ g/mol.

Given mass of $H_2O = 27$ g

To calculate the number of molecules, we proceed as follows.

$$\text{Number of molecules of } H_2O = \frac{m}{M} \times 6.022 \times 10^{23} \text{ molecules of } H_2O/\text{mol}$$

$$= \frac{27 \text{ g}}{18 \text{ g/mol}} \times 6.022 \times 10^{23} \text{ molecules of } H_2O/\text{mol}$$

$$= 9.0333 \times 10^{23} \text{ molecules of water}$$

**Example 5.9**

Calculate the number of atoms in 0.4 mol of nitrogen atoms (Atomic mass: N = 14).

*Solution:*

When the number of moles is given, simply multiply the number of moles by Avogadro's number to calculate the number of particles. Thus,

Number of nitrogen atoms = Number of moles of atoms $\times 6.022 \times 10^{23}$ atoms/mol

$= 0.4 \text{ mol} \times 6.022 \times 10^{23}$ atoms/mol

$= 2.4088 \times 10^{23}$ nitrogen atoms

## ACTIVITY 5.6

Discuss in groups how to determine the number of moles of a substance equivalent to a given number of particles. When you complete, present your group's opinion to the rest of the class. During your presentations, show how many moles of:

a nitrogen atoms are equivalent to $1.5055 \times 10^{23}$ nitrogen atoms.

b sulphur dioxide molecules are equivalent to $7.5275 \times 10^{23}$ sulphur dioxide molecules.

## Exercise 5.3

1 Calculate the mass of :

a 0.25 mol of $Al_2(SO_4)_3$

b 0.8 mol of KOH

c 3 mol of $MgCl_2$

d 0.4 mol NaCl

e 1.2 mol NaOH

f 2.5 mol $C_6H_{12}O_6$

2 How many moles are there in:

a 18.5 g $Ca(OH)_2$
b $1.5055 \times 10^{23}$ molecules of $H_2$
c 250 g $CaCO_3$
d $7.5275 \times 10^{23}$ atoms of Nitrogen
e $9.033 \times 10^{24}$ molecules of $CO_2$
f 157.5 g $HNO_3$
g $1.8066 \times 10^{24}$ molecules of $CH_4$
h $2.4088 \times 10^{23}$ atoms of sodium

3 Calculate the number of atoms in:

a 14 g of Li
b 1.5 mol of carbon
c 20 g of calcium

4 Calculate the number of molecules in:

a 2 mol of $CO_2$
b 51 g of $NH_3$
c 33 g of $CO_2$
d 5 mol of $H_2$
e 2 mol of $SO_2$
f 24.5 g of $H_2SO_4$

5 Calculate the number of formula units present in:

a 60 g NaOH
b 2 mol of KCl

6 How many moles are equivalent to:

a $1.8066 \times 10^{25}$ molecules of $CO_2$
b $1.5055 \times 10^{24}$ atoms of sodium
c $9.033 \times 10^{22}$ formula units of NaCl
d $2.4088 \times 10^{24}$ atoms of chlorine
e $5.4198 \times 10^{24}$ molecules of $H_2$
f $3.6132 \times 10^{25}$ atoms of carbon.

## 5.4 PERCENTAGE COMPOSITION OF COMPOUNDS

***After completing this section, you will be able to:***

- ✓ describe percentage composition of a compound;
- ✓ describe the steps of determining percentage composition;
- ✓ calculate percentage composition of a compound from its formula.

### ACTIVITY 5.7

Discuss the following in groups . When you complete, present your group's work to the rest of the class.

In a chemistry laboratory, a student burned 2.0 g hydrogen in 16.0 g oxygen. After the burning process was complete, he weighed the water formed and found its mass to be 18.0 g. What percent of hydrogen is there in 18.0 g water?

***Percentage composition*** of a compound is the number of parts by mass of each element in one hundred parts by mass of the compound. The percent by mass of each element in a compound is calculated using the relation:

$$\% \text{ composition} = \frac{\text{Mass of element in the compound}}{\text{Formula (molar) mass of a compound}} \times 100$$

To determine the percentage composition of a compound, we use the following steps.

1. Identify the elements and the number of atoms of each kind present in the compound.
2. Calculate the total mass of each element by multiplying its number in the formula of the compound with the respective molar mass.
3. Calculate the molar mass of the compound.
4. Calculate the percentage composition of the compound by dividing the total mass of each element by the molar mass of the compound and then multiply by 100.

**Example 5.10**

Calculate the percentage composition of magnesium carbonate, $MgCO_3$. (Atomic mass: Mg = 24, C = 12, O = 16)

*Solution:*

***Step 1*** Elements: Mg = 1, C = 1, O = 3

***Step 2*** Mass: Mg = $1 \times 24 = 24$ g , C= $1 \times 12 = 12$ g, O = $3 \times 16 = 48$ g

***Step 3*** Molar mass of $MgCO_3$ = 24 g + 12 g + 48 g = 84 g

***Step 4*** $\% \text{ of Mg} = \frac{24 \text{ g}}{84 \text{ g}} \times 100 = 28.57\%$

$$\% \text{ of C} = \frac{12 \text{ g}}{84 \text{ g}} \times 100 = 14.29\ \%$$

$$\% \text{ of O} = \frac{48 \text{ g}}{84 \text{ g}} \times 100 = 57.14\ \%$$

The sum of the percentages of elements in a compound is expected to be 100%. However, due to errors resulting from rounding off, the sum of the percentages of different elements in a compund may sometimes not add up to exactly 100%.

## Exercise 5.4

1. Calculate percentage composition by mass of the constituent elements for each of the following compounds:

| | | | | | |
|---|---|---|---|---|---|
| a | $Ca(NO_3)_2$ | c | NaOH | e | $Fe_2(SO_4)_3$ |
| b | $Na_2CO_3$ | d | $N_2O_5$ | f | $C_9H_8O_4$ |

2 Calculate the percentage composition by mass of nitrogen in each of the following fertilisers.

a DAP, $(NH_4)_2HPO_4$

b Urea, $(NH_2)_2CO$

c Ammonium nitrate, $NH_4NO_3$

d Ammonium sulphate, $(NH_4)_2SO_4$

3 What is the percentage composition by mass of oxygen in each of the following?

a PbO

b $Fe_2O_3$

c $Al_2O_3$

d $MnO_2$

e MgO

f $K_2O$

## 5.5 DETERMINATION OF FORMULAS

***After completing this section, you will be able to:***

- ✓ define empirical and molecular formulas;
- ✓ describe the steps of determining empirical formula;
- ✓ determine empirical formula of a compund from a given percentage composition or mass ratio;
- ✓ describe the relationship between empirical formula and molecular formula.
- ✓ describe, the steps of determining molecular formula;
- ✓ determine molecular formula of a compound from empirical formula and molecular mass.

### ACTIVITY 5.8

Discuss the following in groups. When you complete, present your group's opinion to the rest of the class.

The formula of glucose is $C_6H_{12}O_6$. If we simplify the three subscripts by six, we get another formula; $CH_2O$ .

a What do the two formulas indicate?

b What do we call such type of formulas?

***Molecular formula*** is the formula that shows the actual number of atoms of each type of element present in a compound.

***Empirical Formula*** is the formula that shows the number of atoms of each type of element present in the compound in the lowest possible ratio. It is the simplest formula of the

compound. *Table 5.1* shows molecular formulas and empirical formulas of some compounds.

*Table 5.1* Names, molecular formulas and empirical formulas of some compounds.

| Name of compound | Molecular formula | Empirical formula |
|---|---|---|
| Ethene | $C_2H_4$ | $CH_2$ |
| Butene | $C_4H_8$ | $CH_2$ |
| Hexene | $C_6H_{12}$ | $CH_2$ |

The compounds, ethene, butene and hexene are different compounds. Their molecular formulas are different but have the same empirical formula. The empirical formula $CH_2$, shows that each of these compounds consists of carbon atoms and hydrogen atoms in the ratio 1:2.

Sometimes a compound have the same empirical formula and molecular formula. For example, the empirical formula and molecular formula of ethanol is $C_2H_6O$. The empirical formula and molecular formula of sulphuric acid is $H_2SO_4$.

## Determining an Empirical Formula of a Compound

To determine the empirical formula of a compound from its composition expressed in percentage by mass of each element, we use the following steps.

1. Write the symbols of the consitutent elements.
2. Write the percentage by mass of each element below its chemical symbol.
3. Divide the percentage by mass of the element by the respective atomic mass to get the number of moles of each element.
4. Divide the numbers of moles of all element by the smallest number of mole obtained in step 3 to get their mole ratio.
5. If any number obtained in step 4 is not a whole number multiply all numbers by the appropriate integer to make that number a whole number.
6. Write the symbols of the constituent elements side by side and the numbers obtained as subscripts to get its empirical formula.

**Example 5.11**

What is the empirical formula of the compound composed of 92.3% carbon and 7.7% hydrogen? (Atomic mass: C = 12, H = 1).

*Solution:*

The percentage by mass of an element can be considered as its mass in hundred grams of the compound.

***Step 1*** C H

| | | |
|---|---|---|
| ***Step 2*** | 92.3 g | 7.7 g |
| ***Step 3*** | $\frac{92.3}{12}$ g | $\frac{7.7}{1}$ g |
| | = 7.7 mol | = 7.7 mol |
| ***Step 4*** | $\frac{7.7}{7.7}$ | $\frac{7.7}{7.7}$ |
| | = 1 | = 1 |

***Step 5*** Is not necessary because the numbers are whole numbers.

***Step 6*** Empirical formula of the compound is CH. It is not important to write the subscript 1.

The empirical formula, CH, tell only the simplest ratio of carbon to hydrogen is 1:1 and it tells nothing about the molecular formula of the compound.

**Example 5.12**

What is the empirical formula of the compound composed of 52.94% aluminium and 47.06% oxygen? (Atomic mass: Al = 27, O = 16)

*Solution:*

| | | |
|---|---|---|
| ***Step 1*** | Al | O |
| ***Step 2*** | 52.94 g | 47.06 g |
| ***Step 3*** | $\frac{52.94\text{ g}}{27\text{ g/mol}}$ | $\frac{47.06\text{ g}}{16\text{ g/mol}}$ |
| | = 1.96 mol | = 2.94 mol |

***Step 4*** The smaller number of mole is 1.96. So, divide the numbers by 1.96.

| | |
|---|---|
| $\frac{1.96}{1.96}$ | $\frac{2.94}{1.96}$ |
| = 1 | = 1.5 = 3/2 |

***Step - 5*** Since one of the numbers is not a whole number, multiply both numbers by 2.

| | |
|---|---|
| $1 \times 2 = 2$ | $\frac{3}{2} \times 2 = 3$ |

***Step - 6*** The empirical formula of the compound is $Al_2O_3$. $Al_2O_3$ is the empirical formula and molecular formula of aluminium oxide.

It is also possible to calculate the empirical formula of a compound when the mass ratio of the consituent elements is given using the above steps. The only difference is that we use the given mass in place of percentage composition by mass.

**Example 5.13**

What is the empirical formula of a compound composed of 18 g magnesium and 7 g nitrogen? (Atomic mass: Mg = 24, N = 14).

*Solution:*

| | | |
|---|---|---|
| ***Step 1*** | Mg | N |
| ***Step 2*** | 18 g | 7 g |
| ***Step 3*** | $\frac{18\ g}{24\ g/mol}$ | $\frac{7\ g}{14\ g/mol}$ |
| | = 0.75 mol | = 0.5 mol |
| ***Step 4*** | The smaller number of mole is 0.5. So, divide both numbers by 0.5. | |
| | $\frac{0.75}{0.5}$ | $\frac{0.5}{0.5}$ |
| | = 1.5 = 3/2 | = 1 |
| ***Step - 5*** | Multiply the numbers obtained in step 4 by 2. | |
| | $^3/_2 \times 2 = 3$ | $1 \times 2 = 2$ |
| ***Step - 6*** | The empirical formula of the compound is $Mg_3N_2$. | |

## Determining Molecular Formula of a Compound

As explained above, some compounds have the same empirical formula and molecular formula. However, there are compounds having different empirical formula and molecular formula. In case of these compounds, the molecular formula is a whole number multiple of the empirical formula. In addition to that, molecular mass of the compound is also a multiple of the empirical formula mass. That is:

Molecular formula = Empirical formula × n

Molecular mass = Empirical formula mass × n

Where 'n' is a number greater or equal to 1.

It is possible to determine the molecular formula of a compound from its percentage composition and the molecular mass of the compound using the followoing steps.

1 Determine the empirical formula of the compound.

2 Calculate the empirical formula mass.

3 Divide the molecular mass by the empirical formula mass to get the number that should multiply the empirical formula.

4 Multiply the empirical formula by the number obtained when the molecular mass is divided by the empirical formula mass.

**Example 5.14**

What is the molecular formula of a compound having percentage composition of 85.71% carbon and 14.29% hydrogen whose molecular mass is 140? (Atomic mass: C = 12, H = 1)

First, determine the empirical formula from the given percentage composition using the steps applied in **Examples 5.11, 5.12** and **5.13**.

*Solution:*

***Step 1*** C H

***Step 2*** 85.71 g 4.29 g

***Step 3*** $\frac{85.71\ g}{12\ g/mol}$ $\frac{14.29\ g}{1\ g/mol}$

$= 7.145$ mol $= 14.29$ mol

***Step 4*** The smaller number is 7.145. So, divide by 7.145.

$\frac{7.145}{7.145} = 1$ $\frac{14.29}{7.145} = 2$

***Step 5*** Is not important in this case.

***Step 6*** The empirical formula of the compound is $CH_2$.

After determining the empirical formula, use the steps followed to get the molecular formula from empirical formula and molecular mass.

***Step - 1*** Empirical formula is $CH_2$.

***Step - 2*** Empirical formula mass = $(1 \times 12) + (2 \times 1) = 14$

***Step - 3*** $$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{140}{14} = 10$$

***Step - 4*** Molecular formula = Empirical formula $\times$ n

$= (CH_2) \times 10$

$= C_{10}H_{20}$

So, the molecular formula of the compound is $C_{10}H_{20}$.

When the empirical formula and molecular mass of the compound is given, we proceed in the same manner as shown in **Example 5.13**.

**Example 5.15**

If the empirical formula of a compound is $CH_2$ and it molecular mass is 70, what would be the molecular formula of the compound ?

*Solution:*

***Step 1*** Empirical formula is $CH_2$.

***Step 2*** Empirical formula mass is 14.

***Step 3*** $$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{70}{14} = 5$$

***Step 4*** Molecular formula = Empirical formula × n

$$= (CH_2) \times 5$$

$$= C_5H_{10}$$

## Exercise 5.5

1. Determine the molecular formula of a compound having a simplest formula of CH and formula mass of 78.
2. A compound with a molecular mass of 42 is found to contain 85.64% carbon and 14.36% hydrogen by mass. Find its molecular formula.
3. Analysis of a 10.15 g sample of a compound known to contain only phosphorus and oxygen is found to contain 5.717 g of oxygen. What is the simplest formula of this compound?
4. What is the empirical formula of a compound found to contain 32.38% sodium, 22.65% sulphur and 44.49% oxygen?

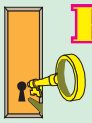
# Unit Review

## CHECK LIST

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

| № | Can I | Yes | No |
|---|---|---|---|
| 1 | describe what information a chemical formula of a compound can provide? | | |
| 2 | describe atomic mass? | | |
| 3 | define the terms molecular mass and formula mass? | | |
| 4 | describe the steps of calculating molecular mass and formula mass? | | |
| 5 | calculate molecular mass and formula mass using formula of a compound and atomic masses? | | |
| 6 | define mole and molar mass? | | |
| 7 | calculate number of moles of atoms, molecules or formula units from a given mass or number of particles and vise versa? | | |
| 8 | convert a given number of moles of atoms, molecules or formula units to number of atoms, molecules or formula units and vise versa? | | |
| 9 | describe percentage composition of a compound? | | |
| 10 | describe the steps of determining percentage composition? | | |
| 11 | calculate percentage composition of a compound from its formula? | | |
| 12 | define empirical and molecular formulas? | | |
| 13 | describe the steps of determining empirical formula? | | |
| 14 | determine empirical formula of a compund from a given percentage composition or mass ratio? | | |
| 15 | describe the relationship between empirical formula and molecular formula? | | |
| 16 | describe, the steps of determining molecular formula? | | |
| 17 | determine molecular formula of a compound from empirical formula and molecular mass? | | |



## Key Terms

- Atomic mass
- Atomic mass unit
- Average atomic mass
- Avogadro's number
- Empirical formula
- Formula mass
- Molar mass
- Mole
- Molecular formula
- Molecular mass
- Percentage composition

## Unit Summary

- ✓ Relative atomic mass is the mass of an atom determined in relation to carbon -12.
- ✓ The carbon -12 atom has been chosen as a standard to determine atomic masses of all atoms.
- ✓ Atomic masses are measured in atomic mass unit (a.m.u).
- ✓ Average atomic mass is the weighted average of the atomic masses of the naturally occurring isotopes of an element.
- ✓ Molecular mass is the sum of the relative atomic masses of the individual atoms the molecule contains.
- ✓ Formula mass is the sum of the total mass of each kind of ions or atoms of the elements in the formula of the compound.
- ✓ The mole is the amount of a substance that contains the same number of particles as the number of atoms in exactly 12 g of carbon -12.
- ✓ A mole is Avogadro's number ($6.022 \times 10^{23}$) of particles (atoms, molecules or ions).
- ✓ Molar mass is the mass of one mole of atoms, molecules or ionic compounds and expressed by the unit gram per mole (g/mol).
- ✓ Percentage composition of a compound is the number of parts by mass of each element in one hundred parts by mass of the compound.
- ✓ Molecular formula is the formula that shows the actual number of atoms of each element present in a compound.
- ✓ Empirical formula is the formula that shows the number of atoms of each element present in the compound in the lowest possible ratio.
- ✓ Some compounds have the same empirical and molecular formula.
- ✓ In case of some compounds, the molecular formula is a whole number multiple of the empirical formula.

# REVIEW EXERCISE ON UNIT 5

## I *Write 'True' if the statement is correct and 'False' if it is wrong.*

1 One mole of any substance contains $6.022 \times 10^{23}$ particles of that substance.

2 Empirical formula shows the actual number of atoms of each kind of element present in the compound.

3 Molecular formula is a short hand representation of molecule of an element or a compound.

4 One mole of different substances have the same mass.

5 The molecular formula and empirical formula of any compound are identical.

6 The atom that serves as a standard in determining relative atomic mass is carbon-12 atom.

7 Atomic mass unit is used as a unit to describe the molar mass of a substance.

8 The sum of the percentages of all elements in a compound is nearly 100%.

## II *Choose the correct answer from the given alternatives for each of the following questions.*

9 Which of the following contains the largest number of atoms?

A 3.5 g Li
B 4 g He
C 4 g C
D 12 g O

10 What information can we get from the empirical formula of a compound?

A The actual composition of the compound.
B The molar mass of the compound.
C The smallest possible ratio of atoms in the compound.
D The actual number of atoms of each kind of element present.

11 The molecular formula of a compound having the empirical formula $CH_2O$ and molecular mass of 180 a.m.u is:

A $C_{12}H_{22}O_{11}$
B $C_6H_{16}O_5$
C $C_8H_{16}O_3$
D $C_6H_{12}O_6$

12 $9.033 \times 10^{23}$ atoms of carbon are equivalent to:

A 18 g
B 16 g
C 12 g
D 24 g

13 Which one of the following quantities contains the same number of molecules?

A 8 g $O_2$ and 32 g $SO_2$
B 2 g $H_2$ and 44 g $CO_2$
C 28 g CO and 14 g $N_2$
D 48 g $O_3$ and 16 g $O_2$

14 What would the atomic mass of an atom be if its mass is approximately 12 times that of carbon -12?

A 120
B 72
C 144
D $12 \times 6.022 \times 10^{23}$

## III *Give short answers for each of the following questions.*

15 What is the mass, in grams, of each of the following ?

a 4.25 mol Na
b 6.5 mol Cu
c 3.6 mol $CO_2$
d 7.2 mol Au

16 How many moles of atoms and number of atoms are there in:

a 150 g S
b 100 g Ca
c 48 g O
d 140 g Fe

17 How many moles of atoms are equivalent to:

a $6.022 \times 10^{23}$ atoms Ne
b $3.011 \times 10^{23}$ atoms Mg
c $2.25 \times 10^{25}$ atoms Zn

18 What is the mass, in grams, of each of the following?

a $3.011 \times 10^{24}$ atoms F
b $8.42 \times 10^{23}$ atoms Br
c $1.505 \times 10^{24}$ atoms Mg
d $6.022 \times 10^{25}$ atoms Cl

19 How many grams and moles contain:

a $3.011 \times 10^{24}$ atoms $CO_2$
b $9.033 \times 10^{22}$ molecules $N_2$

20 Find the simplest formula of a compound that contains 52.2% carbon, 13.0% hydrogen and 34.8% oxygen.

21 A compound is composed of 53.33% carbon, 11.11% hydrogen and 35.56% oxygen. If the molecular mass of the compound is 90, what is the molecular formula of this compound?

22 Define the following terms.

a Atomic mass
b Molecular mass
c Formula mass
d Mole
e Molar mass
f Percentage composition
g Empirical formula
h Molecular formula

# GLOSSARY

- **Acids :** are compounds that release hydrogen ions in water solution.
- **Alloy:** is a mixture of two or more metals, or metals and non-metals.
- **Allotropy:** the existence of one element in two or more different forms under the same physical state.
- **Air:** dry air is mainly a mixture $N_2$ and $O_2$. About 78% of the atmosphere is $N_2$ and 21% is $O_2$ .
- **Air pollution:** is the contamination of atmospheric air caused by gaseous and tiny solid substances entering into it.
- **Air pollutants:** are substances that enter into atmospheric air and cause harmful effects on the lives of animals and plants.
- **An alkali:** is a substance that releases hydrooxide ions in aqueous solution.
- **Atomic masses:** are measured in atomic mass unit (a.m.u)
- **Carbon:** is the key elements of organic compounds. It is one of the very few elements which has the tendency of forming long chains.
- **Crude oil:** is a mixture of hydrocarbons that can be separated into different petroleum fractions used as a fuel or other purposes.
- **Ductility:** is the ability of a metal to be drawn into this wires.
- **Empirical formula:** is the formula that shows the number of atoms of each element present in the compound in the lowest possible ratio.
- **Fertilizers:** are substances that cab be added to the soil to improve its fertility, growth of crop and yield.
- **Formula mass:** is the sum of the total mas of each kind of ions or atoms of the elements in the formula of the compound.
- **Fuel:** is any substance which is capable of burning to release heat and light energy.
- **Global warming:** is an increase in the average temperature of the earth due to an enhanced green house effect.
- **Hard water:** is the water that doesn't form a lather rapidly when soap is dissolved in it.
- **Hydrocarbons:** are organic compounds that contains only carbon and hydrogen.
- **Malleability :** is the property of a metal to be hammereder pressed into this sheets.

- **Molar mass:** is the mass of one mole of atoms, molecules or ionic compounds and expressed by the unit gram per mole (g/mol).
- **Molecular mass:** is the sum of the relative atomic masses of the individual atoms the molecule contains..
- **Molecular formula:** is the formula that shows the actual number of atoms of each element present in a compound.
- **Natural gas:** is a gaseous fuel used at home or in industries consisting of mainly methane.
- **Ore:** is a naturally occurring rock that contain metals or metal compounds in the certain amount.
- **Organic compounds:** are carbon–containing compounds except the oxides of carbon, carbonates, and hydrogen carbonates.
- **Oxides:** are binary inorganic compounds formed when oxygen combines with other elements.
- **Percentage composition of a compound:** is the number of parts by mass of each element in one hundred parts by mass of the compound.
- **Phosphates:** are salts of phosphoric acid.
- **Relative atomic mass:** is the mass of an atom determined in relation to carbon –12.
- **Salts:** are compounds that contains positive ions derived from bases and negative ions derived from acids.
- **Soft water:** is the water that forms a lather immediately when soap is dissolved in it.
- **Softening of water:** The process of removing calcium and magnesium ions form hard water.
- **Sulphates:** are salts of sulphuric acid.
- **Valcanization:** is the process of hardening rubber by the addition of sulphur.

# CHEMISTRY

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## Grade 8

ISBN 978-99944-2-287-6

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