INCREASING ACCESS TO SECONDARY SCHOOL LEVEL EDUCATION THROUGH THE PRODUCTION OF QUALITY LEARNING MATERIALS

JUNIOR SECONDARY LEVEL

CHEMISTRY

Module 5:
Metals and Non-metals

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Ministry of Education, Zambia

Ministry of Education, Sport and Culture, Zimbabwe

Mauritius College of the Air, Mauritius

COMMONWEALTH *of* LEARNING
Suite 600 - 1285 West Broadway, Vancouver, BC V6H 3X8 CANADA
PH: +1-604-775-8200 | FAX: +1-604-775-8210 | WEB: www.col.org | E-MAIL: info@col.org

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CONTRIBUTORS TO PROJECT - CHEMISTRY

Course Writer	D. Puchooa
Course Reviewer	S. Tirbhowan
Course Co-ordinator	R. Dhurbarrylall
Instructional Systems Designer	R. Dhurbarrylall
Editor	C. Sooben
Text Entry	Mrs. S. Deenanath
	Mrs. P. Hurgobin
	Mrs. S. Chengalanee
Graphic Artist	F. Bredel
Lay-out and Formatting	Mrs. M. A. Frivole
Science Course Materials Management	Mauritius College of the Air

REVIEW TEAM

Botswana College of Distance and Open Learning	Lawrence Tshipana
Malawi College of Distance Education	Chris F. Layamaman
Namibian College of Open Learning	Joseph Amon
Institute of Adult Education, Tanzania	Andrew Dominick Swai
Emlalatini Development Centre, Swaziland	Simon Sipho Maseko
NDOLA Institute for Skills Training, Zambia	Christopher Chiluband
Ministry of Education, Sport and Culture, Zimbabwe	Luwis Hlombe

PILOTING TUTORS

Botswana College of Distance and Open Learning	Thandie Keetsaletse
Namibian College of Open Learning	Jona Mushelenga
Sifundzain High School, Swaziland	Saide Richards
Kibasila Secondary School, Tanzania (Ministry of Education)	John Anania
Nilrumah Teacher’s College, Zambia	F. Mubanga
NDOLA Institute for Skills Training, Zambia	Christopher Chiluband
Ministry of Education, Sport and Culture, Zimbabwe	Luwis Hlombe

JUNIOR SECONDARY LEVEL SCIENCE - CHEMISTRY

MODULE 1- Introduction to Chemistry

MODULE 2 – Matter and Change of State

Unit 1 – Matter and Change of State

Unit 2 – Building Blocks of Matter

MODULE 3 – Heat, Energy, Air and Combustion

Unit 1 – Heat, Energy, Air and Combustion

Unit 2 – Conservation of Energy

MODULE 4 – Periodic Classification of the Elements

Unit 1 – Periodic Classification of the Elements

Unit 2 –Bonding

MODULE 5 – Metals and Non-metals

Unit 1 – Metals and Non-metals

Unit 2 – Gases

Unit 3 – Acids and Bases

MODULE 5 – UNIT 1

METALS AND NON-METALS

TABLE OF CONTENTS

MODULE 5

UNIT 1

METALS AND NON-METALS

INTRODUCTION

You will also recall us, dividing the elements into metals and non-metals with interesting properties and applications in Module 2 – Unit 2.

In the present Unit we are going to consider metals and non-metals as two categories of elements. In so doing we will look at some more properties.

OBJECTIVES

After completing this Unit, you will be able to:

- list the physical and chemical properties of metals
- list examples of metals and their uses
- name the form in which carbon appears in nature
- describe the allotropes of carbon
- list the physical properties of carbon
- list the chemical properties of carbon as chemical
- describe the use of some of the chemical properties of carbon.

1.0 METALS

You must have noticed builders using a variety of metals on construction sites e.g. iron bars to reinforce the concrete, aluminium for the windows, copper wires for the electrical installation and so on. The choice of metals depends on the physical and chemical properties of the metal.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

Iron is a common metal.

*Name **ten** other metals*

1.	*6.*
2.	*7.*
3.	*8.*
4.	*9.*
5.	*10*

You will find the answer at the end of the Module.

1.1 PROPERTIES

Properties can be either **Physical** or **Chemical** in nature. Such properties help us to differentiate between the nature of elements for example depending on their physical or chemical properties elements have been grouped as being either **metals** or **non-metals.**

In the following sections, we will look at the Physical and Chemical properties of the elements: **metals** and **non-metals.**

1.1.1 PROPERTIES – PHYSICAL

- Most metals are solids.
- They conduct electricity as well as heat.
- Usually they are lustrous.
- They are strong.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 2

*Write **true** or **false** for each of the following physical characteristics of metals.*

1. *All metals are solids …….*
2. *Metals have shiny appearances ……..*
3. *Metals are good conductors of heat ……..*
4. *Metals are poor conductors of electricity ……..*
5. *Metals feel cold when touched ……..*

You will find the answer at the end of the Module.

If you go around a metal workshop near your home, you will surely notice how metals are available as sheets or wires. Others are available as tubes, rods, and bars. In fact, a whole range is possible. Have you ever tried touching a piece of metal? I hope you've discovered the coldness. When we touch a metal it conducts heat away from our fingers.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 3

*Metals are described as **malleable, ductile** and **cold** (to the touch)*

*Explain **each** of the above:*

……

……

……

……

……

You will find the answer at the end of the Module.

1.1.2 PROPERTIES - CHEMICAL

- Several metals undergo reactions with acids and bases.
- They give off bubbles of hydrogen with solutions of acids or bases.
- They react with non-metals.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 4

*Give one example in **each** case of a*

(a) metal reacting with hydrochloric acid solution to produce bubbles of hydrogen gas.

……

(b) metal reacting with sodium hydroxide solution to form bubbles of hydrogen gas.

……

You will find the answer at the end of the Module.

1.2 BONDING IN METALS

A metal is characterised by metallic bonding within itself. When a metal combines with a non-metal the bonding is ionic. Bonding is a topic we've already covered in Module 4 Unit 2. So do refer to it to refresh your memory, as we won't elaborate further on bonding here.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 5

Explain in terms of electrons, bonding in a

(a) metal

……

……

(b) compound between a metal and a non-metal.

……

……

You will find the answer at the end of the Module.

1.3 METALS – USES AND APPLICATIONS

You must have seen a large number of metals in everyday use and application. There is hardly a moment of our life when we are not making use of metals. The coins in our pocket are metals.

Their uses/applications depend upon their physical and chemical properties. You wouldn't for example use a metal that rusts easily as a material for garden gates or water pipes. In no time you will have to replace them.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 6

Give examples of the metals used

(i) in making coins ……

(ii) to galvanise iron ……

(iii) as jewels ……

(iv) for electrical conductors ……..

(v) as cooking utensils ……

(vi) in cutlery ……..

(vii) during construction (bridges, buildings) ……

(viii) for making cans ……..

(ix) for making sheets ……

(x) in dry cells ……

You will find the answer at the end of the Module.

You will recall us looking at non-metals in Module 2, Unit 2 - Section 2.3.1. We shall now look at them in a bit more detail.

1.4 NON-METALS

Non-metals fall into another class of elements. Obviously they are quite different from metals. This difference becomes clearer when we look at their properties which we shall turn to now.

1.4.1 PROPERTIES - PHYSICAL

- They are not strong. They break up easily.
- They are poor conductors of electricity and heat.
- They have low melting points and boiling points.

1.4.2 PROPERTIES - CHEMICAL

Most of them react with oxygen on heating

e.g. sulphur + oxygen ⟶ sulphur dioxide.

They burn to form the oxide.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 7

Oxygen is a common non-metal.

*Make a list of **ten** other non-metals.*

1.	*6.*
2.	*7.*
3.	*8.*
4.	*9.*
5.	*10.*

You will find the answer at the end of the Module.

We can now proceed with the following investigation.

INVESTIGATION 1: Burning of some non-metals

For each investigation you will require the materials indicated.

You should record your answers in the space provided.

Materials needed:

- 3 gas jars of oxygen
- 3 combustion spoons
- samples of sulphur, phosphorous and carbon
- a Bunsen burner

Method:

(a) In a combustion spoon put a little sulphur.

Using a lighted burner, heat the sulphur by heating below the spoon. When the non-metal catches fire, lower it in a gas jar of oxygen.

Record your observations in the table below.

(b) Repeat the exercise using phosphorous instead of sulphur.

Finally use carbon in the combustion spoon.

Record your observations in the table below:

	Non-metal being burnt	**Colour of flame**	**Product**
a.	Sulphur		
b.	Phosphorous		
c.	Carbon		

I am sure that you observed a **blue** flame for burning sulphur, **white** flame for phosphorous and **yellow** for carbon. In each case the product is the **oxide** of the non-metal being burnt.

We can now proceed with the following investigation.

INVESTIGATION 2: Reaction of carbon with hot black copper oxide

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • A hard glass test tube • Powdered charcoal • Powdered copper oxide • Test tube holder • A Bunsen burner **Method:** *In a hard-glass test tube take an intimate mixture of powdered charcoal and black copper oxide.* *(a) Using a test tube holder, heat it strongly in a luminous Bunsen flame* *Record your observation* …… …… …… …… …… ……

I am sure that you saw a shining pink deposit inside the test tube. The pink substance is copper (formed by reaction of carbon (charcoal) with black copper oxide.

Note: *Carbon often reacts with certain metallic oxides when heated. The products are the metal and carbon monoxide. $C + Cu0 \longrightarrow Cu + C0$.*

1.5 CARBON

Carbon is an extremely important element essential for life. It is found in our essential nutrients such as carbohydrates and proteins. It is a non-metal. It normally exists in many forms e.g.

- Diamond
- Graphite
- Coke
- Coal
- Soot

It also occurs naturally as compounds e.g. carbon dioxide in the atmosphere.

1.5.1 CARBON – ALLOTROPES

Diamond and Graphite are known as ***Allotropes***. Allotropes are elements existing in **two** or more different forms in the same physical state. Let us now look at them in slightly more detail.

Diamond

- Diamond is the hardest natural substance.
- It is colourless.
- It does not conduct electricity.
- It has a very high melting point and in light it sparkles.

This makes it ideal for:

- jewellery,
- cutting glass and stone.

Graphite

- Graphite on the other hand is a soft dark greasy solid.
- It is a good conductor of electricity.
- It breaks easily and it marks paper.

Graphite is used as a:

- lubricant
- in pencils because it marks paper.

1.5.2 OTHER FORMS OF CARBON

Coke, Coal, Soot

While diamond and graphite are pure forms of carbon, we can say that coke, coal and soot are impure forms. They do not occur naturally like diamond and graphite. We can obtain coke, charcoal and soot by heating coal, wood, animal bones in very little air.

- Coke and charcoal provide energy when heated.
- Coal can be used for heating and cooking.
- Coke is used in the extraction of iron in a blast furnace.

1.6 PROPERTIES OF CARBON

We can summarise the properties of carbon as follows:

Physical	Chemical
Black (except diamond)	Burns in plentiful air forming carbon dioxide
Solid at room temperature	Burns in limited air forming carbon monoxide

Carbon monoxide is the poisonous gas produced from car exhausts.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 8

Carbon is a non-metal. In everyday life we come across carbon in different forms.

(a) Give the name of these forms of carbon.

……
……

(b) Select the 2 allotropes from (a)

……

……

Note that they contain atoms of carbon arranged differently.

You will find the answer at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 9

This activity concerns forms of carbon.

*Select your answer in each case from **one** of: diamond, graphite, coal.*

(a) It is transparent……

(b) It is very hard ……..

(c) It is soft and slippery……..

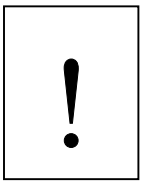
(d) It is used (in the powder form) in the extraction of iron from its ores (in the presence of hot air in the blast furnace). ……

(e) It conducts electricity ……

(f) It is used in rock-borers ……

(g) It is used in jewellery ……

You will find the answer at the end of the Module.



POINTS TO REMEMBER

- Metals are usually solids (except mercury).
- Metals have lustrous appearances.
- Metals are malleable, ductile and feel cold to the touch.
- Metals are very good conductors of heat and electricity
- Metals have affinity for non-metals.
- Non-metals generally do not conduct electricity (except graphite)
- Carbon exists as different allotropes.
- Carbon has many uses, depending upon their properties.

MODULE 5 – UNIT 2

GASES

TABLE OF CONTENTS

MODULE 5

UNIT 2

GASES

INTRODUCTION

Our environment has many gases. These gases play an important role in our day to day living. Carbon dioxide is very useful to plants for photosynthesis. Oxygen is essential to all living organisms.

Air also contains water vapour. This is a compound of oxygen and hydrogen. When water vapour condenses it forms water, another essential compound because without water, life doesn't exist. This Unit will look at a few gases present in our environment.

OBJECTIVES

After completing this Unit, you should be able to:

- discuss the commercial preparation of carbon dioxide
- discuss the preparation of carbon dioxide in the laboratory
- describe the physical properties of carbon dioxide
- describe the chemical properties of carbon dioxide
- explain the uses of carbon dioxide as "dry ice"
- describe the commercial preparation of oxygen
- describe the properties of oxygen
- discuss the uses of oxygen
- discuss the commercial preparation of hydrogen

- describe the physical properties of hydrogen
- discuss the uses of hydrogen
- compare the distribution/availability of water
- discuss the economical/effective utilisation of water
- describe the physical properties of water
- describe the chemical test for water
- define **hard** or **soft** water
- describe hard water as containing dissolved calcium and magnesium salts
- define scum as a product of soap and the magnesium and calcium salts in water
- distinguish between **temporary** and **permanent** water hardness
- establish that temporary water hardness is caused by the process of calcium and/or magnesium hydrogen carbonate
- describe the softening of temporary hard water by boiling

2.0 CARBON DIOXIDE - PREPARATION

Carbon dioxide is released into the air by respiration.

It is also produced during the ***fermentation*** processes. As a matter of fact, this is how we prepare carbon dioxide on a large scale. The carbon dioxide is a by-product of the process of fermentation.

In the laboratory, we prepare a sample of carbon dioxide by the action of an acid on a carbonate.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

On a large scale (industrially) carbon dioxide is generated in various ways.

(a) *Give two of these*

1st

……

2nd……..

b) *How is a sample of carbon dioxide prepared and collected in the laboratory? Include a labelled diagram.*

You will find the answer at the end of the Module.

2.1 CARBON DIOXIDE - PROPERTIES

Carbon dioxide is the only gas that turns lime water milky. You can try this yourself. Exhale through a tube dipped in lime water in a test tube. Lime water in fact is calcium hydroxide in water.

The milkiness is calcium carbonate.

calcium hydroxide + carbon dioxide ⟶ calcium carbonate + water

- Carbon dioxide is colourless, tasteless and odourless.
- It dissolves in water to form carbonic acid.

  WATER + CARBON DIOXIDE ⇌ CARBONIC ACID

- It doesn't support combustion. Put a lighted candle in a gas jar of carbon dioxide. It goes off.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 2

(a) *Give 3 physical properties of carbon dioxide*

……

……

……

(b) *Give 3 chemical properties of carbon dioxide*

……

……

……

(c) *How do we test for the presence of carbon dioxide in a gas jar suspected to contain the gas?*

……

……

……

You will find the answer at the end of the Module.

2.1.1 CARBON DIOXIDE – USES

When you uncork a bottle of soda water, bubbles of carbon dioxide are seen coming out. Carbon dioxide is purposely put in soft drinks like soda, lemonade and coke to produce this fizz.

Solid carbon dioxide resembles ice in appearance. It is also known as dry ice.

- It is used in aeroplanes to keep food cold.

- It can also produce interesting effects in the theatre and on television. This is because the solid changes to vapour directly a phenomenon known as **sublimation**. On stage, lumps of carbon dioxide dropped in a bucket of boiling water gives odourless smoke without any fire risks. This is the smoke or fog you see on TV.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 3

*Tick 'yes' or 'no' for each statement below concerning the **uses of carbon dioxide**.*

		Yes	***No***
I.	*As a fuel in gas burners.*	☐	☐
II.	*As a preservative of fruit juice.*	☐	☐
III.	*When dissolved under high pressure in water it is used to make soda water.*	☐	☐
IV.	*In extinguishing small fires.*	☐	☐
V.	*In combination with ammonia, in the manufacture of the fertilizer, urea.*	☐	☐
VI.	*In making 'dry ice' which is widely used as a cooling agent.*	☐	☐

You will find the answer at the end of the Module.

2.2 OXYGEN

The air around us contains oxygen. This oxygen is essential for life. During respiration, the oxygen breaks down glucose from our food to produce the energy we require to get on with our daily activities. This issue is taken up in depth in Module 4 of the Biology Section.

2.2.1 INDUSTRIAL PREPARATION

Oxygen, a component of air, is isolated industrially making use of air. Here is how it is done. Air is freed from carbon dioxide by absorbing this gas in a sodium hydroxide solution. The remaining air is dried and liquefied. Liquid air contains nitrogen, oxygen and argon. These are separated by fractional distillation. The 3 are collected separately.

You may wish to refer to fractional distillation in Module 2, Unit 2 (Section 2.5.3).

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 4

Air contains oxygen, nitrogen, carbon dioxide, rare gases etc.

Outline how air is used as a source for the commercial preparation of oxygen.

……

……

……

……

……

……

You will find the answer at the end of the Module.

2.2.2 OXYGEN - PROPERTIES

- It is colourless, odourless, and tasteless.
- It dissolves slightly in cold water.
- It supports combustion.
- It also reacts with many substances producing oxides e.g.

  calcium + oxygen ⟶ calcium oxide

  magnesium + oxygen ⟶ magnesium oxide

2.2.3 OXYGEN - USES

Oxygen has many uses in everyday life.

- You must have seen divers, firemen, rescuers and astronauts with oxygen cylinders in situations where there is a shortage of air.
- In hospitals, patients with respiratory difficulties are given oxygen.
- In the manufacture of steel, we use oxygen to purify the steel.
- If you have the opportunity of visiting workshops, watch the artisans welding and cutting metals. They use a flame produced by a gas coming from two cylinders. One cylinder is acetylene gas and the other is oxygen. The mixture burns strongly, producing a very hot flame. This very hot flame cuts metals by melting them.
- When the metals melt, they can be joined or welded to each other.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 5

(a) Give six properties of oxygen.

1. *4.*

2. *5.*

3. *6.*

(b) Make a list of the uses of oxygen.

……

……

……

……

……

You will find the answer at the end of the Module.

2.3 HYDROGEN

You should recall us saying in Module 2, Unit 2 that water is a compound made from two elements i.e. hydrogen and oxygen.

2.3.1 INDUSTRIAL PREPARATION

Hydrogen is produced on a large scale by heating a mixture of natural gas (methane) and steam.

methane + water ⟶ carbon dioxide + hydrogen

We can now proceed with the following investigation.

INVESTIGATION 1: Preparation of hydrogen in the laboratory

We can easily prepare a sample of hydrogen in the laboratory by getting a metal and an acid to react.

For each investigation you will require the materials indicated.

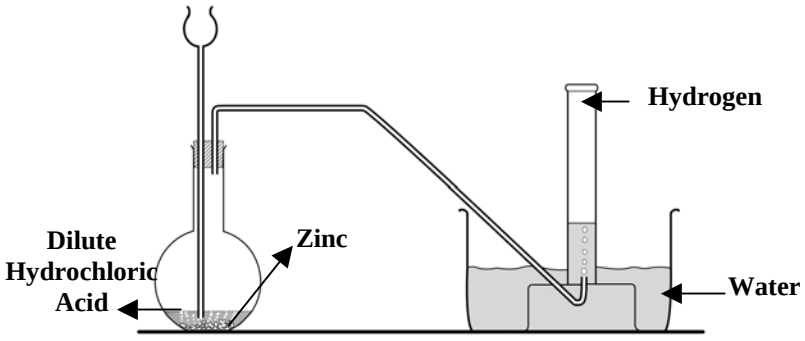
You should record your answers in the space provided.

Materials needed:

- zinc
- dilute hydrochloric acid
- flask
- funnel
- rubber bung
- gas jar, stand
- trough of water
- delivery tube

Method:

(a) Put zinc granules in the flask and assemble the apparatus as shown below. The acid is added through the funnel until the acid is above the bottom of the funnel.



	Record your observation. …… …… …… …… …… …… (b) *Bring a lighted splinter near the mouth of the jar.* *Record what you see and hear*. …… …… …… …… ……

I am sure that in (a) you observed bubbles (effervescence). In (b) a 'pop' sound is heard.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 6

On a commercial scale, hydrogen is prepared from water/steam.

Outline how it is carried out.

……

……

……

……

……

……

You will find the answer at the end of the Module.

2.3.2 HYDROGEN - PROPERTIES

- Hydrogen is colourless, odourless and tasteless.
- It is about 20 times lighter than air and is insoluble in water.

2.3.3 HYDROGEN - USES

- In the meteorological services, weathermen fill weather balloons with hydrogen before release into the atmosphere.
- In the food industry, it is made to react with vegetable oils to produce margarine.
- We make ammonia using hydrogen with nitrogen.
- As a fuel - when burnt (in air) it releases energy.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 7

(a) Give five properties of hydrogen.

……

……

……

……

(b) Make a list of the uses of hydrogen.

……

……

……

……

You will find the answer at the end of the Module.

2.4 WATER

Water is a very precious liquid on our planet. It used to be abundant, but now with growing populations, deforestation, industrialisation and frequent droughts it is becoming a very scare resource. We therefore have to ensure that we use it economically because it occupies a central position in our life. Remember "no water, no life". There is always a risk that we may run out of clean water. There are several sources of water. The liquid is put to a variety of uses.

2.4.1 SOURCES OF WATER

Rain water is normally collected in reservoirs, dams, lakes etc. I think you'll agree with me that this collected rain water is not fit for domestic consumption. It contains bacteria, dissolved substances etc. which can be harmful to health. After treatment, this water is pumped to our homes through pipes. Obviously there is a cost to this.

Unfortunately in some parts of our region, water has not reached all the homes. This may mean fetching water from public fountains, wells, springs etc. We recommend boiling this water before human consumption.

It may be useful to refer to the Biology Section Module 8, Unit 1 - Section 1.7.1 where we discuss the water cycle.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 8

(a) *Draw up a list of the sources of water*

……

……

……

(b) *What use is made of water at home?*

……

……

……

(c) *How is water used on the farm?*

……

……

……

(d) *Give other uses of water (not included in (b), (c) above.*

……

……

……

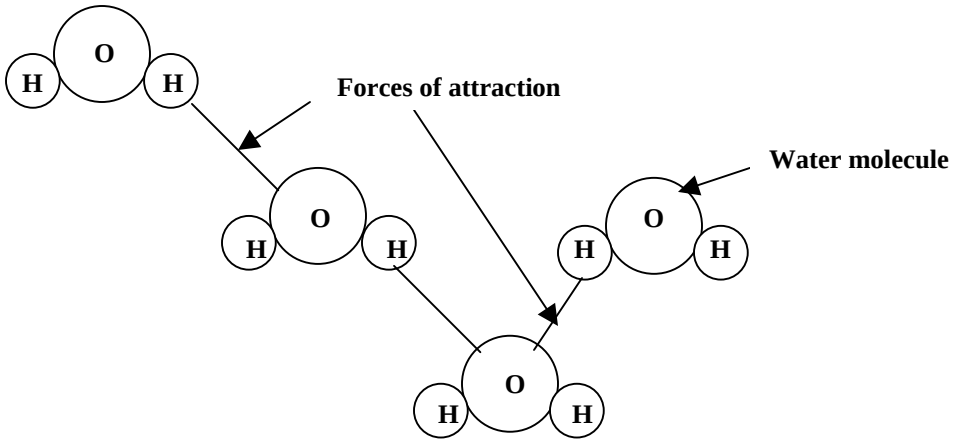
You will find the answer at the end of the Module.

2.4.2 WATER - PROPERTIES

- Pure water freezes at 0^0C.
- It is the **only** liquid that boils at 100^0C.

Unusual properties

Note: Water has some unusual properties, *e.g. its boiling point of 100^0c is exceptionally high*. We can explain this as follows: The forces of attraction between water molecules are strong. Therefore more heat energy is required to break these forces of attraction.



When water freezes, its volume increases and its density decreases. You must have noticed cubes of ice floating on drinks. Solid ice is less dense than liquid water. Again icebergs float rather than sink.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 9

Tick 'yes' or 'no' for each of the following concerning the physical properties of water.

		Yes	*No*
1.	*It is a colourless liquid*		
2.	*It has a pleasant smell*		
3.	*It has no taste*		
4.	*It is odourless*		
5.	*It boils at 100k*		
6.	*It freezes at 273k*		
7.	*Its boiling point is 100^0C*		
8.	*Its freezing point is O^0C*		
9.	*It does not burn*		
10.	*It turns red litmus blue*		
11.	*It turns blue litmus red*		

You will find the answer at the end of the Module.

We can now proceed with the following investigation.

INVESTIGATION 2: Chemical test for water

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Water • Dry cobalt chloride paper (blue) • Anhydrous copper sulphate (white) • Watch glass • Dropper **Method:** (a) *Dip a piece of cobalt chloride paper in water.* *Record the colour change.* …… …… …… (b) *Sprinkle a little anhydrous copper sulphate in a clean watch glass. With the help of a dropper, add a few drops of water to the white copper sulphate.* *Record the colour change* …… …… ……

I am sure that in (a) you noted a change from blue to pink.

In (b) the change is from white to blue.

2.5 WATER – HARD AND SOFT

The water from our taps is clean but not necessarily pure. In many regions, river water and hence reservoir water contains small amounts of dissolved calcium salts and dissolved magnesium salts. These salts are washed from the rocks present in the soil. They are not harmful to us. With soap, these salts form products which appear as **SCUM** floating on water. We describe such water as '***hard water***'.

Distilled water, rain water are examples of '***soft water'***. With soap, soft water forms a **lather** readily but no scum. They do not contain calcium and magnesium salts dissolved in them.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 10

(a) *Name 2 calcium salts normally present in 'hard' water*.

……

……

……

……

(b) Name 2 magnesium salts contained in natural samples of 'hard' water.

……

……

……

……

You will find the answer at the end of the Module.

2.5.1 HARDNESS - TEMPORARY AND PERMANENT

Now that you know about hard and soft water, we would like to point out that hardness can be either temporary or permanent.

Temporary hardness: this is a hardness that we can easily remove from the water to render it soft. If your region has hard water, try and look inside an electric kettle. You will notice a deposit on the sides of the kettles. This is calcium carbonate.

Temporary hardness is caused by calcium bicarbonate dissolved in the water. When boiled, the calcium bicarbonate decomposes to calcium carbonate. This deposits on the sides on the kettle. The water becomes soft.

Permanent hardness: this type of hardness is not easily removed, therefore the name permanent

Permanent hardness is due to calcium sulphate and magnesium sulphate dissolved in the water.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 11

(a) *Hardness in water is of 2 types. One type is temporary hardness as it can be removed by boiling.*
What is the other type of hardness in water?
……
……

(b) i. *Temporary hardness is caused by calcium hydrogen carbonate and by* ……..
ii. The other type of hardness, namely …… is caused by calcium sulphate and by ……

(c) *Suggest how boiling removes temporary hardness.*

You will find the answer at the end of the Module.

POINTS TO REMEMBER

- Carbon dioxide is obtained on a large scale by heating calcium carbonate.
- In the laboratory, carbon dioxide is prepared by reacting together calcium carbonate and hydrochloric acid.
- Oxygen is obtained commercially by the fractional distillation of liquid air.
- Hydrogen is obtained on a large scale using steam and carbon as raw materials.
- Water is a compound of hydrogen and oxygen.
- Water is the only liquid which freezes at 0^0 C and boils at 100^0C.
- Soft water forms a lather readily with soap.
- Hardness in natural samples of water is caused by the presence of magnesium salts and calcium salts in water.

MODULE 5 – UNIT 3

ACIDS AND BASES

TABLE OF CONTENTS

MODULE 5

UNIT 3

ACIDS AND BASES

INTRODUCTION

Acids and Bases belong to an important group of chemicals useful to us in the home and elsewhere too. Think of the vinegar used as a dressing in salads. It is ethanoic acid which is a weak acid.

Fruits like apples and citrus fruits contain acids. The tea we drink contains tannic acid. Hydrochloric acid is secreted in the stomach to assist digestion.

Any substance that can counteract an acid is called ***a base***. You must surely be aware of us using indigestion tablets. Excess hydrochloric acid causes indigestion which is very uncomfortable. To combat this we take tablets containing sodium bicarbonate, a base.

Acid rain is a problem for farmers, as plants cannot tolerate acidic soils. Quicklime is a base added to treat acidic soils. Some fertilizers too contribute to the acidity of the soil.

In the Biology section Module 8 Unit 3 - Section 3.8, we discuss acid rain, please refer to it. In this Unit, we shall look at **Acids and Bases.**

OBJECTIVES

After completing this Unit, you should be able to:

- explain what is meant by acids and bases
- give examples of acids and bases
- describe the properties of acids and bases
- name some natural sources of acids and bases
- define neutralisation
- explain the uses of acids
- explain the uses of alkalis
- classify acids and alkalis into weak and strong ones using pH scale
- prepare an indicator using coloured leaves and flowers

3.0 ACIDS

Acids are substances with sour tastes. In everyday life, we come across a number of acids. Vinegar contains acid - we use it for adding a special touch to salads. When we suffer from indigestion we may be having excess acidity in the stomach.

Do be careful; do not put acids found on your laboratory benches in your mouth. It is dangerous to do so.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

Give the name of each of the acids:

(a) it is present in small quantities in the stomach

……

(b) it is part of the lead acid accumulator in many motor vehicles.

……

(c) it forms the basis of nitrogen - containing fertilisers

……

(d) it is used as a seasoning for green salads

……

(e) it is present in milk which has gone sour

……

(f) it is present in soda water

……

(g) it is present in fruits of the citrous family

……

(h) it is used in preserving a number of fruit juices

……

You will find the answer at the end of the Module.

Acids which are found in laboratories have to be handled with care – especially the concentrated ones. In order to dilute a concentrated acid, water has to be used. It is important to know that for such purposes we should add acid to water (and **never** water to acid).

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 2

So far we have come across a large number of acids.

How can we define an acid?

……

*(a) Name **three** acids which are normally available in the science laboratory.*

(1) ……

(2) ……

(3) ……..

(b) Bottles containing concentrated acids should be handled with care. Why is it so?

……

……

*(c) How is a **concentrated acid** converted into the corresponding **dilute acid**?*

……

……

You will find the answer at the end of the Module.

3.1 BASES

To 'combat' acidity we use substances known as ***bases.*** For instance when we have to cure indigestion due to excess acidity in the stomach, we use 'antacids' that are bases.

You must have seen people rubbing baking soda on bee stings. Again baking soda is a base which counteracts the acidic liquid released by the bee.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 3

Give the chemical names of the following bases

1. *Caustic soda*

   ……..

2. *Caustic potash*

   ……..

3. *Lime water*

   ……..

4. *Slaked lime*

   ……..

5. *Quick lime*

   ……..

You will find the answer at the end of the Module.

3.1.1 BASES – USES & APPLICATION

Bases have a number of uses/applications. These include those in industries, agricultural practices and pharmaceuticals.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 4

Give the name of the base in each case.

1. *It is used in the manufacture of soap.*
   ……..
2. *It is applied to counteract excess acidity of the soil.*
   ……
3. *It is used to prepare paints for concrete walls.*
   ……..
4. *Its solution in water has a strong (pungent) smell. It is used in dry-cleaning for removing stains from clothes.*
   ……
5. *It is used as a reagent for detecting/showing the presence of carbon dioxide.*
   ……

You will find the answer at the end of the Module.

3.1.2 BASES – NATURAL SOURCES

Limestone found in quarries and corals in the sea are natural substances. They have a chemical name i.e. calcium carbonate. When we decompose calcium carbonate on heating, calcium oxide is produced. This is commonly known as ***quicklime***. Quicklime is a base.

3.2 INDICATORS

There are specific reagents we use in order to detect the acidic nature, or otherwise, of a given substance. They are known as *indicators*. In a sense, they indicate the presence or absence of acidity. They comprise a plant dye in solution.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 5

Look around your laboratory.

Identify the indicator, in each case, which is available as

(1) blue strips of paper.

Answer: ……..

(2) an orange solution in water.

Answer: ……

You will find the answer at the end of the Module.

We can now proceed with the following investigation.

INVESTIGATION 1: Testing for an acid

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Blue litmus paper • Methyl orange solution • Dilute hydrochloric acid • Test tubes **Method:** *(a) to a small sample of dilute hydrochloric acid taken in a test tube add a piece of blue litmus paper.* *Record your observations.* …… …… …… *(b) to a small portion of dilute hydrochloric acid taken in a test tube add a few drops of methyl orange.* *Record your observations.* …… …… ……

I am sure that in (a) you noted the **blue** litmus paper turning **red**.

In (b) the solution turns **red.**

Acids turn litmus red.

We can now proceed with the following investigation.

INVESTIGATION 2: Reaction of acids with carbonates

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Dilute hydrochloric acid • Dilute nitric acid • Marble chips (calcium carbonate) • Test tubes **Method:** *(a) In a clean test tube take about 5cm^3 of dilute hydrochloric acid. Now add a few marble chips.* *Record your observations.* …… …… …… *(b) Take about 5cm^3 of dilute nitric acid in a test tube. Add a few marble chips.* *Record your observations.* …… …… ……

I am sure that in both cases you noted bubbles of gas i.e. effervescence. (The gas in both cases is carbon dioxide).

Acids liberate carbon dioxide from carbonates.

We can now proceed with the following investigation.

INVESTIGATION 3: Reaction of acids with some metals

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Dilute hydrochloric acid • Dilute sulphuric acid • Zinc granules • Magnesium ribbon • Test tubes **Method:** *(a) In a test tube take about 5cm^3 of dilute sulphuric acid. Add a few zinc granules.* *Record your observations*. …… …… …… *(b) In a test tube take about 5cm^3 of dilute hydrochloric acid. Add a few strips of magnesium ribbon.* *Record your observations.* …… …… ……

I am sure that in both cases you observed effervescence. (The gas evolved in each case is hydrogen).

Acids liberate hydrogen from some metals like Magnesium and Zinc which are above Hydrogen in the reactivity series.

We can now proceed with the following investigation.

INVESTIGATION 4: Effect of an alkali on some indicators

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Test tube rack with test tubes • Calcium hydroxide solution • Methyl orange indicator • Phenolphthalein indicator **Method:** *(a) In the first test tube take about 3cm^3 of calcium hydroxide solution.* *(b) Drop a piece of red litmus paper, in the test tube.* *(c) To the second add a few drops of methyl orange solution.* *(d) To the third add a few drops of phenolphthalein solution (in alcohol)* **N.B. Phenolphthalein doesn't dissolve in water**. *Record your observations below:* *(a) with litmus* *……..* *(b) with methyl orange* *……..* (c) *with phenolphthalein* *……..*

I am sure that you observed red litmus turning blue in (a).

In (b) a yellow colour should be seen.

In (c) you should have observed a pink colour.

We can now proceed with the following investigation.

INVESTIGATION 5 : Reaction of some alkalis with Ammonium salts.

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Hard glass test tubes • Burner • Test tube holder • Ammonium Sulphate (solid) • Sodium hydroxide solution • Quick Lime (or slaked lime) **Method:** *(a) Take a little ammonium sulphate in a hard-glass test tube. Add about 5cm^3 sodium hydroxide solution. Heat the mixture using a flame.* *Describe the smell.* …… …… *(b) Take half-spoonful of ammonium sulphate crystals in a hard-glass test tube. Now add 1 spoonful of quicklime (or slaked lime). Heat the mixture using a flame.* *Note the smell.* …… ……

I am sure that in both cases you noticed a sharp pungent smell. This smell is of ammonia gas.

Alkalis react with ammonium salts to liberate ammonia gas.

We can now proceed with the following investigation.

INVESTIGATION 6: Reaction of an alkali with Zinc and Aluminium

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** • Boiling tubes • Zinc granules • Aluminium foil • Sodium hydroxide solution **Method:** *(a) In a boiling tube take about 10cm^3 sodium hydroxide solution. Now drop (carefully) aluminium foil in the solution.* *Record your observations* …… …… …… *(b) Repeat (a) using zinc granules instead of aluminium foil.* …… …… *Record your observations* …… …… ……

I am sure that you observed bubbles of a colourless gas. (The gas is hydrogen). Also the reaction mixture becomes hot in each case.

3.2.1 INDICATORS - PREPARATION

We said earlier that indicators are plant dyes. We can prepare them ourselves. The following investigation helps us to do this.

We can now proceed with the following investigation.

INVESTIGATION 7 : Preparing an indicator

For each investigation you will require the materials indicated. **You should record your answers in the space provided.**	**Materials needed:** Petals of roses or dahlias • Coloured leaves • Pestle and mortar • Thin cloth (*or filtration apparatus)* • Water **Method:** *Take a clean pestle and mortar. Using it, grind a mixture of coloured petals and leaves. To the paste, add water, grind again.* *Filter the mixture through a thin cloth (or filtration apparatus). Collect the coloured solution.* *How can you verify that the coloured solution is a simple indicator?* …… …… …… ……

I am sure you thought of testing samples of the coloured solution separate with an acid (e.g. hydrochloric acid) and with a base (e.g. ammonia solution). Different colours should result. Hence the solution extracted from petals and leaves is in fact an indicator.

3.3 NEUTRALISATION

We saw earlier in 1.1 that acids can be 'combated' by 'bases'. In fact we describe the reaction between an acid and a base as ***neutralisation***. An acid can neutralise a base. A base can neutralise an acid. The products of neutralisation are a salt and water.

You can personally experience neutralisation. Get hold of an acid drop sweet if you can and suck it for a few minutes. The sour taste will be obvious because of the citric acid. Now lick some sodium bicarbonate. The sour taste should disappear. The citric acid is neutralised.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 6

Complete the blanks below:

1. *An acid is neutralised by a ……..*

2. *A base is neutralised by an ……*

3. *Thus, neutralisation is a chemical reaction between an …… and a……..*

4. *The main product of a neutralisation reaction is ……*

You will find the answer at the end of the Module.

3.3.1 NEUTRALISATION - APPLICATION

In agriculture, the yields of crops are affected by the nature of the soil. This is because most plants grow best when the soil is not too acidic nor too basic. With acid rain, this balance can be shifted. Excess acidic nature or basic nature can be "corrected" by neutralisation.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 7

(a) *If a soil is found to be too acidic and has to be neutralised, what can be done?*

……

……..

(b) *In case a soil is found to be too basic and has to be made less basic or even neutralised, what has to be done?*

……

……

(c) *At times we suffer from indigestion due to excess acidity in the stomach. What medical treatment is required in such cases?*

……

……..

You will find the answer at the end of the Module.

3.4 TABLE SALT - PREPARATION

Table salt or kitchen salt is sodium chloride. It can be prepared by the neutralisation of sodium hydroxide by hydrochloric acid.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 8

This concerns the preparation of a sample of table salt by neutralisation.

(a) Give the chemical name of table salt

……

……

(b) Name the acid to be used in its preparation.

……

……

(c) Name the base to be used in its preparation.

……

……

(d) In a beaker we take about 20cm^3 of the dilute used acid from (b) and add 2 drops of indicator (methyl orange solution).
We add the base from (c), a little at a time, with stirring/swirling until the red first changes to orange. We now add a spoonful of powdered charcoal and boil (to absorb the indicator).
We filter. We collect the colourless solution. We evaporate off the water carefully from the solution. We are left with a sample of……..

……

……

You will find the answer at the end of the Module.

3.5 THE pH SCALE

To express the acidic nature, basic nature and neutral nature of materials, chemists have designed a numeric scale – the pH scale. It is a scale from 0 to 14. This scale shows how strong or weak an acid or base is.

- Acids have a pH below 7
- Bases have a pH above 7 (up to 14)
- 7 is neutral

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 9

(a) The pH scale is a scale of numbers ranging from …….. to ……..

(b) For solutions which are neutral (neither acidic nor basic) the pH value is ……..

(c) Solutions which are acidic have pH values in the range of ……..

(d) Solutions, which are bases, have pH values in the range of ……..

You will find the answer at the end of the Module.

The acids we commonly come across in the laboratory are sulphuric acid, nitric acid and hydrochloric acid. They are described as 'strong' (pH values 0-4). Strong bases have pH 11-14.

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 10

Acids and bases are separate groups of substances. Each group is subdivided into 'strong' and 'weak'.

*(a) Name two **strong** acids.*

……..

*(b) Name one **weak** acid.*

……..

*(c) Name two **strong** bases.*

……..

*(d) Name one **weak** base.*

……..

(e) What is the pH range for

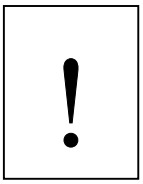
(1) strong acids ……

(2) weak acids ……

(3) strong bases ……

(4) weak bases ……

You will find the answer at the end of the Module.



POINTS TO REMEMBER

- Acids have sour tastes.
- Acids are classified into strong and weak.
- Acids can be neutralised by bases and vice-versa.
- The pH scale ranges from 0 to 14.
- Acids have pH less than 7.
- Bases have pH greater than 7

ANSWERS TO ACTIVITIES

Unit 1

Activity 1

1.	Aluminium	2.	Silver	3.	Gold	4.	Zinc
5.	Copper	6.	Tin	7.	Lead	8.	Mercury
9.	Calcium	10.	Barium				

Activity 2

1.	False	2.	True	3.	True	4.	False
5.	True						

Activity 3

Malleable: can be 'beaten' or hammered into sheets.

Ductile: can be drawn into wires

When we touch a metal, heat from the hand is conducted away by the metal. The hand is cooled.

Activity 4

(a) Iron (b) Aluminium

Activity 5

(a) A metal has positive ions drowned in a '*sea of electrons*'. Attraction between the ions and electrons results in metallic bonding.

(b) A metal has surplus electrons. A non-metal lacks electrons. The metal transfers surplus electrons and becomes positive. The non-metal gains the electrons to become negative. The positive and negative get bonded by attraction.

Activity 6

(i)	Silver, copper	(ii)	Zinc
(iii)	Gold	(iv)	Aluminium, copper
(v)	Aluminium	(vi)	Iron (as stainless steel)
(vii)	Iron	(viii)	Tin
(ix)	Lead	(x)	Zinc

Activity 7

1.	Sulphur	2.	Carbon
3.	Hydrogen	4.	Nitrogen
5.	Phosphorous	6.	Chlorine
7.	Argon	8.	Iodine
9.	Helium	10.	Silicon

Activity 8

(a) Diamond, Graphite, Soot, Lamp-black, Coal

(b) Allotropes - Diamond, Graphite

Activity 9

(a)	Diamond	(b)	Diamond	(c)	Graphite	(d)	Coal
(e)	Graphite	(f)	Diamond	(g)	Diamond		

ANSWERS TO ACTIVITIES

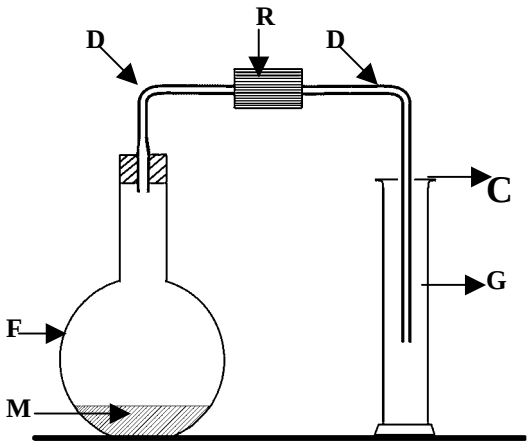
Unit 2

Activity 1

(a) 1st Heating limestone
2nd Fermentation

(b) Carbon dioxide is prepared in the laboratory by the action of dilute hydrochloric acid on marble chips (calcium carbonate).

Lab preparation of carbon dioxide



C	-	Loose cover
D	-	Delivery tube
F	-	Flat bottomed flask
G	-	Gas Jar
M	-	Mixture of Marble chips and hydrochloric acid
R	-	Rubber tubing

Activity 2

(a) (i) It is a colourless gas.
(ii) It is odourless.
(iii) It does **NOT** support combustion.

(b) (i) It turns lime water milky.
(ii) It is absorbed by sodium hydroxide solution.
(iii) When passed over heated carbon, it produces carbon monoxide.

(c) A little lime water is added and shaken. The lime water turns milky.

Activity 3

(i) No (ii) No (iii) Yes (iv) Yes
(v) Yes (vi) Yes

Activity 4

Air is freed from carbon dioxide by absorbing this gas in a sodium hydroxide solution. The remaining air is dried and liquefied. Liquid air contains nitrogen, oxygen and argon. These are separated by fractional distillation. The 3 are collected separately.

Activity 5

(a) (i) It is a colourless gas.
(ii) It is odourless.
(iii) It has no taste.
(iv) It allows substances to burn.
(v) It combines with heated carbon to form carbon dioxide.
(vi) It combines with burning sulphur to produce sulphur dioxide.

(b) (i) In burning substances
(ii) In germination of seeds
(iii) In respiration
(iv) In oxygen tents (in hospitals, clinics).
(v) In bottles used by divers, mountaineers, rescuers etc.

Activity 6

Steam is passed over heated carbon. A mixture of hydrogen and carbon monoxide is produced. It is reacted with steam to produce more hydrogen and carbon dioxide. The latter is absorbed by water. Hydrogen is left.

Activity 7

(a) (i) It is a colourless gas.
(ii) It is tasteless.
(iii) It is without smell.
(iv) It burns with a 'pop' sound.
(v) It is much lighter than air.

(b) (i) In the synthesis of ammonia.
(ii) In converting edible oils into margarine.
(iii) To fill weather balloons.
(iv) To make synthetic petrol.

Activity 8

(a) Rain; River; Lake; Reservoir; Underground sources.
(b) For cleaning/washing; cooking; preparing tea, coffee, milk; drinking.
(c) Cleaning; drinking; irrigating.
(d) In cooling industrial machines; For recreational purposes.

Activity 9

1..	Yes	2.	No	3.	Yes	4.	Yes	5.	No
6.	Yes	7.	Yes	8.	Yes	9.	Yes	10.	No
11.	No								

Activity 10

(a) Calcium Sulphate; Calcium Hydrogen Carbonate
(b) Magnesium Sulphate; Magnesium Hydrogen Carbonate

Activity 11

(a) (i) Permanent hardness

(b) (i) Magnesium hydrogen carbonate

(ii) permanent; magnesium sulphate

(c) When water containing temporary hardness is boiled, the soluble compounds of calcium and magnesium responsible for it are decomposed. The solid products of decomposition get deposited. This temporary hardness is removed.

ANSWERS TO ACTIVITIES

Unit 3

Activity 1

(a) Hydrochloric acid (b) Sulphuric acid

(c) Nitric acid (d) Vinegar (ethanoic acid)

(e) Lactic acid (f) Carbonic acid

(g) Citric acid (h) sulphurous acid

Activity 2

(a) It is a substance characterised by a sour taste.

(b) 1. Sulphuric acid 2. Hydrochloric acid 3. Nitric acid

(c) They are very corrosive to the skin, wood, floor and table tops.

(d) By taking water first and then adding slowly to it the concentrated acid while stirring.

Activity 3

1. Sodium hydroxide 2. Potassium hydroxide
3. Calcium hydroxide solution 4. Calcium hydroxide (solid)
5. Calcium oxide

Activity 4

1. Sodium hydroxide 2. Calcium hydroxide
3. Calcium oxide 4. Ammonia
5. Lime water

Activity 5

1. Litmus 2. Methyl orange

Activity 6

1. Base 2. Acid 3. Acid and base 4. A salt

Activity 7

(a) A sufficient amount of slaked lime can be added.

(b) A suitable compound must be added just sufficient to cancel the basic nature for example, rock sand or organic litter such as poultry litter, beef litter.

(c) Tablets or suitable mixtures of bases are prescribed. They contain magnesium oxide or magnesium hydroxide or aluminium hydroxide.

Activity 8

(a) Sodium chloride (b) Hydrochloric acid (c) sodium hydroxide

(d) table salt

Activity 9

(a) zero to 14 (b) 7 (c) 0 to less than 7

(d) more than 7 to 14

Activity 10

(a) Hydrochloric acid, Nitric Acid

(b) Vinegar (ethanoic acid)

(c) Sodium hydroxide, Potassium hydroxide

(d) Ammonia

(e) 1. 0 – 4 2. 4 – 7

3. 11 – 14 4. 7 - 11