



DEPARTMENT OF EDUCATION

**GRADE 10**

**SCIENCE**

**STRAND 3**



**CHEMICAL REACTIONS**



**FLEXIBLE OPEN AND DISTANCE EDUCATION**  
**PRIVATE MAIL BAG, P.O. WAIGANI, NCD**  
**FOR DEPARTMENT OF EDUCATION**  
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**Writer**

Selected Contract Writers

**Content Editors**

FODE Edit Team

Science Review Committee

**Course Format Editor**

Joydee Mabbagu

# **GRADE 10**

## **SCIENCE**

### **UNIT 3**

#### **CHEMICAL REACTIONS**

**IN THIS UNIT YOU WILL LEARN ABOUT:**

**TOPIC 1: CHEMICAL CHANGES**

**TOPIC 2: REACTIONS OF ACIDS**

**TOPIC 3: REACTIONS OF ORGANIC SUBSTANCES**

**TOPIC 4: ANALYSING MATTER**

**TOPIC 5: CORROSION**

### **Acknowledgement**

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DIANA TEIT AKIS

PRINCIPAL



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Papua New Guinea

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## **SECRETARY'S MESSAGE**

Achieving a better future by individual students and their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is part and parcel of the new reformed curriculum. The learning outcomes are student-centred with demonstrations and activities that can be assessed.

It maintains the rationale, goals, aims and principles of the national curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The course promotes Papua New Guinea values and beliefs which are found in our Constitution and Government Policies. It is developed in line with the National Education Plans and addresses an increase in the number of school leavers as a result of lack of access to secondary and higher educational institutions.

Flexible, Open and Distance Education curriculum is guided by the Department of Education's Mission which is fivefold:

- to facilitate and promote the integral development of every individual
- to develop and encourage an education system that satisfies the requirements of Papua New Guinea and its people
- to establish, preserve and improve standards of education throughout Papua New Guinea
- to make the benefits of such education available as widely as possible to all of the people
- to make the education accessible to the poor and physically, mentally and socially handicapped as well as to those who are educationally disadvantaged.

The college is enhanced through this course to provide alternative and comparable pathways for students and adults to complete their education through a one system, two pathways and same outcomes.

It is our vision that Papua New Guineans' harness all appropriate and affordable technologies to pursue this program.

I commend all the teachers, curriculum writers and instructional designers who have contributed towards the development of this course.

## UNIT INTRODUCTION

---



Dear Student,

Welcome to Unit 3 of your Grade 10 Science Course! I hope that you enjoyed studying the earlier Units. This Unit, Chemical Reactions is a skills course and requires a lot of concentration. If you study well, you will learn a lot. I hope that you will find this unit an enjoyable unit to study as well.

This Unit is based on the Lower Secondary Schools Science Curriculum.

In this Unit, there are five topics which comprises 20 Lessons. The five topics are:

- **Chemical Changes**
- **Reactions of Acids**
- **Reactions of Organic Substances**
- **Analysing Matter**
- **Corrosion**

Each topic has 5 Lessons. The lessons in the first topic will discuss about the chemical changes. They are changes that result in the formation of new chemical substances. At the molecular, chemical changes involve making or breaking of bonds between atoms.

The second topic also has 5 Lessons and will discuss how acids react. When an acid and a base are placed together, they react to neutralise the acid and base properties, producing a salt.

In the third topic, there are four Lessons that will discuss organic reactions. Organic reactions are chemical reactions involving organic compounds. In organic synthesis organic reactions are used in the construction of new organic molecules.

There are also five Lessons in the fourth topic. It is about analysing matter.

The last Topic talks about corrosion.

Remember, you have to do all the activities and carry out the Practice Exercises after each lesson. Answers to the Practice Exercises are at the end of each Topic.

If you have any problems in understanding any of the lessons in this Unit, please do not hesitate to inform the Science Department at FODE Headquarters. This will help the teacher to revise the lessons for the next edition.

You may study this Unit now following the Study Guide on the next page.

All the Best!

## STUDY GUIDE

---

**Follow the steps given below and work through the lessons.**

- Step 1      Start with Topic 1 and work through it in order. You may come across new terms in your lessons which are written in bold with an asterisk (\*) For example in Lesson 1, you will come across **asteroids\***. Words like this will require you to look up their meaning in the glossary section at the end of this book.
- Step 2      When you study Lesson 1, do the Activities. When you complete the Activities, check your work. The answers are given at the end of each Lesson.
- Step 3      After you have completed the Practice Exercise, correct your work. The answers are given at the end of each Topic.
- Step 4      Then, revise and correct any mistake.
- Step 5      When you have completed all of these steps, tick the check box for Lesson 1, on the Contents page, like this:



Lesson 1:      Chemical Change

Then, go on to the next Lesson. Repeat this process until you complete all the Lessons on a Topic. When you have done this, revise using the Review Section.

**Remember, as you complete each lesson, tick the box for that lesson on the Contents page. This will help you check your progress.**

### **Assignment:              Topic Tests and Unit Test**

When you have completed all the lessons in a Topic, do the Topic Test for that Topic, in your Assignment Book. The Unit Book tells you when to do this. When you have completed all the Topic Tests for the Unit, revise well and do the Unit Test. The Assignment Book tells you when to do the Unit test.

When you have completed the entire Assignment Book, check and revise again before sending it to the Provincial Centre. If you have any questions, write them on the Student's page. Your teacher will advise you when he/she returns your marked Assignment.

**The Topic Tests and the Unit Test in each Assignment will be marked by your Distance Teacher. The marks you score in each Assignment will count towards the final result. If you score less than 50%, you will repeat that Assignment.**

Remember, if you score less than 50% in three consecutive Assignments, your enrolment will be cancelled. So, work carefully and ensure that you pass all the Assignments.

## **TOPIC 1**

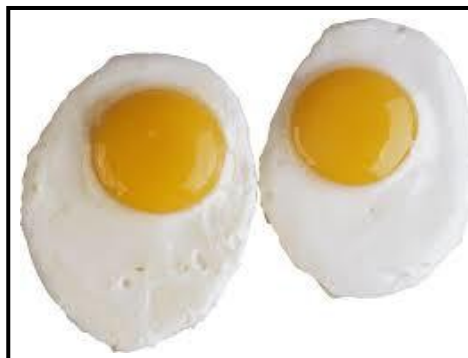
### **CHEMICAL CHANGES**

**In this topic you will learn about:**

- **chemical change**
- **chemical equations**
- **decomposition**
- **precipitation**
- **combustion**

**INTRODUCTION TO TOPIC 1: Chemical Changes**

There are two types of change in matter, physical change and chemical change. As the names suggest, a physical change affects a substance's physical properties, and a chemical change affects its chemical properties. Many physical changes are reversible (such as heating and cooling), whereas chemical changes are often irreversible or only reversible with an additional chemical change.



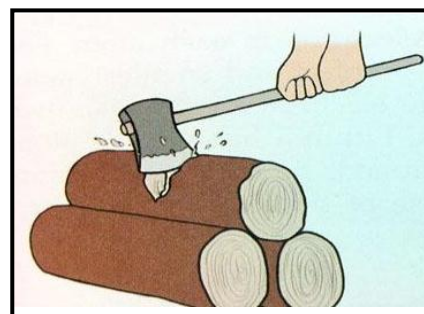
Observations are things or events that are not noticed. A good observer uses all the senses, not just sight. See how good an observer you can be.



A scientist makes a careful record of what is observed. Scientist also try to explain why things happen in terms of what they see and what they already know.

Chemists are interested in two types of change, they are physical and chemical.

Physical changes such as melting, freezing and dissolving do not involve any change in the chemical composition of a substance so you can get back what you started with by reversing the process, example, freezing and melting or dissolving and evaporating.



Chemical changes involve a change in chemical composition in the substances which are being investigated so you cannot easily get back your original substances as something new has been formed.

Some questions will arise such as:

- What is Conservation of Matter?
- Where does a water drop of when it turns into vapour?
- Which weighs more? A whole cookie or a cookie that has been broken and crumbled?
- Why does a balloon inflate when it is put over a bottle where baking soda and vinegar are mixed together?

**In this topic, you will find the answers to these questions and other questions relating to Chemical Changes.**

## Lesson 1: Chemical Change

---



Welcome to Lesson 1. In this lesson we will see substances changing chemically thus displaying different physical and chemical properties. When chemical change occurs a new substance is formed through a re-organisation of the atoms which is irreversible.



### Your Aims:

- identify the signs of chemical change
- define the law of conservation of matter
- distinguish physical change from chemical change

### Chemical Changes

This involves chemical reactions and the creation of new products. Everything you see and touch has the ability to change. Substances change to form new substances is called chemical change. A chemical change is a process in which one or more substances are changed into one or more different substances.

Sometimes substances change but keep the same identity. This is called a **physical change**. As opposed to physical changes, chemical changes are present when the substance undergoes a chemical reaction and produces a new substance. Chemical change results in one or more substances of entirely different composition from the original substances. The elements and compounds at the start of the reaction are rearranged into new products or compounds.

### The law of conservation of matter

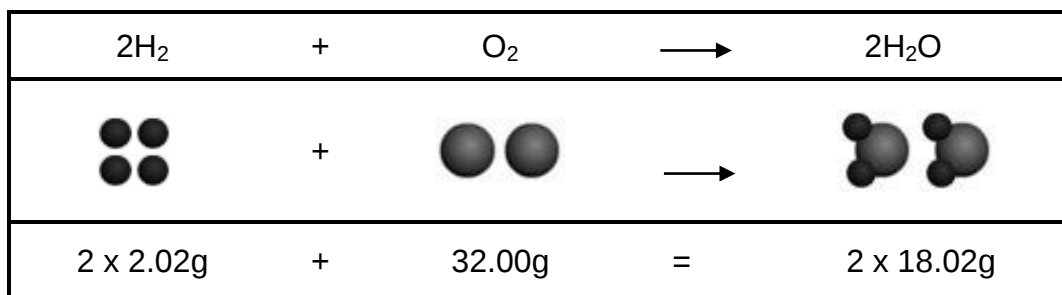
The law of conservation of matter states that matter cannot be created or destroyed in chemical and common physical changes. The particles of one substance are rearranged to form a new substance. The same number of particles that exist before the reaction also exist after the reaction.

Chemical reactions happen all around us for example, when we light a match, start a car, eat dinner, or walk the dog. A chemical reaction is the process by which substances bond together and, in doing so, either release or consume energy. A chemical equation is the shorthand that the scientists use to describe a chemical reaction.

During a chemical reaction, atoms are neither created nor destroyed. The number of atoms remains constant throughout the reaction. Since the number of atoms does not change, the mass must remain constant as well.

Thus, if we have a certain number of atoms of an element on the left side of an equation, we must have the same number on the right side. This implies that mass is also conserved during a chemical reaction.

Let us look at the reaction of water for example:



The total mass of the reactants, 36.04g, is equal to the total mass of the products, 36.04g. This is true for all balanced chemical equations.

### Signs of a chemical change

#### A. Formation of precipitate

There are a number of observations that indicate a chemical change has occurred.

For example, sometimes the pipes in our homes get clogged because precipitates of magnesium and calcium oxides have deposited themselves within the pipes. This can happen with hard water or we call as **bore water**.



Magnesium and Calcium oxides deposited in the pipe

Another example, a precipitate is a solid formed in a chemical reaction that is different from either of the reactants. This can occur when solutions containing **ionic compounds** are mixed and an insoluble product is formed.



Crystals formed a decay of acid precipitate on cooling

#### B. Colour change

A colour change may also indicate that a chemical change has occurred. For example, leaves may change colour when they are dry.

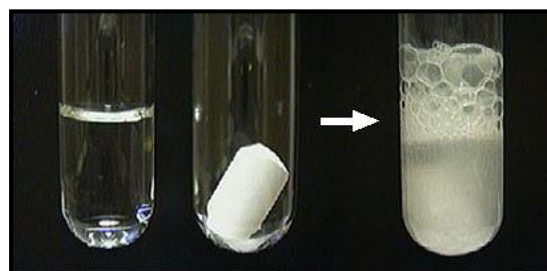


fresh green leaves

dry leaves

#### C. Gas formation

The formation of bubbles when two liquids are mixed also indicates that a gas has been formed. A gas can also be formed when a solid is added to a solution.



When a dispirin tablet is dissolved in water, it begins to bubble. The formation of bubbles is the indicator that a chemical change may have occurred.



- D. Production of heat, light, and sound  
When you look at the fireworks, you see glittering sparkles of red, white and blue trickle down in all directions. The explosion of fireworks is an example of chemical change. It is a violent reaction that has heat, light and sound as the product. The fireworks release energy in a form of light that you can see.



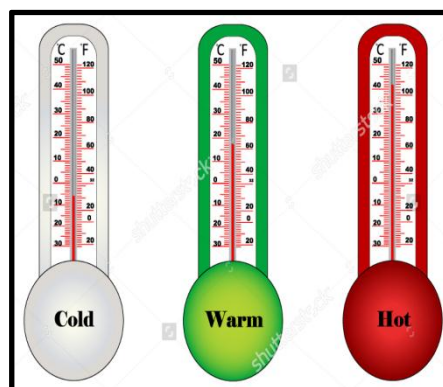
Another sign of a chemical change is the gain of energy by an object. Energy is absorbed during chemical changes for example, baking a cake. When you bake a cake, energy is absorbed by the butter as it changes from a runny mix into a cake.



- E. Noticeable odour  
When two or more compounds or elements are mixed, **odour** is present, a chemical change has taken place. For example, when an egg begins to smell, (a rotten egg) a chemical reaction has taken place. This is the result of a chemical decomposition.



- F. Temperature change  
An increase or decrease in temperature indicates that a chemical change has occurred. Whether a thermometer is available or not, a change in temperature can be detected by felt. If it feels hot, the temperature increased. If it feels cold, the temperature decreased. Since some reactions generate large amounts of heat, you should be very cautious when touching a reaction vessel. Here the temperature increased when two liquid were mixed.



### Differences between physical and chemical changes

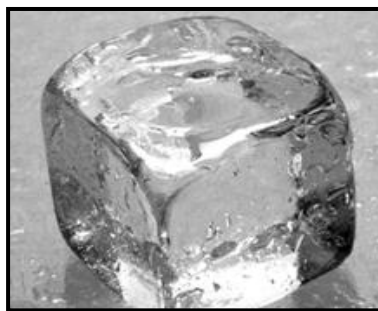
**Physical change** is a change in which the substance changes form but keeps its same chemical composition (reversible). For example, changes of state are considered to be physical changes. A cup of water can be frozen when cooled and then can be returned to a liquid form when heated. Liquid water and ice (frozen water) are both the same substance, water.



Water as steam or water vapour is formed when water is heated to the boiling point or it evaporates.



Water as a liquid is formed when water vapour is cooled or ice is heated.



Ice is formed when water is cooled to the freezing point.

If a piece of paper is cut into small pieces it is still paper. This would be a physical change in the shape and size of the paper. You have changed the form of the paper but you have not changed the fact that it is paper.

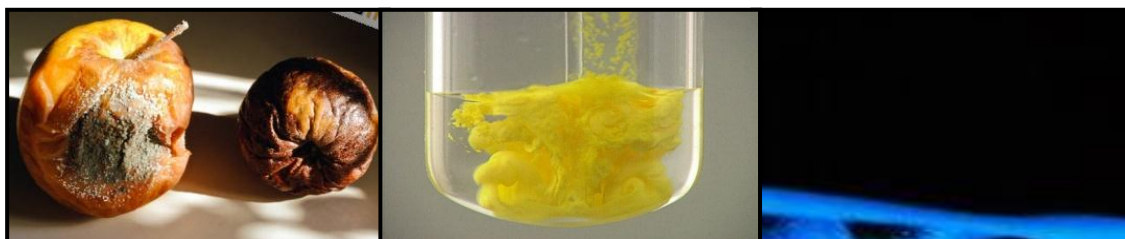
If you heat an iron bar until it glows red hot, it is still chemically the same iron. The iron has not changed into something else.

If you dissolve salt in water you have not changed the materials chemically. You still have salt and you still have water. This can be shown if you choose to separate the mixture by distillation or the simple evaporation of the water. The salt would be the residue and the water would be the distillate.

A **chemical change** is a change of solution resulting in something new being formed (irreversible). The starting materials change into an entirely different substance or substances. This new substance has a different chemical composition than the starting materials. Examples of chemical changes would be the reaction of iron with air (rusting) or the reaction of a metal and an acid.

Certain observations will indicate that a chemical change has occurred. These are

- the reaction produced a change in temperature. The temperature could go up (gets hotter) or the temperature could go down (gets colder).
- formation of gas bubbles.
- formation of a solid (precipitate).
- a change in colour. You may start with two colourless solutions but when they are mixed you might see a bright purple colour.
- formation of a different odour. The starting materials may not smell at all but as you mix these materials you may end up with a bad odour or a pleasant smell.



**Note: Reactions that produce heat are known as exothermic reactions whereas reactions that absorb heat are known as endothermic reactions.**



**Activity:** Now test yourself by doing this activity.

**Circle the letter of the correct answer.**

1. Which is an example of a physical change?

- A. Iron rusting
  - B. A steak cooking
  - C. A candle burning
  - D. Sugar dissolving in water
- 

2. Physical changes are\_\_\_\_\_.

- |                 |                |
|-----------------|----------------|
| A. temporary    | B. permanent   |
| C. irreversible | D. endothermic |
- 

3. An example of a chemical change is

- A. formation of clouds.
  - B. glowing of an electric bulb.
  - C. dropping sodium into water.
  - D. dissolving salt in water.
- 

4. Which of these will cause a chemical change to occur?

- A. Lighting of a gas stove
  - B. Ringing of an electric bell
  - C. Grinding of wheat into flour
  - D. Evaporation of water in a lake
- 

5. Chemical changes are

- A. always accompanied by the exchange of light.
- B. temporary, reversible and a new substance is produced.
- C. permanent, irreversible and a new substance is produced.
- D. never accompanied by the exchange of light and heat energy.

6. Which of the following information is conveyed by a chemical reaction?

- A. The absorption of energy only
  - B. The colour changes taking place
  - C. The structure of the reactants and products
  - D. The masses of the reactants and products involved in the reaction
- 

7. Which one of the following represents a chemical change?

- A. Heating water to form steam
  - B. Sugar dissolving in hot coffee
  - C. Sliced apples, in contact with air and turn brown
  - D. Cutting a bar of sodium metal into pieces with a knife
- 

8. Which one of the following is not a physical change?

- A. Boiling an egg
  - B. Chopping wood
  - C. Making a cup of coffee
  - D. Clothes drying in the dryer
- 

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 1.**



## Summary

You have come to the end of lesson 1. In this lesson you have learnt that:

- physical change is a change in which the substance changes form but keeps its same chemical composition (reversible).
  - a chemical change is a change in which something new is formed (irreversible). The starting materials change into an entirely different substance or substances.
  - signs that a chemical change is taking place are the formation of a solid (precipitate), colour change, formation of gases (bubbles), production of heat or light, noticeable odor and temperature change.
  - a precipitate is a solid formed in a chemical reaction that is different from either of the reactants.
  - reactions that produce heat are known as exothermic reactions.
  - reactions that absorb heat are known as endothermic reactions.
- 

**NOW DO PRACTICE EXERCISE 1 ON THE NEXT PAGE.**

**Practice Exercise 1**

---

**Answer the following questions.**

1. Define the law of conservation of matter.

---

---

2. Differentiate physical change from chemical change.

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---

3. Identify the six (6) signs of chemical reactions.

- |          |          |
|----------|----------|
| a. _____ | d. _____ |
| b. _____ | e. _____ |
| c. _____ | f. _____ |

4. State whether the following changes are physical or chemical.

| CHANGES                    | PHYSICAL/<br>CHEMICAL | CHANGES                     | PHYSICAL/<br>CHEMICAL |
|----------------------------|-----------------------|-----------------------------|-----------------------|
| Melting butter for popcorn |                       | Pouring milk on your cereal |                       |
| Corroding metal            |                       | Bleaching your hair         |                       |
| Glass breaking             |                       | Spoiling food               |                       |
| Burning leaves             |                       | Frying an egg               |                       |
| Hammering nail to wood     |                       | Fireworks exploding         |                       |
| Toasting bread             |                       | Melting ice cream           |                       |

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.**

**Answers to the Activity**

- |      |      |
|------|------|
| 1. D | 5. C |
| 2. A | 6. D |
| 3. C | 7. C |
| 4. A | 8. A |

## Lesson 2: Chemical Equations

---



Welcome to Lesson 2. You have learnt from the previous lesson what a chemical change is and the differences between physical and chemical changes. You also have learnt the different signs of a chemical change. For this lesson, you will be studying about chemical equations.



### Your Aims:

- define chemical equations
- identify the steps in writing chemical equation
- write word equations into chemical equations and balance them

### What is a Chemical Equation?

A chemical equation is a short form of expression for describing a chemical change. It is most important for a chemist to be able to write correctly balanced equations and to interpret equations written by others. It is also very helpful if he/she knows how to predict the products of certain specific types of reactions.

Chemical equations show the

- reactants which enter into a reaction
- products which are formed by the reaction
- amounts of each substance used and each substance produced.

Things to Remember About Writing Equations:

- Every chemical compound has a formula which cannot be altered.
- A chemical reaction must account for every atom that is used. This is an application of the Law of Conservation of Matter which states that in a chemical reaction atoms are neither created nor destroyed.
- The **diatomic elements** when they stand alone are always written  $H_2$ ,  $N_2$ ,  $O_2$ ,  $F_2$ ,  $Cl_2$ ,  $Br_2$ ,  $I_2$ .
- The sign ( $\rightarrow$ ) means “produces” and shows the direction of the action.
- Before balancing an equation, check the formula to see that it is correct. **Never** change a formula during the balancing of an equation.
- Balancing is done by placing coefficients in front of the formulas to ensure the same number of atoms of each element on both sides of the arrow.

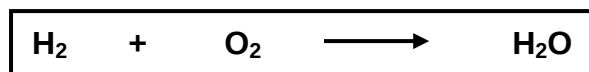
### Steps in writing a balanced equation for a chemical reaction

1. Determine the reactants and the products.
2. Write the **un-balanced** equation using formulas of reactants and products.
3. Write **balanced** equation by determining the coefficients that provide equal numbers of each type of atom on each side of the equation (generally, whole number values).

**Note:** Subscripts should **never** be changed when trying to balance a chemical equation. Changing a subscript changes the actual identity of a product or reactant. Balancing a chemical equation only involves changing the relative amounts of each product or reactant.

### Writing balanced chemical equations

Chemical reactions are represented on paper by **chemical equations**. For example, hydrogen gas ( $\text{H}_2$ ) can react (burn) with oxygen gas ( $\text{O}_2$ ) to form water ( $\text{H}_2\text{O}$ ).



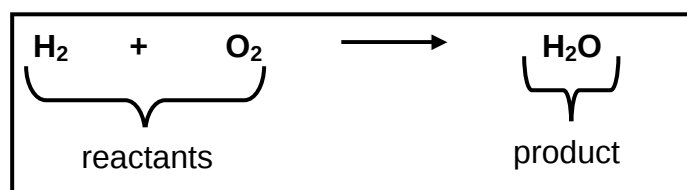
This equation is **not** balanced.

There are 2 atoms of Hydrogen on the left and 2 on the right, but while there are 2 atoms of Oxygen on the left there is only 1 on the right. Something is not correct. Atoms cannot just disappear.

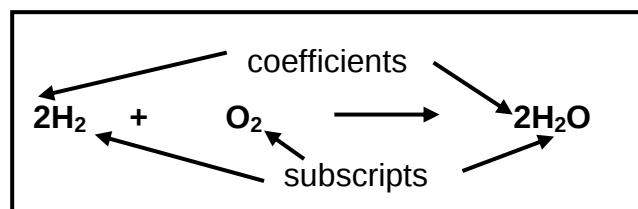
You might want to change the formula of water to  $\text{H}_2\text{O}_2$ , but  $\text{H}_2\text{O}_2$  is Hydrogen Peroxide, very strong bleach. If you drank a bottle of  $\text{H}_2\text{O}_2$  it would probably kill you.

You cannot change the formula of a substance to try to **balance** the equation. You might also be tempted to write Oxygen as just  $\text{O}$ , but Oxygen is a di-atomic gas. It exists as two atoms bonded together. It must be written as  $\text{O}_2$ .

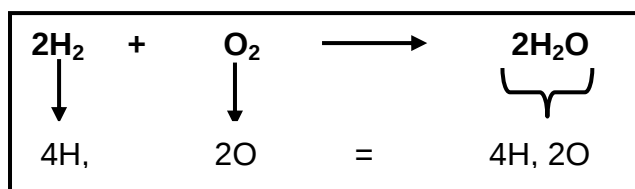
The chemical equation for this reaction is written as:



The '+' is read as 'reacts with' and the arrow means 'produces'. The chemical formulas on the **left** represent the starting substances, called **reactants**. The substances produced by the reaction are shown on the **right**, and are called **products**. The numbers in front of the formulas are called **coefficients** (the number '1' is usually omitted).



Because atoms are neither created nor destroyed in a reaction, a **chemical equation must have an equal number of atoms of each element on each side of the arrow** (the equation is said to be 'balanced').

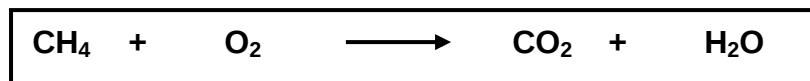


Now, let us have some more examples.

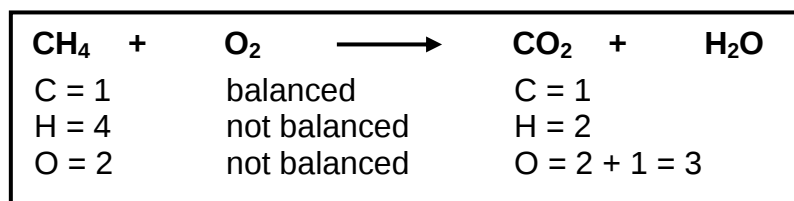
### Example 1

Consider the reaction of burning the gas methane ( $\text{CH}_4$ ). We know that this reaction consumes oxygen ( $\text{O}_2$ ) and produces water ( $\text{H}_2\text{O}$ ) and carbon dioxide ( $\text{CO}_2$ ).

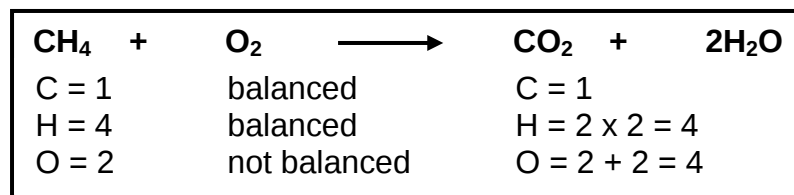
Thus, we have accomplished step #1 (writing the balance equation) above. We now write the **unbalanced chemical equation** (step #2):



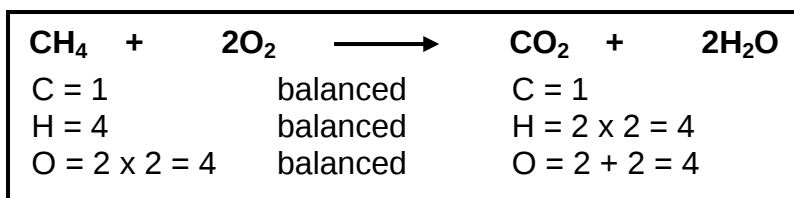
Now let us count the atoms in the reactants and products:



We seem to be fine with our number of carbon atoms in both the reactants and products, but we have only half the hydrogen in our products as in our reactants. We can fix this by doubling the relative number of water molecules in the list of products:



Note that while this has balanced our carbon and hydrogen atoms, we now have 4 oxygen atoms in our products, and only have 2 in our reactants. We can balance our oxygen atoms by doubling the number of oxygen atoms in our reactants:



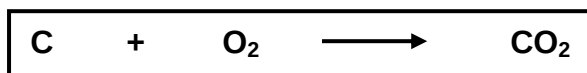
We now have fulfilled step #3, we have a **balance chemical equation** for the reaction of methane with oxygen.

Thus, **one molecule of methane reacts with two molecules of oxygen to produce one molecule of carbon dioxide and two molecules of water.**

When balancing an equation one trick is to focus on just **one** element at a time. Do not try and do it all in your head. Choose an element, balance it and then in the next step worry about how your attempt at balancing has effected other elements.

**Example 2**

When Carbon burns in Oxygen it produces Carbon dioxide. An **equation** would represent this reaction as:

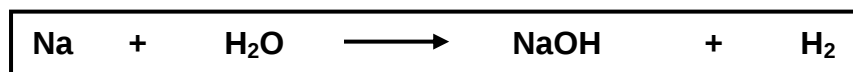


The equation would be read as: Carbon reacts with Oxygen to form Carbon dioxide. If you count the numbers of atoms of each element on each side of the arrow (1 carbon atom and 2 Oxygen atoms on the left and 1 Carbon and 2 Oxygen atoms on the right) you will see that the numbers are **equal**. This is where the term "equation" comes from.

The number of atoms of each element on the left of the arrow must equal the number of atoms of each element on the right of the arrow.

**Example 3**

Consider the reaction between water and Sodium metal to produce Sodium hydroxide and Hydrogen gas. (This is a **very** violent reaction. The Hydrogen gas usually ignites, resulting in several reactions occurring at the same time.)

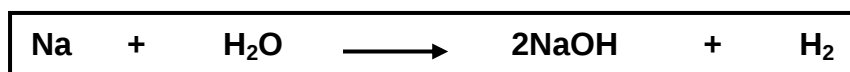


This equation is **not** balanced.

The Na is alright. We will look at the Hydrogen. Hydrogen has two atoms on the left and three on the right. Another trick in balancing equations is to **eliminate 'odd'** numbers.

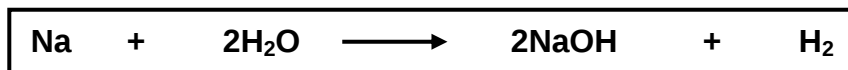
**Steps in Balancing**

1. To eliminate the odd number of Hydrogen we put a '2' in front of the NaOH on the right.



We now have two hydrogen on the left and four on the right. (Ignore the Sodium for a while.)

2. To balance the Hydrogen we put a two in front of the H<sub>2</sub>O on the left.



We now have four hydrogen on the left and four on the right. We now need to look at the Sodium. There is one sodium on the left and two on the right.

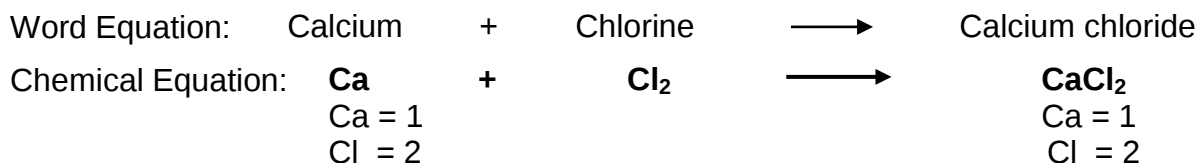
3. Put a two in front of the **Na** on the left.



This means that when the Sodium metal reacts with water, two atoms of Sodium combine with two molecules of water to produce two molecules of Sodium hydroxide and one molecule of Hydrogen gas.

#### Example 4

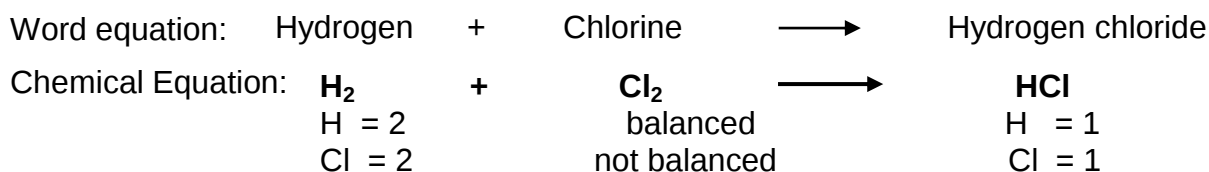
Calcium burns in chlorine to form Calcium chloride.



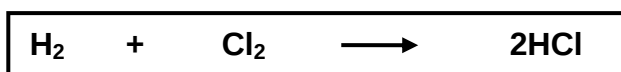
The equation is balanced.

#### Example 5

In industry, Hydrogen chloride is formed by burning hydrogen in chlorine.



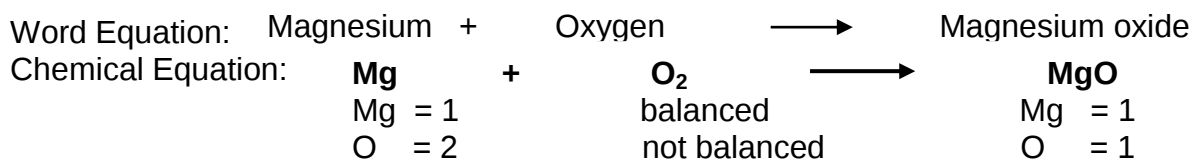
The equation is **not** balanced. It needs another molecule of Hydrogen chloride on the right. So, a 2 is put **in front of** the HCl.



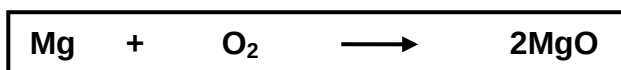
The equation is now balanced.

#### Example 6

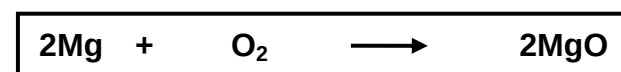
Magnesium burns in oxygen to form magnesium oxide, a white solid.



The equation is **not** balanced. Put 2 in front of the MgO.



Another magnesium atom is now needed on the left.



The equation is balanced.



**Activity:** Now test yourself by doing this activity.

**Circle the letter of the correct answer.**

- Which of the following is **not** a diatomic molecule?  

A. Boron

B. Oxygen

C. Nitrogen

D. Hydrogen
- A substance that accelerates a chemical reaction but can be recovered unchanged is known as a \_\_\_\_\_.  

A. product

B. reactant

C. catalyst

D. precipitate
- You look at a chemical equation and notice that a triangle is written on top of the arrow. What does the triangle indicate?  

A. The reactants are heated

B. Three reactants are required

C. A secondary path in the reaction

D. Electricity is required for the reaction
- Which is used to indicate a reactant or product in an aqueous solution (dissolved in water)?  

A. (d)

B. (a)

C. (aq)

D. (l)
- What are used to indicate the molar quantities of reactants and products in an equation?  

A. Subscripts

B. Coefficients

C. Superscripts

D. Molar masses
- In order to properly balance an equation, which numbers are added or changed?  

A. Subscripts

B. Coefficients

C. Superscripts

D. Molar masses

7. The correct balanced equation for  $\text{Fe}_2 + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 + \text{SO}_2$  is.

- A.  $2\text{FeS}_2 + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 + 4\text{SO}_2$
- B.  $2\text{FeS}_2 + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 4\text{SO}_2$
- C.  $4\text{FeS}_2 + 4\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 2\text{SO}_2$
- D.  $4\text{FeS}_2 + 11\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 8\text{SO}_2$

---

**NOW DO PRACTICE EXERCISE 2 ON THE NEXT PAGE.**



## Summary

You have come to the end of lesson 2. In this lesson you have learnt that:

- a chemical equation is a chemist's shorthand expression for describing a chemical change.
- chemical equations show the reactants which enter into a reaction, the products which are formed by the reaction and the amounts of each substance used and each substance produced.
- the numbers in front of the formulas are called coefficients (the number '1' is usually omitted).
- a chemical equation must have an equal number of atoms of each element on each side of the arrow to be balanced.
- here are things to remember about writing equations:
  - every chemical compound has a formula which cannot be altered.
  - a chemical reaction must account for every atom that is used. This is an application of the Law of Conservation of Matter.
  - the diatomic elements when they stand alone are always written  $\text{H}_2$ ,  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$ .
  - never change a formula during the balancing of an equation.
  - balancing is done by placing coefficients in front of the formulas to insure the same number of atoms of each element on both sides of the arrow.
  - subscripts should never be changed when trying to balance a chemical equation. Changing a subscript changes the actual identity of a product or reactant.
- steps in writing a balanced equation for a chemical reaction:
  - determine the reactants and the products.
  - write 'un-balanced' equation using formulas of reactants and products.
  - Write 'balanced' equation by determining coefficients that provide equal numbers of each type of atom on each side of the equation (generally, whole number values).

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**CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 2.**



## Practice Exercise 2

Answer the following questions.

1. Define chemical equation.

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2. Identify the steps in writing chemical equation.

Steps in writing a balanced equation for a chemical reaction:

- a. 

---
- b. 

---
- c. 

---

3. Balance the following equations:

- a. Sodium + chlorine  $\longrightarrow$  Sodium chloride  
Na + Cl<sub>2</sub>  $\longrightarrow$  NaCl
- b. Hydrogen + Iodine  $\longrightarrow$  Hydrogen iodide  
H<sub>2</sub> + I<sub>2</sub>  $\longrightarrow$  HI
- c. Carbon + Carbon dioxide  $\longrightarrow$  Carbon monoxide  
C + CO<sub>2</sub>  $\longrightarrow$  CO
- d. Sodium + Water  $\longrightarrow$  Sodium hydroxide + Hydrogen gas  
Na + H<sub>2</sub>O  $\longrightarrow$  NaOH + H<sub>2</sub>
- e. Sulphur + Oxygen  $\longrightarrow$  Sulphur dioxide  
S + O<sub>2</sub>  $\longrightarrow$  SO<sub>2</sub>

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.**

### Answers to Activity

- |    |   |    |   |
|----|---|----|---|
| 1. | A | 5. | B |
| 2. | C | 6. | B |
| 3. | A | 7. | D |
| 4. | C |    |   |

## Lesson 3: Decomposition



Welcome to Lesson 3. You have learnt from the previous lesson that a chemical equation is a chemist's shorthand expression for describing a chemical change. Chemical equations show the reactants which enter into a reaction, the products which are formed by the reaction and the amounts of each substance used and each substance produced. You also learned that a chemical equation must have an equal number of atoms for each element on each side of the arrow for it to be balanced.



### Your Aims:

- define decomposition reaction
- identify the types of decomposition reaction
- balance decomposition reactions from a given equation

### What is Decomposition Reaction?

A decomposition reaction is a type of chemical reaction in which a single compound breaks down into two or more elements or new compounds as shown below:

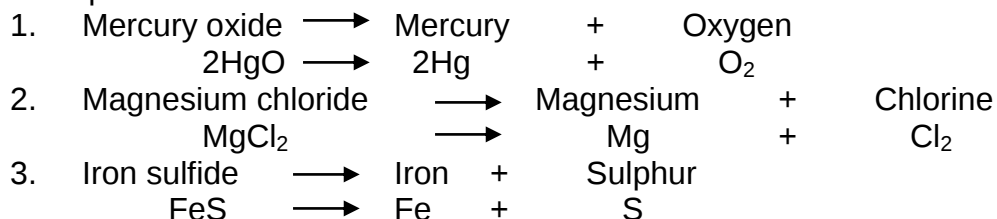
Written using generic symbols, it is usually shown as:



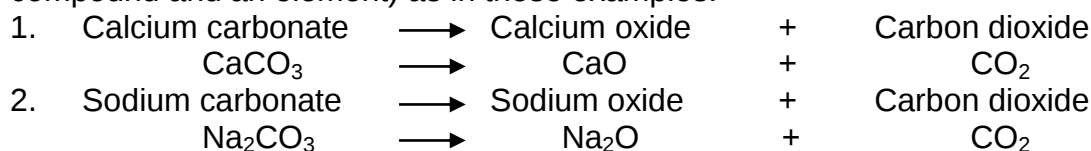
All the reactions in this lesson have one thing in common, one reactant. These reactions involve an energy source such as heat, light, or electricity that breaks apart the bonds of compounds.

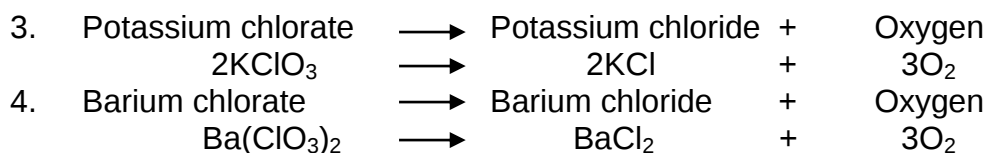
Important notes to remember: None of the equations are balanced and make sure to write correct formulas. Do not just copy the subscripts from the reactants over into the products. During decomposition, one compound splits apart into two (or more pieces). These pieces can be elements or simpler compounds.

However, that really only works for splitting apart into the elements, like these examples.



Decomposition can also split one compound into two simpler compounds (or compound and an element) as in these examples:





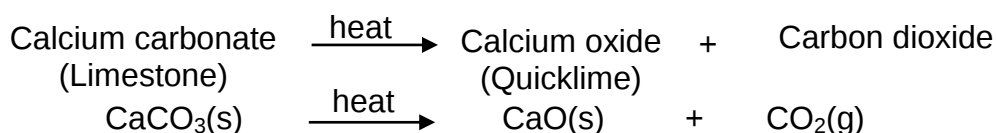
Notice how, in every case so far, there is only one substance on the left-hand (reactant) side. This is always the case in a decomposition reaction.

### Types of decomposition reaction

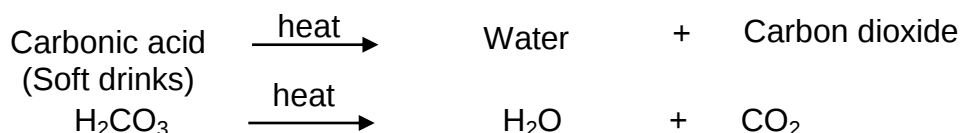
#### 1. By heat

Decomposition by heat is called **thermal decomposition**.

An example is the industrial preparation of lime (calcium oxide) involving the decomposition of calcium carbonate (limestone) by heating it. This reaction is carried out on a large scale in lime ovens. The quicklime that is produced in the reaction is used on soil to make it less acidic and to make a mortar.

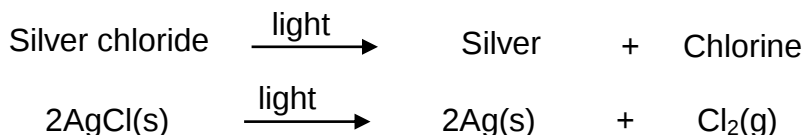


Carbonates will decompose when heated, a notable exception being that of carbonic acid,  $\text{H}_2\text{CO}_3$ . Carbonic acid, the "fizz" in sodas, pop cans and other carbonated beverages, will decompose over time (spontaneously) into carbon dioxide and water



#### 2. By light

Silver chloride is a white solid. If you expose it to daylight, it quickly breaks down to give tiny black crystals of silver.

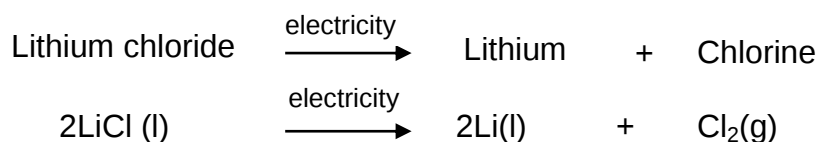


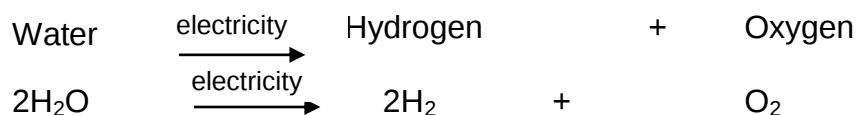
Silver bromide and silver iodide decompose in the same way. These reactions are important in photography.

#### 3. By electrolysis

A powerful way to decompose a substance is to pass electricity through it.

For example, if you connect two graphite rods to a battery and stand them in molten lithium chloride, the lithium chloride decomposes. You get silver beads of silvery lithium at one rod and bubbles of chlorine gas at the other.

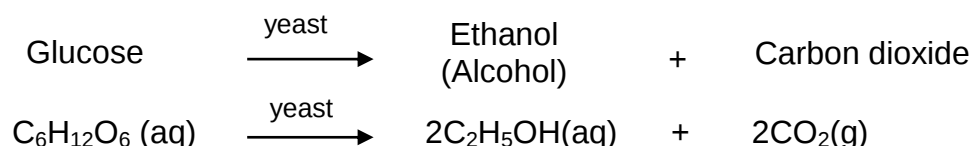




The process is called **electrolysis** and it is very important in industry. For example, it is used to extract aluminium from its ore, and to get chlorine from sodium chloride.

4. By fermentation

Like all other living organisms, yeast and bacteria need to feed. They do so by producing enzymes that cause decomposition. For example, yeast produces an enzyme that breaks down the sugar glucose from fruit and grains into ethanol (alcohol) and carbon dioxide. This process is called fermentation. It releases energy which the yeast cells use to multiply.



Without fermentation, the beer and wine industries would not exist.



**Activity:** Now test yourself by doing this activity.

**Answer all questions according to the given instructions.**

Encircle the best answer.

1.  $2\text{HgO} \rightarrow 2\text{Hg} + \text{O}_2$  is an example of a decomposition reactions

A. True

B. False

2. When water decomposes ( $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$ ) what two elements are produced?

A. Oxygen in the form of a liquid and Hydrogen in the form of gas.

B. Oxygen and Hydrogen in a liquid form.

C. Oxygen in the form of a gas and hydrogen in liquid form.

D. Oxygen and Hydrogen in the form of gases.

3.  $2\text{N}_2\text{O}_5 \longrightarrow \text{O}_2 + 4\text{NO}_2$ , is what type of chemical equation?

A. Synthesis

B. Decomposition

C. Single Replacement

D. Double Displacement

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 3.**



## Summary

You have come to the end of lesson 2. In this lesson you have learnt that:

- a chemical equation is a chemist's shorthand expression for describing a chemical change.
- written using generic symbols, it is usually shown as:  
$$AB \longrightarrow A + B$$
- types of decomposition reaction; by heat, light, electrolysis, and fermentation.

---

**NOW DO PRACTICE EXERCISE 3 ON THE NEXT PAGE.**



## Practice Exercise

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### Answer the following:

Write correct formulas for the decomposition reaction. Note that none of the example below are balanced.

- 1) Nickel chlorate  $\text{Ni}(\text{ClO}_3)_2 \longrightarrow \text{NiCl}_2 + \text{O}_2$
- 2) Silver oxide  $\text{Ag}_2\text{O} \longrightarrow \text{Ag} + \text{O}_2$
- 3) Nitrous acid  $\text{HNO}_2 \longrightarrow \text{N}_2\text{O}_3 + \text{H}_2\text{O}$
- 4) Iron hydroxide  $\text{Fe}(\text{OH})_3 \longrightarrow \text{Fe}_2\text{O}_3 + \text{H}_2\text{O}$
- 5) Zinc carbonate  $\text{ZnCO}_3 \longrightarrow \text{ZnO} + \text{CO}_2$
- 6) Cesium carbonate  $\text{Cs}_2\text{CO}_3 \longrightarrow \text{Cs}_2\text{O} + \text{CO}_2$
- 7) Aluminium hydroxide  $\text{Al}(\text{OH})_3 \longrightarrow \text{Al}_2\text{O}_3 + \text{H}_2\text{O}$
- 8) Sulfuric acid  $\text{H}_2\text{SO}_4 \longrightarrow \text{SO}_3 + \text{H}_2\text{O}$
- 9) Rubidium chlorate  $\text{RbClO}_3 \longrightarrow \text{RbCl} + \text{O}_2$
- 10) Radium chloride  $\text{RaCl}_2 \longrightarrow \text{Ra} + \text{Cl}_2$

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|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.</b> |
|------------------------------------------------------------|

### Answers to Activity

1. A
2. C
3. A
4. C
5. B
6. B

## Lesson 4: Precipitation

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Welcome to Lesson 4. In Lesson 3 you learned about decomposition reaction and its different types. In this lesson you will learn about precipitation.



### Your Aims:

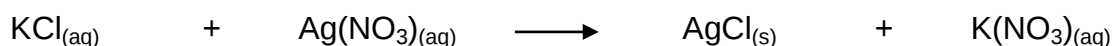
- distinguish precipitate from precipitation
- describe precipitation
- identify uses of precipitation
- give examples of precipitation and balance the reactions

### Precipitation and Precipitate

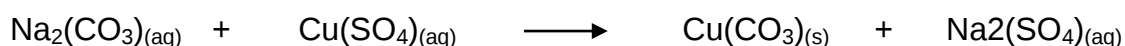
When clear solutions of two substances are mixed, they react to produce a finely divided solution. A solid produced by reaction between two clear solutions is called a **precipitate**, and such reactions are called **precipitation reactions**. The verb, to precipitate, means to fall out – solids fall out of solution.

Common examples of precipitation reaction are as follows:

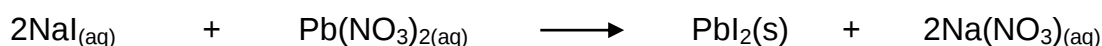
1. When colourless solutions of potassium chloride and silver nitrate are mixed, a white precipitate of silver chloride is formed.



2. When a colourless solution of sodium carbonate is added to a clear blue solution of copper sulphate, a pale blue precipitate of copper carbonate forms.



3. Colourless solutions of sodium iodide and lead nitrate react to form a bright yellow precipitate of lead iodide.

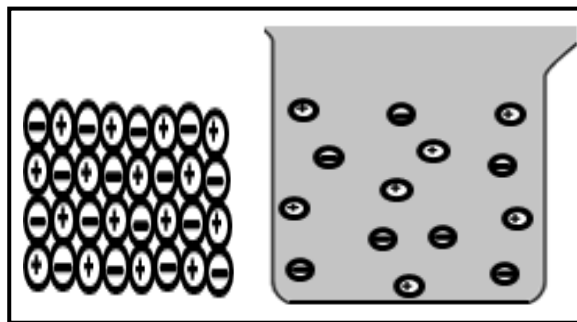


To understand why precipitates form when certain solutions are mixed, we need to recall the nature of ionic solutions (solutions made of positive and negative ions).

When solid ionic substances are dissolved in water, the crystals break up into individual ions which disperse throughout the whole solution. A crystal of sodium chloride consists of  $\text{Na}^+$  and  $\text{Cl}^-$  ions (ions are charged particles) packed closely together in an orderly array as shown in diagram overleaf. When the crystal is dissolved in water, it breaks up and the ions disperse throughout the whole solution.

A sodium chloride solution consists of individual  $\text{Na}^+$  and  $\text{Cl}^-$  ions moving independently and randomly throughout the whole volume of liquid as shown in diagram below.

A crystal of sodium chloride consists of an orderly packing of  $\text{Na}^+$  and  $\text{Cl}^-$  ions. On the right side is a solution of sodium chloride in water consisting of separated  $\text{Na}^+$  and  $\text{Cl}^-$  ions dispersed uniformly throughout the water.



When solutions of zinc sulphate and magnesium nitrate are mixed, the resulting solution consists of  $\text{Zn}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Mg}^{2+}$  and  $\text{NO}_3^-$  ions all moving randomly throughout the whole volume of liquid. This mixed solution is identical with one formed by mixing solutions of zinc nitrate and magnesium sulphate. Both mixed solutions contain the same four types of ion moving freely around. Similarly, a mixture of solutions of sodium chloride and copper sulphate is identical with a mixture of solutions of sodium sulphate and copper chloride – both mixtures consist of  $\text{Na}^+$ ,  $\text{Cu}^{2+}$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  ions moving randomly throughout the whole volume.

The 'driving force' behind a precipitation reaction is the formation of an insoluble substance for the precipitate. When solutions of two ionic substances are mixed, precipitation occurs if one type of positive ion present can combine with one type of negative ion present to form the precipitate.

**Precipitation is a chemical reaction in which insoluble salts are made. When two chosen solutions are added, the insoluble salt precipitates.**



## Summary

You have come to the end of lesson 4. In this lesson, you have learnt that:

- precipitate is a solid produced by reaction between two clear solutions.
- precipitation reaction is a reaction when a solid is formed by reaction between two clear solutions.
- a white precipitate of silver chloride is formed when colourless solutions of potassium chloride and silver nitrate are mixed.

**NOW DO PRACTICE EXERCISE 4 ON THE NEXT PAGE.**



## Practice Exercise 4

---

**Answer the following questions:**

1. Mixed solutions of what pairs of substances would be identical to solutions containing mixtures of:

- a) sodium sulphate and magnesium nitrate? \_\_\_\_\_  
b) aluminium chloride and copper sulphate? \_\_\_\_\_

- 
2. Name and give the formula of the precipitate which forms, when solutions of the following pairs of substances are mixed.

- a) sodium chloride and silver nitrate: \_\_\_\_\_  
b) lead nitrate and ammonium sulphate: \_\_\_\_\_  
c) zinc sulphate and potassium carbonate: \_\_\_\_\_

- 
3. Write balanced equations of those reaction in question 2.

- a) \_\_\_\_\_  
b) \_\_\_\_\_  
c) \_\_\_\_\_

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|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 4.</b> |
|------------------------------------------------------------|

## Lesson 5: Combustion Reaction



Welcome to Lesson 5. You have learnt from the previous lesson about decomposition reaction. Synthesis reaction is a reaction in which two or more elements or compounds combine to form a single product. In essence, synthesis is the reversal of a decomposition reaction.



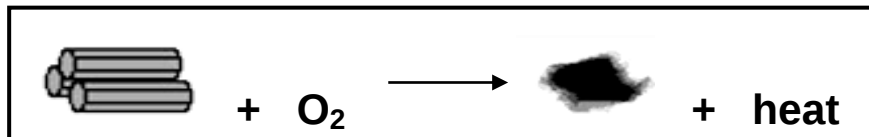
### Your Aims:

- define combustion
- give different examples of combustion
- balance combustion reactions from a given equation

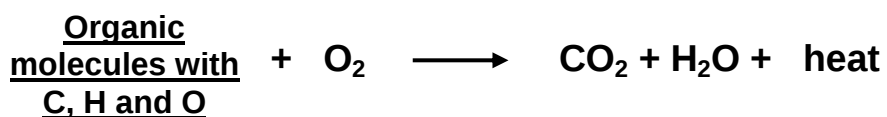
### What is Combustion?

**Combustion** is the burning of a fuel with the production of energy or heat. Combustion reactions always involve oxygen gas ( $O_2$ ). Anything that burns is always a combustion reaction. Combustion reactions require oxygen and always exothermic (they give off heat).

For example when wood burns, it must do so in the presence of  $O_2$  and a lot of heat is produced.



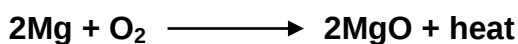
Wood as well as many common items that combust are organic (they are made up of carbon, hydrogen and oxygen). When organic molecules combust; the reaction products are carbon dioxide and water (as well as heat).



For example consider the combustion of methanol (rubbing alcohol):



Not all combustion reactions release carbon dioxide ( $CO_2$ ) and water ( $H_2O$ ) and the combustion of magnesium metal:



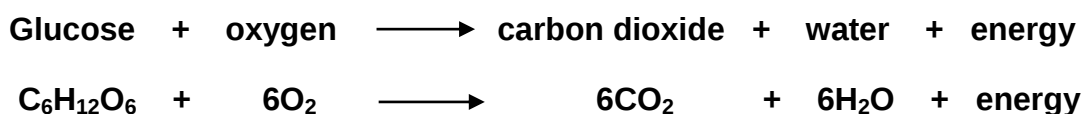
A combustion reaction takes place when a fuel and an oxidant react, producing heat or heat and light. The most recognizable form of combustion reaction is flame, with explosions being an even faster form of combustion reaction. Combustion can happen at a wide range of speeds, and can occur in many different environments, but the majority of combustions we know and recognize are limited.

Combustion reactions are an essential part of our lives: the burning of gas, coal, petrol and oil are all combustion reactions. The heat they give off is used to cook food, warm houses and drive engines.

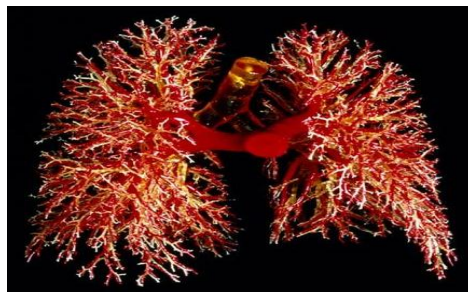
### Examples of Combustion Reactions

#### A. Cellular respiration

**Cellular respiration** is the process whereby cells in our bodies obtain energy. This is the process that keeps us alive. During respiration, oxygen reacts with glucose in our bodies producing carbon dioxide and water with the release of energy.



The glucose comes from digested food, and the oxygen from air. When we breathe in, air travels to our lungs. It passes along tiny tubes to the surface of the lungs. There the oxygen diffuses through the surface, into the blood. The blood carries it to the cells, along with glucose from digested food. There are millions of cells in the body. Respiration takes place in each one.



The carbon dioxide and water pass from the cells back into the blood. The blood carries them to the lungs, and we breathe them out. Respiration goes on in the cells of **all** living things, not just humans. Fish use the oxygen dissolved in water, which they take in through their gills. Plants use oxygen from the air, and take it in through tiny holes in their leaves. The energy from respiration keeps our hearts and muscles working. It also keeps us warm.

#### B. The combustion of fossil fuels

Fuels are substances we burn to get energy which is usually in the form of heat. The burning needs oxygen. North Sea gas is a fuel. It is mainly methane. It is pumped to towns and cities from gas wells in the North Sea.



In the pipes of a cooker, the methane mixes with air. When the mixture is lit, the methane reacts with oxygen in the air. The reaction gives out energy as heat and light. The heat is used to cook food.

Fossil fuels are made up of hydrocarbons. **Hydrocarbons** are compounds that contain the elements hydrogen and carbon. Examples are methane ( $\text{CH}_4$ ), propane ( $\text{C}_3\text{H}_8$ ), butane ( $\text{C}_4\text{H}_{10}$ ) and octane ( $\text{C}_8\text{H}_{18}$ ).

Hydrocarbons readily burn or undergo combustion reactions. Combustion may be complete or incomplete.

The **complete combustion** of fossil fuels results in the production of carbon dioxide and water.

The **incomplete combustion** of fossil fuels results in the formation of carbon (soot) and water.

Other examples are:

1. Complete combustion of methane: Burns with a blue flame

Methane + oxygen  $\longrightarrow$  carbon dioxide and water



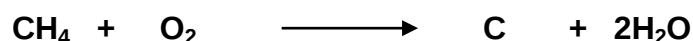
2. Incomplete combustion of methane producing carbon monoxide and water

Methane + oxygen  $\longrightarrow$  carbon monoxide and water



3. Incomplete combustion of methane producing carbon (soot) and water: Burns with a yellow flame

Methane + oxygen  $\longrightarrow$  carbon and water



As the amount of oxygen is decreased from 2 to 1.5 to 1 in the above three equations the combustion products respectively move from carbon dioxide to carbon monoxide to carbon or soot. As the soot is heated in the flame, it produces a yellow flame. In real life there is a mixture of carbon monoxide and soot from the incomplete combustion of hydrocarbons as well as unburnt hydrocarbons.

### Sample Exercise 1

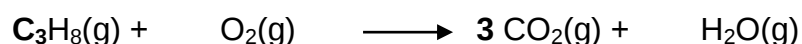
Write a balanced chemical equation for the complete combustion of propane gas -  $\text{C}_3\text{H}_8$ .

Hydrocarbon + Oxygen  $\longrightarrow$  Carbon dioxide + Water



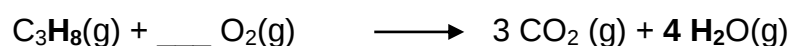
1. Balance C first:

3 C on the left -- multiply  $\text{CO}_2$  by 3 to get 3 C on the right



2. Balance H second:

8 H on the left -- multiply  $\text{H}_2\text{O}$  by 4 to get 8 H on the right



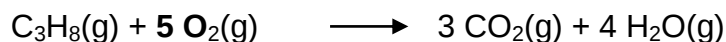
## 3. Balance O last:

We have two sources of O on the right:

$$3 \times \text{CO}_2 = 6 \text{ O}$$

$$4 \times \text{H}_2\text{O} = 4 \text{ O}$$

Thus we have 10 O on the right -- multiply  $\text{O}_2$  by 5 to get 10 O on the left.

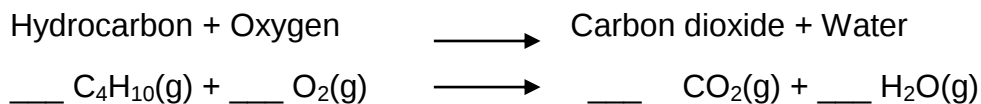


Do a recheck of the whole equation:

| Left   | Right |
|--------|-------|
| • 3 C  | 3 C   |
| • 8 H  | 8 H   |
| • 10 O | 10 O  |

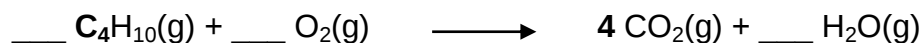
**Sample Exercise 2**

Write a balanced chemical equation for the complete combustion of butane gas  $\text{C}_4\text{H}_{10}(\text{g})$ .



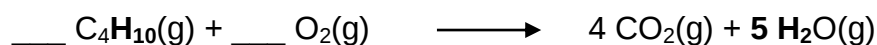
## 1. Balance C first:

4 C on the left -- multiply  $\text{CO}_2$  by 4 to get 4 C on the right



## 2. Balance H second:

10 H on the left -- multiply  $\text{H}_2\text{O}$  by 5 to get 10 H on the right



## 3. Balance O last:

We have two sources of O on the right:

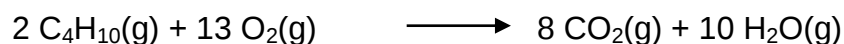
$$4 \times \text{CO}_2 = 8 \text{ O}$$

$$5 \times \text{H}_2\text{O} = 5 \text{ O}$$

We have 13 O on the right -- multiply  $\text{O}_2$  by  $6 \frac{1}{2}$  to get 13 O on the left.



To **remove the fraction** we multiply the whole equation by 2.



Do a recheck of the whole equation:

| Left   | Right        |
|--------|--------------|
| • 8 C  | 8 C          |
| • 20 H | 20 H         |
| • 26 O | 26 O (16+10) |

**Note:** In certain cases when there is an even number of carbon atoms in a hydrocarbon ( $C_4H_{10}$ ), you will end up with an odd number of oxygen atoms on the left side of the equation.

Let us look at some more examples:

- $$\begin{array}{ccccccc} \text{Ethene (C}_2\text{H}_4) & + & \text{oxygen} & \longrightarrow & \text{carbon dioxide} & + & \text{water} \\ \text{C}_2\text{H}_4 & + & 3\text{O}_2 & \longrightarrow & 2\text{CO}_2 & + & 2\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{ccccccc} \text{Benzene (C}_6\text{H}_6) & + & \text{oxygen} & \longrightarrow & \text{carbon dioxide} & + & \text{water} \\ 2\text{C}_6\text{H}_6 & + & 15\text{O}_2 & \longrightarrow & 12\text{CO}_2 & + & 6\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{ccccccc} \text{Pentane (C}_5\text{H}_{12}) & + & \text{oxygen} & \longrightarrow & \text{carbon dioxide} & + & \text{water} \\ \text{C}_5\text{H}_{12} & + & 8\text{O}_2 & \longrightarrow & 5\text{CO}_2 & + & 6\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{ccccccc} \text{Ethane (C}_2\text{H}_6) & + & \text{oxygen} & \longrightarrow & \text{carbon dioxide} & + & \text{water} \\ 2\text{C}_2\text{H}_6 & + & 7\text{O}_2 & \longrightarrow & 4\text{CO}_2 & + & 6\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{ccccccc} \text{Ethyne (C}_2\text{H}_2) & + & \text{oxygen} & \longrightarrow & \text{carbon dioxide} & + & \text{water} \\ 2\text{C}_2\text{H}_2 & + & 5\text{O}_2 & \longrightarrow & 4\text{CO}_2 & + & 2\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{ccccccc} \text{Hexane (C}_6\text{H}_{14}) & + & \text{oxygen} & \longrightarrow & \text{carbon dioxide} & + & \text{water} \\ 2\text{C}_6\text{H}_{14} & + & 19\text{O}_2 & \longrightarrow & 12\text{CO}_2 & + & 14\text{H}_2\text{O} \end{array}$$



**Activity:** Now test yourself by doing this activity.

**Answer the following questions.**

**Part A. Circle the best answer.**

- Which term refers to a chemical reaction which releases energy?
 

|                |               |
|----------------|---------------|
| A. Endothermic | B. Exothermic |
| C. Endergonic  | D. Fusion     |

2. What are the products of a complete combustion reaction involving oxygen and a hydrocarbon such as butane?
- A. Water only
  - B. Salt and water
  - C. Carbon dioxide and water
  - D. Carbon monoxide and carbon dioxide
- 
3. Which product indicates an incomplete combustion reaction?
- A. Water
  - B. Carbon dioxide
  - C. Carbon monoxide
  - D. Sulfur dioxide
- 
4. Which best describes an exothermic reaction?
- A. Heat is absorbed during a reaction.
  - B. The reaction results in the formation of ice.
  - C. Heat and or light are released during the reaction.
  - D. The reaction cannot occur unless the temperature is high.
- 
5. Which is an example of an endothermic reaction?
- A. Burning of magnesium in the air.
  - B. Potassium chlorate decomposes when heated.
  - C. Hydrogen and oxygen react in a rocket engine.
  - D. Warm blooded animals produce heat from their food
- 

**Part B. Write and balance the following combustion reactions that produce carbon dioxide and gaseous water.**

6. Decene ( $C_{10}H_{20}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $C_{10}H_{20}(g) + \_\_O_2(g) \longrightarrow \_\_CO_2(g) + \_\_H_2O(g)$
7. Sucrose ( $C_{12}H_{22}O_{11}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $C_{12}H_{22}O_{11}(s) + \_\_O_2(g) \longrightarrow \_\_CO_2(g) + \_\_H_2O(g)$
8. Heptane ( $C_7H_{16}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $C_7H_{16}(g) + \_\_O_2(g) \longrightarrow \_\_CO_2(g) + \_\_H_2O(g)$
9. Propene ( $C_3H_6$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $\_\_C_3H_6(g) + \_\_O_2(g) \longrightarrow \_\_CO_2(g) + \_\_H_2O(g)$

10. Nonane ( $\text{C}_9\text{H}_{20}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $\text{C}_9\text{H}_{20}(\text{g}) + \_\_\text{O}_2(\text{g}) \longrightarrow \_\_\text{CO}_2(\text{g}) + \_\_\text{H}_2\text{O}(\text{g})$
11. Octane ( $\text{C}_8\text{H}_{18}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $\_\_\text{C}_8\text{H}_{18}(\text{g}) + \_\_\text{O}_2(\text{g}) \longrightarrow \_\_\text{CO}_2(\text{g}) + \_\_\text{H}_2\text{O}(\text{g})$
12. Decane ( $\text{C}_{10}\text{H}_{22}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $\_\_\text{C}_{10}\text{H}_{22}(\text{g}) + \_\_\text{O}_2(\text{g}) \longrightarrow \_\_\text{CO}_2(\text{g}) + \_\_\text{H}_2\text{O}(\text{g})$
13. Octene ( $\text{C}_8\text{H}_{16}$ ) + oxygen  $\longrightarrow$  carbon dioxide + water  
 $\text{C}_8\text{H}_{16}(\text{g}) + \_\_\text{O}_2(\text{g}) \longrightarrow \_\_\text{CO}_2(\text{g}) + \_\_\text{H}_2\text{O}(\text{g})$

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 5.**

## Summary



You have to come to the end of lesson 5. In this lesson you have learnt that:

- combustion is the burning of a fuel with the production of energy or heat.
- combustion reactions are almost always exothermic (they give off heat).
- when organic molecules combust; the reaction products are carbon dioxide and water (as well as heat).
- combustion reactions are an essential part of our lives: the burning of gas, coal, petrol and oil are all combustion reactions. The heat they give out is used to cook food, warm houses and drive engines.
- cellular respiration is the process whereby cells in our bodies obtain energy. This is the process that keeps us alive.
- during respiration, oxygen reacts with glucose in our bodies producing carbon dioxide and water with the release of energy.
- fuels are substances we burn to get energy – usually in the form of heat. The burning needs oxygen.
- fossil fuels are made up of hydrocarbons. Hydrocarbons are
- compounds that contain the elements hydrogen and carbon. Examples are methane,  $\text{CH}_4$ , propane,  $\text{C}_3\text{H}_8$ , butane,  $\text{C}_4\text{H}_{10}$  and octane,  $\text{C}_8\text{H}_{18}$ .
- hydrocarbons readily burn or undergo combustion reactions. Combustion may be complete or incomplete.
- complete combustion of fossil fuels results in the production of carbon dioxide and water.
- the incomplete combustion of fossil fuels results in the formation of carbon monoxide + water and carbon (soot) + water.
- in certain cases when there is an even number of carbon atoms in a hydrocarbon (example: propane -  $\text{C}_3\text{H}_8$ ), you will end up with an odd number of oxygen atoms on the left side of the equation.

**NOW DO PRACTICE EXERCISE 5 ON THE NEXT PAGE.**



## Practice Exercise 5

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Answer the following:

1. Define combustion reaction.

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2. Explain cellular respiration and combustion of fossil fuels.

Cellular respiration

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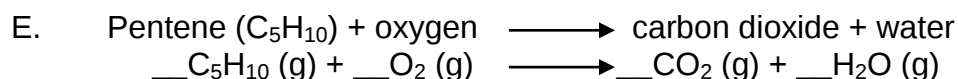
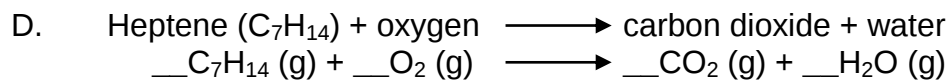
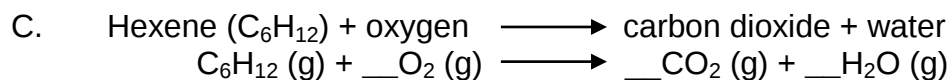
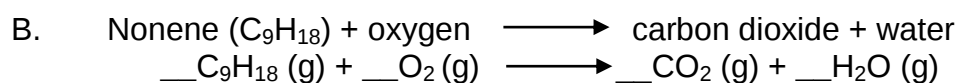
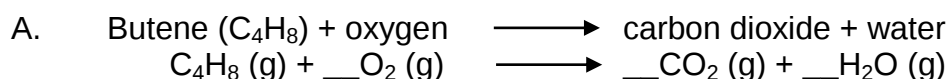
Fossil fuels

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3. Balance the following combustion reactions.



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|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.</b> |
|------------------------------------------------------------|

**Answers to Activities**

## Part A.

1. B
2. C
3. C
4. C
5. B

## Part B.

6.  $\text{C}_{10}\text{H}_{20} (\text{g}) + 15\text{O}_2 (\text{g}) \longrightarrow 10\text{CO}_2 (\text{g}) + 10\text{H}_2\text{O} (\text{g})$
7.  $\text{C}_{12}\text{H}_{22}\text{O}_{11} (\text{s}) + 6\text{O}_2 (\text{g}) \longrightarrow 6\text{CO}_2 (\text{g}) + 11\text{H}_2\text{O} (\text{g})$
8.  $\text{C}_7\text{H}_{16} (\text{g}) + 11\text{O}_2 (\text{g}) \longrightarrow 7\text{CO}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{g})$
9.  $2\text{C}_3\text{H}_6 (\text{g}) + 9\text{O}_2 (\text{g}) \longrightarrow 6\text{CO}_2 (\text{g}) + 6\text{H}_2\text{O} (\text{g})$
10.  $\text{C}_9\text{H}_{20} (\text{g}) + 14\text{O}_2 (\text{g}) \longrightarrow 9\text{CO}_2 (\text{g}) + 10\text{H}_2\text{O} (\text{g})$
11.  $2\text{C}_8\text{H}_{18} (\text{g}) + 25\text{O}_2 (\text{g}) \longrightarrow 16\text{CO}_2 (\text{g}) + 18\text{H}_2\text{O} (\text{g})$
12.  $2\text{C}_{10}\text{H}_{22} (\text{g}) + 33\text{O}_2 (\text{g}) \longrightarrow 20\text{CO}_2 (\text{g}) + 22\text{H}_2\text{O} (\text{g})$
13.  $\text{C}_8\text{H}_{16} (\text{g}) + 12\text{O}_2 (\text{g}) \longrightarrow 8\text{CO}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{g})$

## Answers to Practice Exercises 1 - 5

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### Practice Exercise 1

1. The law of conservation of matter states that matter is neither lost nor gained in chemical reactions; it simply changes form.
2. Physical change is a change in which the substance changes form but keeps its same chemical composition (reversible). For example, changes of state are considered to be physical changes. A cup of water can be frozen when cooled and then can be returned to a liquid form when heated. Liquid water and ice (frozen water) are both the same substance, water.

A chemical change is a change in which something new is formed (irreversible). The starting materials change into an entirely different substance or substances. This new substance has a different chemical composition than the starting materials. Examples of chemical changes would be the reaction of iron with air (rusting) or the reaction of a metal and acid.

3.
  - a. Formation of a solid (precipitate)
  - b. Colour change
  - c. Formation of gases (bubbles)
  - d. Production of heat or light
  - e. Noticeable odor
  - f. Temperature change
4. Write physical or chemical for the following changes.

| CHANGES                         | PHYSICAL/<br>CHEMICAL |
|---------------------------------|-----------------------|
| Melting butter for popcorn      | <b>Physical</b>       |
| Corroding metal                 | <b>Chemical</b>       |
| Glass breaking                  | <b>Physical</b>       |
| Burning leaves                  | <b>Chemical</b>       |
| Hammering wood to build a house | <b>Physical</b>       |
| Burning toast                   | <b>Chemical</b>       |

| CHANGES                      | PHYSICAL/<br>CHEMICAL |
|------------------------------|-----------------------|
| Bleaching your hair          | <b>Chemical</b>       |
| Pouring milk on your oatmeal | <b>Physical</b>       |
| Spoiling food                | <b>Chemical</b>       |
| Fireworks exploding          | <b>Chemical</b>       |
| Frying an egg                | <b>Chemical</b>       |
| Melting ice cream            | <b>Physical</b>       |

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**Practice Exercise 2**

1. A chemical equation is a chemist's shorthand expression for describing a chemical change.
  2. Steps in writing a balanced equation for a chemical reaction:
    - a. Determine the reactants and the products.
    - b. Write an **un-balanced** equation using formulas of reactants and products.
    - c. Write a **balanced** equation by determining coefficients that provide equal numbers of each type of atom on each side of the equation (generally, whole number values).
  3.
    - a. Sodium + chlorine  $\longrightarrow$  Sodium chloride  
 $\text{Na} + \text{Cl}_2 \longrightarrow \text{NaCl}$   
 **$2\text{Na} + \text{Cl}_2 \longrightarrow 2\text{NaCl}$**
    - b. Hydrogen + Iodine  $\longrightarrow$  Hydrogen iodide  
 $\text{H}_2 + \text{I}_2 \longrightarrow \text{HI}$   
 **$\text{H}_2 + \text{I}_2 \longrightarrow 2\text{HI}$**
    - c. Carbon + Carbon dioxide  $\longrightarrow$  Carbon monoxide  
 $\text{C} + \text{CO}_2 \longrightarrow \text{CO}$   
 **$\text{C} + \text{CO}_2 \longrightarrow 2\text{CO}$**
    - d. Sodium + Water  $\longrightarrow$  Sodium hydroxide + Hydrogen gas  
 $\text{Na} + \text{H}_2\text{O} \longrightarrow \text{NaOH} + \text{H}_2$   
 **$2\text{Na} + 2\text{H}_2\text{O} \longrightarrow 2\text{NaOH} + \text{H}_2$**
    - e. Sulphur + Oxygen  $\longrightarrow$  Sulphur dioxide  
 $\text{S} + \text{O}_2 \longrightarrow \text{SO}_2$   
 **$\text{S} + \text{O}_2 \longrightarrow \text{SO}_2$**
- 

**Practice Exercise 3**

- 1)  $\text{Ni}(\text{ClO}_3)_2 \longrightarrow \text{NiCl}_2 + 3\text{O}_2$
- 2)  $2\text{Ag}_2\text{O} \longrightarrow 4\text{Ag} + \text{O}_2$
- 3)  $4\text{HNO}_2 \longrightarrow 2\text{N}_2\text{O}_3 + 2\text{H}_2\text{O}$
- 4)  $2\text{Fe}(\text{OH})_3 \longrightarrow \text{Fe}_2\text{O}_3 + 3\text{H}_2\text{O}$
- 5)  $\text{ZnCO}_3 \longrightarrow \text{ZnO} + \text{CO}_2$

- 6)  $\text{Cs}_2\text{CO}_3 \longrightarrow \text{Cs}_2\text{O} + \text{CO}_2$
- 7)  $2\text{Al}(\text{OH})_3 \longrightarrow \text{Al}_2\text{O}_3 + 3\text{H}_2\text{O}$
- 8)  $\text{H}_2\text{SO}_4 \longrightarrow \text{SO}_3 + \text{H}_2\text{O}$
- 9)  $2\text{RbClO}_3 \longrightarrow 2\text{RbCl} + 3\text{O}_2$
- 10)  $\text{RaCl}_2 \longrightarrow \text{Ra} + \text{Cl}_2$
- 

#### Practice Exercise 4

1. a) Sodium nitrate and magnesium sulphate  
b) Barium chloride and potassium hydroxide.
2. a) silver chloride,  $\text{AgCl}(\text{s})$   
b) lead sulphate,  $\text{PbSO}_4$   
c) zinc carbonate,  $\text{ZnCO}_3$
3. a)  $\text{NaCl}(\text{aq}) + \text{AgNO}_3(\text{aq}) \longrightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$   
b)  $\text{Pb}(\text{NO}_3)_2(\text{aq}) + (\text{NH}_4)_2\text{SO}_4 \longrightarrow \text{PbSO}_4(\text{s}) + 2\text{NH}_4\text{NO}_3$   
c)  $\text{ZnSO}_4(\text{aq}) + \text{K}_2\text{CO}_3(\text{aq}) \longrightarrow \text{ZnCO}_3(\text{s}) + \text{K}_2\text{SO}_4(\text{aq})$
- 

#### Practice Exercise 5

1. **Combustion** is the burning of a fuel with the production of energy or heat.
2. **Cellular respiration** is the process whereby cells in our bodies obtain energy. This is the process that keeps us alive. During respiration, oxygen reacts with glucose in our bodies producing carbon dioxide and water with the release of energy.  
**Fuels** are substances we burn to get energy which is usually in the form of heat. The burning needs oxygen. North Sea gas is a fuel. It is mainly methane. It is pumped to towns and cities from gas wells in the North Sea.
3. A.  $\text{C}_4\text{H}_8(\text{g}) + \underline{6} \text{O}_2(\text{g}) \longrightarrow \underline{4} \text{CO}_2(\text{g}) + \underline{4} \text{H}_2\text{O}(\text{g})$
- B.  $\underline{2} \text{C}_9\text{H}_{18}(\text{g}) + \underline{27} \text{O}_2(\text{g}) \longrightarrow \underline{18} \text{CO}_2(\text{g}) + \underline{18} \text{H}_2\text{O}(\text{g})$
- C.  $\text{C}_6\text{H}_{12}(\text{g}) + \underline{9} \text{O}_2(\text{g}) \longrightarrow \underline{6} \text{CO}_2(\text{g}) + \underline{6} \text{H}_2\text{O}(\text{g})$
- D.  $\underline{2} \text{C}_7\text{H}_{14}(\text{g}) + \underline{21} \text{O}_2(\text{g}) \longrightarrow \underline{14} \text{CO}_2(\text{g}) + \underline{14} \text{H}_2\text{O}(\text{g})$
- E.  $\underline{2} \text{C}_5\text{H}_{10}(\text{g}) + \underline{15} \text{O}_2(\text{g}) \longrightarrow \underline{10} \text{CO}_2(\text{g}) + \underline{10} \text{H}_2\text{O}(\text{g})$

## REVIEW OF TOPIC 1:      CHEMICAL CHANGES

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Now, revise all lessons in this Topic and then do **ASSIGNMENT 3**.  
Here are the main points to help you revise.

### Lesson 1:    Chemical Changes

- Physical change is a change in which the substance changes form but keeps its same chemical composition (reversible).
- A chemical change is a change in which something new is formed (irreversible). The starting materials change into an entirely different substance or substances.
- Signs that a chemical change is taking place are the formation of a solid (precipitate), color change, formation of gases (bubbles), production of heat or light, noticeable odor and temperature change.
- A precipitate is a solid formed in a chemical reaction that is different from either of the reactants.
- The law of conservation of matter states that matter is neither lost nor gained in chemical reactions; it simply changes form. The particles of one substance are rearranged to form a new substance. The same numbers of particles that exist before the reaction exist after the reaction.
- Reactions that produce heat are known as exothermic reactions.
- Reactions that absorb heat are known as endothermic reactions.

### Lesson 2:    Chemical Equations

- A chemical equation is a chemist's shorthand expression for describing a chemical change.
- Chemical equations show the reactants which enter into a reaction, the products which are formed by the reaction and the amounts of each substance used and each substance produced.
- The numbers in front of the formulas are called coefficients (the number '1' is usually omitted).
- A chemical equation must have an equal number of atoms of each element on each side of the arrow to be balanced.
- There are things to remember about writing equations:
  - every chemical compound has a formula which cannot be altered.
  - a chemical reaction must account for every atom that is used. This is an application of the Law of Conservation of Matter.
  - the diatomic elements when they stand alone are always written  $H_2$ ,  $N_2$ ,  $O_2$ ,  $F_2$ ,  $Cl_2$ ,  $Br_2$ ,  $I_2$ .
  - never change a formula during the balancing of an equation.
  - balancing is done by placing coefficients in front of the formulas to insure the same number of atoms of each element on both sides of the arrow.
  - subscripts should never be changed when trying to balance a chemical equation. Changing a subscript changes the actual identity of a product or reactant.
  - provide equal numbers of each type of atom on each side of the equation (generally, whole number values).

**Lesson 3: Length**

- A chemical equation is a chemist's shorthand expression for describing a chemical change.
- Written using generic symbols, it is usually shown as:  
$$AB \longrightarrow A + B$$
- types of decomposition reaction; by heat, light, electrolysis, and fermentation.

**Lesson 4: Precipitation**

- Precipitate is a solid produced by reaction between two clear solutions.
- Precipitation reaction is a reaction when a solid is formed by reaction between two clear solutions.
- A white precipitate of silver chloride is formed when colourless solutions of potassium chloride and silver nitrate are mixed.

**Lesson 5: Combustion Reaction**

- Combustion is the burning of a fuel with the production of energy or heat.
- Combustion reactions are almost always exothermic (they give off heat). when organic molecules combust; the reaction products are carbon dioxide and water (as well as heat).
- Combustion reactions are an essential part of our lives: the burning of gas, coal, petrol and oil are all combustion reactions. The heat they give out is used to cook food, warm houses and drive engines.
- Cellular respiration is the process whereby cells in our bodies obtain energy. This is the process that keeps us alive.
- During respiration, oxygen reacts with glucose in our bodies producing carbon dioxide and water with the release of energy.
- Fuels are substances we burn to get energy – usually in the form of heat. The burning needs oxygen.
- Fossil fuels are made up of hydrocarbons. Hydrocarbons are
- Compounds that contain the elements hydrogen and carbon. Examples are methane,  $\text{CH}_4$ , propane,  $\text{C}_3\text{H}_8$ , butane,  $\text{C}_4\text{H}_{10}$  and octane,  $\text{C}_8\text{H}_{18}$ .
- Hydrocarbons readily burn or undergo combustion reactions. Combustion may be complete or incomplete.
- Complete combustion of fossil fuels results in the production of carbon dioxide and water.
- The incomplete combustion of fossil fuels results in the formation of carbon monoxide + water and carbon (soot) + water.
- In certain cases when there is an even number of carbon atoms in a hydrocarbon (e.g.  $\text{C}_4\text{H}_{10}$ ), you will end up with an odd number of oxygen atoms on the left side of the equation.

---

**REVISE WELL AND THEN DO TOPIC TEST 1 IN YOUR ASSIGNMENT 3.**

## **TOPIC 2**

### **REACTIONS OF ACIDS**

**In this topic you will learn about:**

- **a closer look at acids**
- **a closer look at bases**
- **neutralisation**
- **rate of reaction**
- **reactions involving enzymes**

## INTRODUCTION TO TOPIC 2: REACTIONS OF ACIDS

---

Acids and bases play central role in chemistry because, with the exception of redox reactions, every chemical reaction can be classified as an acid-base reaction. Our understanding of chemical reactions as acid-base inter-actions comes from the wide acceptance of the Lewis definition of acids and bases, which replaced both the earlier Bronsted – Lowry concept and the first definition – the Arrhenius model.



Finally, Lewis gave us the more general definition of acids and bases that we are using today. According to Lewis, acids are electron pair acceptors and bases are electron pair donors. Any chemical reaction that can be represented as a simple exchange of valence electron pairs to break and form bonds is therefore an acid-base reaction.



Acid-base chemistry is important to us on a practical level as well, outside of laboratory chemical reactions. Our bodily functions, ranging from the microscopic transport of ions across nerve cell membranes to the macroscopic acidic digestion of food in the stomach, are all ruled by the principles of acid-base chemistry. Homeostasis, the temperature and chemical balances in our bodies, is maintained by acid-base reactions. For example, fluctuations in the pH, or

concentration of hydrogen ions, of our blood is moderated at a comfortable level through use of buffers. Learning how **buffers** work and what their limitations are can help us to better understand our physiology. We will start by introducing fundamentals of acid-base chemistry and the calculation of pH, and then we will cover techniques for measuring pH. We learn about buffers and see how they are applied to measure the acidic content of solutions through titration.

Some questions will arise such as:

- What happens in a neutralisation reaction?
- What happens to the pH of an acid as it is neutralised?
- What happens to the pH of an alkali as it is neutralised?

---

**In this Topic, you will find the answers to these questions and all other questions relating to the measurement.**

## Lesson 6: A Closer Look at Acids

---



Welcome to Lesson 6. For thousands of years people have known vinegar, lemon juice and many other foods that taste sour. However, it was not until a few hundred years ago that it was discovered why these things taste sour, because they are all acids. The term acid, comes from the Latin term **acere**, which means **sour**.



### Your Aims:

- identify the properties of acids
- identify naturally occurring acids
- balance different chemical reactions of acids

### Properties of Acids

Acids are some of the things that are found in the laboratory and at home. They can be irritant and corrosive and must be handled carefully. They can be measured on the **pH scale**, using indicators like litmus and universal indicator.

Acids are **corrosive** which means they will attack and weaken many things including metals, paper, clothing and skin.

A **concentrated** acid is more dangerous than a **diluted** one. To make something more dilute water needs to be added.

Concentrated means **without much** or **without any** water added. Dilute means **a lot** of water added.

Acids have the following properties:

- corrosive
- turn blue litmus to red
- have a pH value less than 7
- have a sour taste (Warning: never taste any chemicals)
- form electrolytic solutions (conduct electricity) because they contain ions
- can neutralise an alkali (neutralised means that the substance no longer has acidic, or basic properties)

### Examples of common acids

Weak or organic acids

- Tannic acid (found in tea)
- Formic acid (found in ant stings)
- Acetic (ethanoic) acid (found in vinegar)
- Citric acid (found in lemons and other citrus fruits)

Strong or in-organic acids

- Hydrochloric acid (to maintain homeostasis or balance chemicals in the body)
- Sulphuric acid (accumulator acid, found in car batteries)
- Nitric acid (used in the manufacture of explosives and fertilizers)

**Note:**

- Strong acid has a very low pH (0-3)
- Weak acid has a high pH close to 7 (4-6)
- Strong acids are a lot more dangerous than weak acids

**Examples of Weak Acids**

Vinegar - Ethanoic Acid



Fizzy drink - Carbonic Acid



Tea – Tannic Acid



Vitamin C- Ascorbic Acid



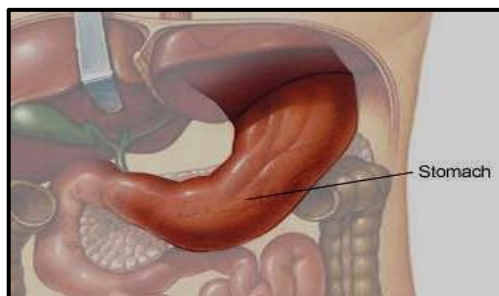
Lemons - Citric Acid



Ant stings - Formic Acid

**Examples of Strong Acids**

Car batteries – Sulphuric Acid



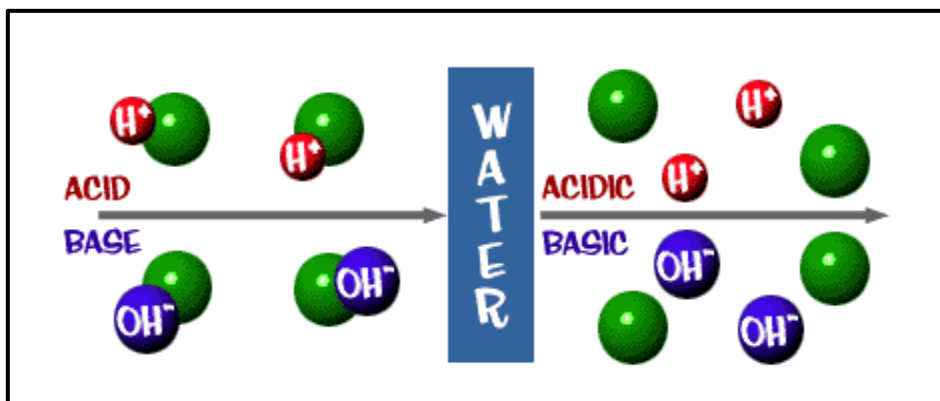
Stomach – Hydrochloric Acid



Explosives – Nitric Acid

## Hydrogen (+) ions in Acids

Hydrogen ion causes acidity in acids. Acids are compounds that break into hydrogen ( $H^+$ ) ions and another compound when placed in an aqueous solution. If you have an ionic compound and you put it in water, it will break apart into two ions. If one of those ions is  $H^+$ , the solution is acidic. If one of the ions is  $OH^-$ , the solution is basic.

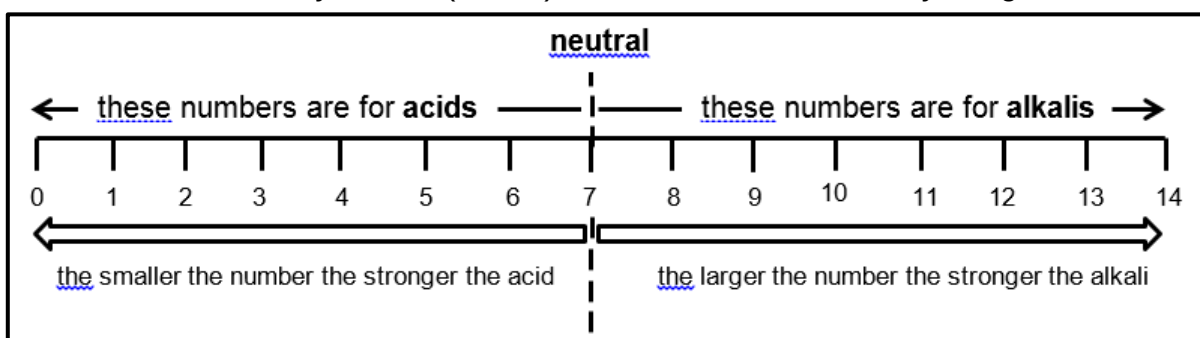


Every liquid you see will probably have either acidic or basic traits. One exception might be distilled water. Distilled water is just water. That's it. The positive and negative ions in distilled water are in equal amounts and cancel each other out. Most water you drink has ions in it. Those ions in solution make something acidic or basic. In your body there are small compounds called amino acids. Those are acids. In fruits there is something called citric acid. That is an acid, too.

Acids also turn litmus paper red. Litmus is a coloured chemical which can change from red to blue and back again. Which colour it is depends upon the concentration of Hydrogen ( $H^+$ ) ions. If the concentration of Hydrogen ions is higher than it is in pure water then the litmus will turn red. If it is lower than in pure water the litmus will turn blue.

Scientists use something called the **pH scale** to measure how acidic or basic a liquid is. That pH scale is actually a measure of the number of Hydrogen ( $H^+$ ) ions in a solution. If there are a lot of  $H^+$  ions, the pH is very low. If there are a lot of  $OH^-$  ions, the pH is high.

The scale goes from values very close to 0 through 14. Distilled water is 7 (right in the middle). Acids are found between a number very close to 0 and 7. Bases are from 7 to 14. Most of the liquids you find every day have a pH near 7. They are either a little below or a little above that mark. When you start looking at the pH of chemicals, the numbers go to the extremes. There are also very strong acids with pH values below one such as battery acid. Bases with pH values near 14 include drain cleaner and sodium hydroxide ( $NaOH$ ). These chemicals are very dangerous.



**Naturally Occurring Acids**

| <b>Name</b>   | <b>Also known as</b>       | <b>Description</b>                                                               | <b>Commonly found in</b>                        |
|---------------|----------------------------|----------------------------------------------------------------------------------|-------------------------------------------------|
| Acetic acid   | Ethanoic acid              | Clear colourless liquid with a very distinctive odour, dissolves easily in water | Vinegar (5% solution), Wine due to fermentation |
| Ascorbic acid | Vitamin C                  | Crystals soluble in ethanol and acetone                                          | Vitamin C                                       |
| Folic acid    | Vitamin B <sub>9</sub>     | Yellowish orange crystals, not very soluble                                      | Green leaves, apricots                          |
| Carbonic acid | Acid rain                  | Only found as a solution in water                                                | Rain water                                      |
| Tartaric acid | Di-carboxylic acid         | White crystalline                                                                | Wine                                            |
| Citric acid   | 1,2,3- Tri-carboxylic acid | Soluble white powder                                                             | Citrus fruit                                    |

| <b>Name</b>   | <b>Found naturally in</b>                                                    | <b>Used in</b>                                                            | <b>Effects</b>                                 |
|---------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------|
| Acetic acid   | Apples, cocoa, coffee, grapes, milk, wine and in other fruits and vegetables | Some bleaching agents, hand lotions and hair dyes, control of fruit decay | Mildly irritating to skin                      |
| Ascorbic acid | Aloe Vera plant                                                              | Dye production, pharmaceuticals, perfumery                                | Irritating to skin, eyes and respiratory tract |
| Folic acid    | Beans, green leafy vegetables                                                | B vitamin complex                                                         | Prevents spina bifida of newborns              |
| Carbonic acid | Solution in water                                                            | Carbonated beverages                                                      | Gives sharp taste to drinks                    |
| Tartaric acid | In dregs after wine fermentation, many plants (example – grapes)             | Carbonated drinks, metal cleaner, dyeing                                  | Dust may cause coughing and sneezing           |

|             |               |                                                      |                                                        |
|-------------|---------------|------------------------------------------------------|--------------------------------------------------------|
| Citric acid | Citrus fruits | Food to give a pleasant acid flavour, stabilize dyes | Irritating to skin, eyes and gut (example-fruit salts) |
|-------------|---------------|------------------------------------------------------|--------------------------------------------------------|

### Home Remedy for Acidity

Acidity can be described as a condition wherein there is an excess of acid secretion by the gastric glands of stomach. Heartburn and pus formation are the major symptoms of acidity. Our body produces acid to digest the food we eat. However, problem strikes, when it produces more acid than what is required. It is, then, that the gastric juices move from the stomach, into the lower oesophagus, making it dysfunctional. There are a number of reasons that lead to the formation of acidity. In the following lines, we have listed the causes as well as the symptoms of acidity.

### Causes of Acidity

|                                                                                                   |                                                                                                  |
|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>Excessive smoking</li> </ul>                               | <ul style="list-style-type: none"> <li>Not having meals on time</li> </ul>                       |
| <ul style="list-style-type: none"> <li>Problems in the functioning of digestive system</li> </ul> | <ul style="list-style-type: none"> <li>Eating fried and spicy food on a regular basis</li> </ul> |
| <ul style="list-style-type: none"> <li>Peptic ulcer</li> </ul>                                    | <ul style="list-style-type: none"> <li>Skipping breakfast</li> </ul>                             |
| <ul style="list-style-type: none"> <li>Hyper secretion of hydrochloric acid</li> </ul>            | <ul style="list-style-type: none"> <li>Eating rich in fats like chocolates</li> </ul>            |
| <ul style="list-style-type: none"> <li>Drinking too much alcohol</li> </ul>                       | <ul style="list-style-type: none"> <li>Obesity</li> </ul>                                        |
| <ul style="list-style-type: none"> <li>Pregnancy</li> </ul>                                       | <ul style="list-style-type: none"> <li>Excessive exposure to sun and heat</li> </ul>             |
| <ul style="list-style-type: none"> <li>Weakness of the valves</li> </ul>                          | <ul style="list-style-type: none"> <li>Inappropriate food habits</li> </ul>                      |

### Symptoms of Acidity

|                                                                                                                  |                                                                         |
|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>Inflammation in chest</li> </ul>                                          | <ul style="list-style-type: none"> <li>Belching</li> </ul>              |
| <ul style="list-style-type: none"> <li>Feeling hungry frequently</li> </ul>                                      | <ul style="list-style-type: none"> <li>Nausea</li> </ul>                |
| <ul style="list-style-type: none"> <li>Prolonged heartburn</li> </ul>                                            | <ul style="list-style-type: none"> <li>Chest pain</li> </ul>            |
| <ul style="list-style-type: none"> <li>Burning sensation or pain in the stomach, 1-4 hours after meal</li> </ul> | <ul style="list-style-type: none"> <li>Bitter taste in mouth</li> </ul> |
| <ul style="list-style-type: none"> <li>Loss of appetite</li> </ul>                                               | <ul style="list-style-type: none"> <li>Respiratory problems</li> </ul>  |
| <ul style="list-style-type: none"> <li>Vomiting</li> </ul>                                                       | <ul style="list-style-type: none"> <li>Coughing</li> </ul>              |
| <ul style="list-style-type: none"> <li>Gastro-oesophageal reflux</li> </ul>                                      | <ul style="list-style-type: none"> <li>Pain in ears</li> </ul>          |

### Treatment

There are medical treatments available for people who are suffering from stomach acidity. One, and the most popular way, is by taking antacids that can be bought

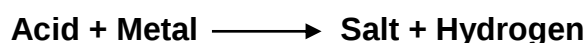
over-the-counter. Homeopathic treatment is also available that also considers the physiological balancing of the patient. Usually, using both the conventional and the homeopathic treatment proves to be effective in treating stomach acidity.

### Chemical reactions of acids

#### A. Acid - Metal

A reaction between an acid and a metal forms a metal salt and hydrogen as the only products.

(The term **salt** refers to any ionic compound resulting from a reaction involving acids.)



- $$\begin{array}{lcl} \text{Hydrochloric acid} + \text{zinc} & \longrightarrow & \text{Zinc chloride} + \text{hydrogen} \\ 2\text{HCl} + \text{Zn} & \longrightarrow & \text{ZnCl}_2 + \text{H}_2 \end{array}$$
- $$\begin{array}{lcl} \text{Sulphuric acid} + \text{magnesium} & \longrightarrow & \text{Magnesium sulphate} + \text{hydrogen} \\ \text{H}_2\text{SO}_4 + \text{Mg} & \longrightarrow & \text{MgSO}_4 + \text{H}_2 \end{array}$$
- $$\begin{array}{lcl} \text{Ethanoic acid} + \text{calcium} & \longrightarrow & \text{Calcium ethanoate} + \text{hydrogen} \\ 2\text{CH}_3\text{COOH} + \text{Ca} & \longrightarrow & \text{Ca}(\text{OOCCH}_3)_2 + \text{H}_2 \end{array}$$
- $$\begin{array}{lcl} \text{Hydrochloric acid} + \text{copper} & \longrightarrow & \text{Copper chloride} + \text{hydrogen} \\ 2\text{HCl} + \text{Cu} & \longrightarrow & \text{CuCl}_2 + \text{H}_2 \end{array}$$
- $$\begin{array}{lcl} \text{Sulphuric acid} + \text{zinc} & \longrightarrow & \text{Zinc sulphate} + \text{hydrogen} \\ \text{H}_2\text{SO}_4 + \text{Zn} & \longrightarrow & \text{ZnSO}_4 + \text{H}_2 \end{array}$$

#### B. Acid - Metal Oxide

A reaction between an acid and a metal oxide forms a salt and water as the only products. This is a special example of an acid - base reaction.



- $$\begin{array}{lcl} \text{Hydrochloric acid} + \text{iron oxide} & \longrightarrow & \text{Iron chloride} + \text{water} \\ 6\text{HCl} + \text{Fe}_2\text{O}_3 & \longrightarrow & 2\text{FeCl}_3 + 3\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{lcl} \text{Sulphuric acid} + \text{copper oxide} & \longrightarrow & \text{Copper sulphate} + \text{water} \\ \text{H}_2\text{SO}_4 + \text{CuO} & \longrightarrow & \text{CuSO}_4 + \text{H}_2\text{O} \end{array}$$
- $$\begin{array}{lcl} \text{Hydrochloric acid} + \text{sodium hydroxide} & \longrightarrow & \text{Sodium chloride} + \text{water} \\ \text{HCl} + \text{NaOH} & \longrightarrow & \text{NaCl} + \text{H}_2\text{O} \end{array}$$
- $$\begin{array}{lcl} \text{Nitric acid} + \text{calcium hydroxide} & \longrightarrow & \text{Calcium nitrate} + \text{water} \\ 2\text{HNO}_3 + \text{Ca}(\text{OH})_2 & \longrightarrow & \text{Ca}(\text{NO}_3)_2 + 2\text{H}_2\text{O} \end{array}$$
- $$\begin{array}{lcl} \text{Sulphuric acid} + \text{potassium hydroxide} & \longrightarrow & \text{Potassium sulphate} + \text{water} \\ & \longrightarrow & \end{array}$$

**C. Acid - Carbonate**

A reaction between an acid and a carbonate forms a salt, carbon dioxide and water as the only products.



- |    |                                          |                   |                                                     |
|----|------------------------------------------|-------------------|-----------------------------------------------------|
| 1. | Nitric acid + sodium carbonate           | $\longrightarrow$ | Sodium nitrate +<br>carbon dioxide + water          |
|    | $2\text{HNO}_3 + \text{Na}_2\text{CO}_3$ | $\longrightarrow$ | $2\text{NaNO}_3 + \text{CO}_2 + \text{H}_2\text{O}$ |
| 2. | Sulphuric acid + calcium carbonate       | $\longrightarrow$ | Calcium sulphate +<br>carbon dioxide + water        |
|    | $\text{H}_2\text{SO}_4 + \text{CaCO}_3$  | $\longrightarrow$ | $\text{CaSO}_4 + \text{CO}_2 + \text{H}_2\text{O}$  |
| 3. | Hydrochloric acid + calcium carbonate    | $\longrightarrow$ | Calcium chloride +<br>carbon dioxide + water        |
|    | $2\text{HCl} + \text{CaCO}_3$            | $\longrightarrow$ | $\text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$  |
| 4. | Hydrochloric acid + zinc carbonate       | $\longrightarrow$ | Zinc chloride +<br>carbon dioxide + water           |
|    | $2\text{HCl} + \text{ZnCO}_3$            | $\longrightarrow$ | $\text{ZnCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$  |
| 5. | Sulphuric acid + copper carbonate        | $\longrightarrow$ | Copper sulphate +<br>carbon dioxide + water         |
|    | $\text{H}_2\text{SO}_4 + \text{CuCO}_3$  | $\longrightarrow$ | $\text{CuSO}_4 + \text{CO}_2 + \text{H}_2\text{O}$  |



**Activity:** Now test yourself by doing this activity.

**Encircle the best answer.**

- An acid is any substance which produces
    - strong burns.
    - a red colour in water.
    - metal ions in solution.
    - hydrogen ions in water.
- 
- An example of a strong acid is \_\_\_\_\_.
    - citric
    - nucleic
    - ethanoic
    - hydrochloric

3. A strong acid is one which
- A. has a low concentration.
  - B. has a high concentration.
  - C. is completely ionized in water.
  - D. is only partly ionized in water.
- 
4. Do you get more products from a strong or a weak acid? You get
- A. more products from a hot acid.
  - B. more products from a weak acid.
  - C. more products from a strong acid.
  - D. the same amount of products from either a weak or strong acid.
- 
5. An acid will
- A. have a pH less than 7.
  - B. have a pH more than 7.
  - C. turn moist litmus paper blue.
  - D. turn universal indicator purple.
- 
6. An acid is used to
- A. repair the ozone layer.
  - B. speed up global warming.
  - C. treat steel before painting.
  - D. stop the road surface freezing.
- 

**B. Write a balanced chemical equation for the following:**

1. Hydrochloric acid + magnesium carbonate  $\longrightarrow$  Magnesium chloride + carbon dioxide + water  
\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_
2. Nitric acid + copper oxide  $\longrightarrow$  Copper nitrate + water  
\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_
3. Hydrochloric acid + calcium  $\longrightarrow$  Calcium chloride + hydrogen  
\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_
- 

|                                                             |
|-------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 6.</b> |
|-------------------------------------------------------------|



## Summary

You have come to the end of lesson 5. In this lesson you have learnt that:

- acids are some of the things that are found in the laboratory and at home. They can be irritant and corrosive.
- corrosive which means they will attack and weaken many things including metals, paper, clothing and skin.
- concentrated means without much or without any water added. Dilute means a lot of water added.
- strong acid is an acid that has a very low pH (0-3). Weak acid is an acid that has a high pH close to 7 (4-6).
- hydrogen ion causes acidity in acids.
- pH scale measures how acidic or basic a liquid is. The pH scale is actually a measure of the number of Hydrogen ( $H^+$ ) ions in a solution.
- stomach acidity can be described as a condition wherein there is an excess of acid secretion by the gastric glands of stomach.
- the term *salt* refers to any ionic compound resulting from a reaction involving acids.
- acid + metal - a reaction that forms a metal salt and hydrogen as the only products.
- acid + metal oxide - a reaction that forms a salt and water as the only products.
- acid + carbonate - a reaction that forms a salt, carbon dioxide and water as the only products.

---

|                                                     |
|-----------------------------------------------------|
| <b>NOW DO PRACTICE EXERCISE 6 ON THE NEXT PAGE.</b> |
|-----------------------------------------------------|



## Practice Exercise 6

Answer the following:

1. Identify three properties of acids.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

2. Match Column A with Column B. Write the letter of the correct answer on the space provided.

|  | Column A      |
|--|---------------|
|  | Carbonic acid |
|  | Ascorbic acid |
|  | Acetic acid   |
|  | Citric acid   |
|  | Folic acid    |
|  | Tartaric acid |

|   | Column B                                        |
|---|-------------------------------------------------|
| A | Vitamin C                                       |
| B | Vitamin B <sub>9</sub>                          |
| C | Gives sharp taste to drinks                     |
| D | Dust may cause coughing and sneezing            |
| E | Citrus fruits                                   |
| F | Vinegar (5% solution), Wine due to fermentation |

3. Write a balanced chemical equation for the following:

A. Hydrochloric acid + Magnesium oxide  $\longrightarrow$  Magnesium chloride + water

\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_

B. Nitric acid + Calcium carbonate  $\longrightarrow$  Calcium nitrate +  
Carbon dioxide + water

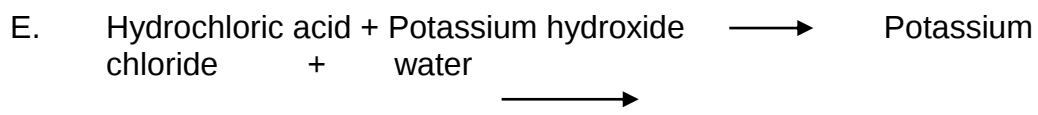
\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_

C. Sulphuric acid + calcium  $\longrightarrow$  Calcium sulphate + hydrogen

\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_

D. Nitric acid + Copper carbonate  $\longrightarrow$  Copper nitrate +  
Carbon dioxide + water

\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_



**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 1.**

---

### Answers to Activities

#### Part A

1.     D
2.     D
3.     C
4.     D
5.     A
6.     C

#### Part B

1.      $2\text{HCl} + \text{MgCO}_3 \longrightarrow \text{MgCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
  2.      $2\text{HNO}_3 + \text{CuO} \longrightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$
  3.      $2\text{HCl} + \text{Ca} \longrightarrow \text{CaCl}_2 + \text{H}_2$
- 

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 2.**

## Lesson 7: A Closer Look at Bases

---



Welcome to Lesson 7, you have learnt from the previous lesson about acid and its properties. We recognize acids and bases by their simple properties, such as taste. We know that a lemon is sour, so it is acidic. Bases tend to taste bitter. Acids and bases also change the color of certain dyes, such as phenolphthalein and litmus. Acids and bases neutralize the action of each other. This is why we take antacids for stomachaches, because the antacid is a base, and neutralizes the acid in the stomach.

In this lesson, we will be looking closely at bases.



### Your Aims:

- identify the properties of bases
- identify naturally occurring bases
- describe indicators and pH scale

### Properties of Bases

A **base** is any compound that yields **hydroxide ions ( $\text{OH}^-$ )** when dissolved in water. There are quite a few identifiable bases with hydroxide in the formula such as Sodium hydroxide ( $\text{NaOH}$ ) and magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ). A **soluble base** is referred to as an **alkali** if it contains and releases hydroxide ions ( $\text{OH}^-$ ) quantitatively. Base is known to accept hydrogen ions (protons) or more generally, donate electron pairs.

A **strong** base is a base which hydrolyzes (decomposition of a chemical compound by reaction with water) completely, raising the pH of the solution toward 14. **Concentrated bases**, like concentrated acids, attack living tissue and cause serious burns. The reaction of bases upon contact with the skin is different from that of acids. So while either may be quite destructive, strong acids are called corrosive and strong bases are referred to as caustic (most nearly means toxic, usually referring to a substance that generates heat and having the potential to burn you). Bases may also be weak bases such as ammonia, which is used for cleaning. An **alkali** is a special example of a base, where in an aqueous environment, hydroxide ions are donated.

The usual way of comparing the strengths of bases is to see how readily they produce hydroxide ions in solution. This may be because they already contain hydroxide ions, or because they take hydrogen ions from water molecules to produce hydroxide ions.

Bases have the following properties:

- Slimy or soapy feel on fingers, due to saponification of the lipids in human skin.
- Concentrated or strong bases are caustic on organic matter and react violently with acidic substances.
- Aqueous solutions or molten bases dissociate in ions and conduct electricity. Bases are electrolytes, because they form ions in solution. The stronger the base (the more alkaline the solution, in other words), the more it ionizes, and therefore the better it conducts electricity.
- The pH level of a basic solution is higher than 7.

- Reactions with indicators: bases turn red litmus paper blue, phenolphthalein pink; keep bromothymol blue in its natural colour of blue, and turns methyl orange yellow.
- Bases are bitter in taste.

**Weak Bases** – is one which does not convert fully into hydroxide ions in solution. Not all its molecule breaks apart and it does not furnish hydroxide ions ( $\text{OH}^-$ ) by dissociation. Examples are:

- Ammonia (water) – solutions are widely used as commercial and household cleaners and detergents.
- Alanine – a source of energy for muscle tissue, the brain, and central nervous system.
- Methylamine – used to make agricultural chemicals including herbicides, fungicides, insecticides, biocides, and miticides.
- Di methylamine – used in the rubber industry, as a raw material to product potable and wastewater treatment plants.
- Tri methylamine – use in the production of supplement in animal feed such as chickens, turkeys, and pigs.
- Glycine – used for treating schizophrenia, stroke, memory enhancement, cancer prevention and protects kidneys.
- Hydrazine – used as energy rocket propellant, as a foaming agent in preparing polymer foams and pharmaceuticals.

### Strong Bases

The hydroxides of Group I and Group II metals usually are considered to be strong bases. It dissociates 100% into cat ion and  $\text{OH}^-$  (hydroxide ion). Examples are:

- Lithium hydroxide ( $\text{LiOH}$ ) – use in ceramics & some Portland cement formulations, as a heat transfer medium, for the production of lithium greases and as a storage-battery electrolyte.
- Sodium hydroxide ( $\text{NaOH}$ ) – It is used in many industries mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents and as a drain cleaner.
- Potassium hydroxide ( $\text{KOH}$ ) – active ingredient in chemical "cuticle removers" used in manicure treatments, as the electrolyte in alkaline batteries, used to manufacture soft soaps and in the manufacture of biodiesel.
- Calcium hydroxide ( $\text{Ca(OH)}_2$ ) – in water and sewage treatment and improvement of acid soils, used as a lye substitute in no-lye hair relaxers, an ingredient in whitewash, mortar and plaster.
- Barium hydroxide ( $\text{Ba(OH)}_2$ ) – used as an additive in thermoplastics, used in for the titration of weak acids, used in homeopathic remedies ,also used to clean up acid spills.
- Cesium hydroxide ( $\text{CsOH}$ ) – used as electrolyte in alkaline batteries at subzero temperatures, use as agent in the removal of sulphur from heavy oils, as a catalyst in organic synthesis and colour photography
- Strontium hydroxide ( $\text{Sr(OH)}_2$ ) – used chiefly in the refining of beet sugar, as a stabilizer in plastic and paint drier.

### Note:

- **Strong Base:** A base that has a very high pH (11-14). Another word for base is alkali.
- **Weak Base:** A base that has a pH close to 7 (8-10).
- **Aqueous:** A solution that is mainly water. Think about the word aquarium, aqua means water.

## Examples of Common Bases

1. Sodium Hydroxide (caustic soda and flakes) – make soap and textiles, oven cleaner and liquid plumber



Caustic soda flakes



Lye

2. Magnesium Hydroxide (Milk of magnesia) – laxative and antacid



Magnesium hydroxide powder

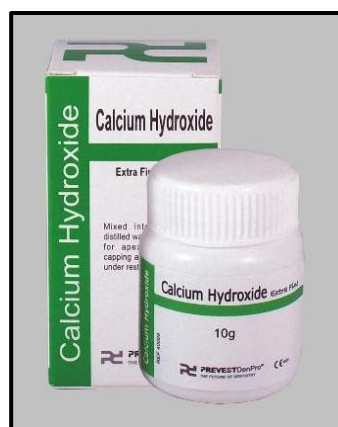


Milk of Magnesia

3. Calcium Hydroxide (Slaked lime) – Lime water; astringent, causes contraction of skin pores



Slaked lime powder



Calcium hydroxide

4. Ammonium Hydroxide – Ammonia in water; window cleaner, other cleaning solutions



5. Ammonia – Gas; inhalant to revive an unconscious person, anhydrous or liquid ammonia is injected into soil as a fertiliser.



6. Sodium Carbonate – Soda Ash; Detergents



| Key Characteristics of Bases                                                | Some Common Bases                                              |
|-----------------------------------------------------------------------------|----------------------------------------------------------------|
| Bitter taste                                                                | Sodium hydroxide, NaOH<br>(lye or caustic soda)                |
| Generally no noticeable reaction with active metals                         | Potassium hydroxide, KOH<br>(lye or caustic potash)            |
| Form electrolytic solutions (conduct electricity) because they produce ions | Magnesium hydroxide, Mg(OH) <sub>2</sub><br>(milk of magnesia) |
| Cause certain dyes to change color; litmus paper turns blue for example     | Calcium hydroxide, Ca(OH) <sub>2</sub><br>(slaked lime)        |
| Slippery feel (example soapy feel)                                          | Ammonia, NH <sub>3</sub>                                       |
| Neutralised by acids                                                        |                                                                |

### Naturally Occurring Bases

| Name         | Composition                                                  | Description                                                                                                         | Commonly found in                                                         |
|--------------|--------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Caffeine     | C <sub>8</sub> H <sub>10</sub> N <sub>4</sub> O <sub>2</sub> | White crystalline powder, very bitter taste                                                                         | Coffee, tea                                                               |
| Nicotine     | C <sub>8</sub> H <sub>14</sub> N <sub>2</sub>                | A nitrogen-containing chemical - an alkaloid, which is made by several types of plants, including the tobacco plant | Cigarettes                                                                |
| Ammonia      | NH <sub>3</sub>                                              | Colourless with a very sharp odour                                                                                  | Water, soil, and air, and is a source of nitrogen for plants and animals. |
| Theobromine  | C <sub>7</sub> H <sub>8</sub> N <sub>4</sub> O <sub>2</sub>  | Very fine white powder                                                                                              | Chocolate                                                                 |
| Theophylline |                                                              | White odourless crystalline powder                                                                                  | Tea                                                                       |

| Name     | Found naturally in                   | Used in                                                                    | Effects                                                 |
|----------|--------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------|
| Caffeine | Coffee, tea, colanuts, mate, guarana | Soft drinks especially colas, cardiac stimulant, mild diuretic, flavouring | Addictive, Stimulant of central nervous system, cardiac |

|              |                                                                                 |                                                                                            |                                                                  |
|--------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|------------------------------------------------------------------|
|              |                                                                                 | agent (sharp bitterness), pain killers                                                     | muscle, and respiratory system, diuretic, delays fatigue         |
| Nicotine     | Tobacco leaves                                                                  | Nicotine gum and lozenges are medical products used to aid in smoking cessation in adults. | Addictive                                                        |
| Ammonia      | Volcanic gases and as a product of decomposition of animal and vegetable matter | Fertilizer, synthetic fibers, plastics and explosives                                      | Mildly irritating to skin                                        |
| Theobromine  | Cocoa bean (1.5-3%), cola nuts and tea                                          | Treat high blood pressure.                                                                 | Cardiac stimulant, smooth muscle relaxant, diuretic, vasodilator |
| Theophylline | Tea                                                                             | Bronchodilator - treatment of the symptoms of chronic asthma                               | Stimulant, smooth muscle relaxant, diuretic, vasodilator         |

## Indicators

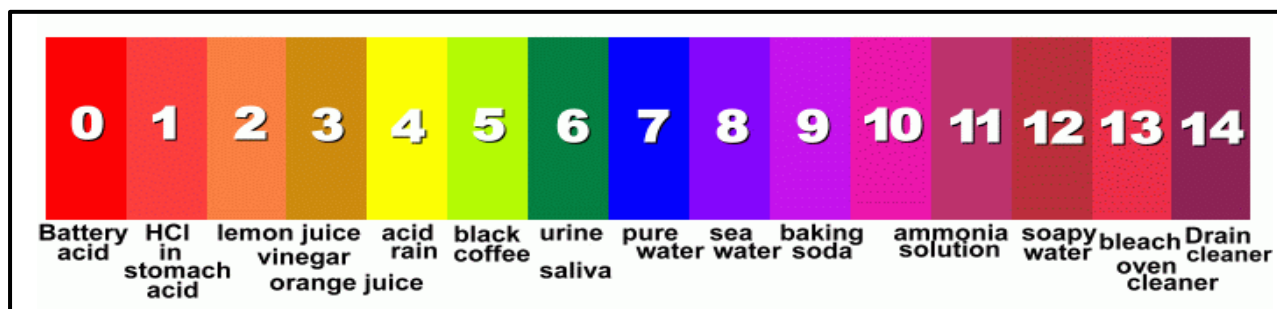
Indicators are chemical substances that are used to find out whether a given solution is acidic or alkaline by showing a colour change. You can prepare homemade indicators from red cabbage or beetroot juice - these will help you see if a solution is acidic or alkaline.

Litmus and universal indicator are two indicators that are commonly used in the laboratory.

### 1. pH Indicator

The **pH indicator** indicates the nature as well as the strength of the given medium (solution). pH is a scale that measures the acidity or alkalinity (basicity) of a solution. A pH of 7 is a neutral solution, and bases have a pH of more than 7. Each increase of one in pH is a tenfold increase in base strength. A base with a pH of 10 is ten times more basic than one with a pH of 9.

### Examples of pH Scale Readings



A pH scale reading of less than 7 indicates an acidic medium.

A pH scale reading of more than 7 indicates a basic medium.

A pH scale reading equal to 7 indicates a neutral medium or solution (pure distilled water).

A pH scale reading of 2 indicates a strong acid.

A pH scale reading of 13 indicates a strong base.

A pH scale reading of 6 indicates a weak acid.

A pH scale reading of 8 indicates a weak base.

## 2. Litmus Indicator

**Litmus indicator** solution turns red in acidic solutions and blue in alkaline solutions - and it turns purple in neutral solutions. Litmus paper is usually more reliable, and comes as red litmus paper and blue litmus paper.

Acids turn blue litmus paper red.  
Bases turn red litmus paper blue.

### Examples of Litmus Paper Colour Changes

Sulphuric acid is obviously acidic in nature. It turns blue litmus paper red.

Sodium hydroxide is a base. It turns red litmus paper blue.

### Other Indicators

**Phenolphthalein solution** is a colourless indicator. **Methyl orange solution** is obviously an orange-coloured indicator. **Bromothymol blue** solution is an indicator.

### Examples of colour changes using other indicators

Phenolphthalein solution causes no colour change in acids whereas it turns bases pink. Methyl orange solution turns acids pink whereas it turns bases yellow. Bromothymol blue solution turns acids yellow whereas it turns bases blue.



**Activity:** Now test yourself by doing this activity.

### Circle the best answer.

1. A substance was dissolved in water containing universal indicator. The indicator turned violet. This shows the dissolved substance was a

A. weak acid

B. weak alkali

C. strong acid

D. strong alkali

- 
2. A student tested some solutions with universal indicator to see whether they were acid, alkaline or neutral. The resulting colours were as follows:

Solution U - violet

Solution V – orange

Solution W - green

Solution X - blue

Solution Y - red

Solution Z - yellow

Which solutions were neutral?

- |    |                   |    |                   |
|----|-------------------|----|-------------------|
| A. | only solution W   | B. | only solution Z   |
| C. | solutions U and V | D. | solutions X and Y |
- 

3. Which statement about acids or alkalis is **true**?

- A. Aspirin is a weak alkali
  - B. Antacids in indigestion mixtures are weak acids
  - C. Acids are not safe enough to be used in food preparations
  - D. Spilled acids and alkalis are made safer by diluting with water
- 

4. Which of these is a weak alkali in solution?

- |    |                |                                 |
|----|----------------|---------------------------------|
| A. | battery acid   | (Sulphuric acid)                |
| B. | Oven cleaner   | (Ammonia solution)              |
| C. | Salt solution  | (Aqueous sodium chloride)       |
| D. | Fizzy lemonade | (Flavouring + Carbonated water) |
- 

5. Which word matches the following hazard warning description, “may cause reddening or blistering of the skin”?

- |    |         |    |           |
|----|---------|----|-----------|
| A. | Toxic   | B. | Irritant  |
| C. | Harmful | D. | Corrosive |
- 

6. A pH scale reading of 13 indicates a

- |    |             |    |             |
|----|-------------|----|-------------|
| A. | weak acid   | B. | weak base   |
| C. | strong acid | D. | strong base |
- 

7. Bases taste \_\_\_\_\_.

- |    |       |    |        |
|----|-------|----|--------|
| A. | sour  | B. | salty  |
| C. | sweet | D. | bitter |
-



13. In a neutralisation reaction between sodium hydroxide (NaOH) and hydrochloric acid (HCl), the salt produced would be
- A. sodium chloride
  - B. sodium acid
  - C. hydrochloric hydroxide
  - D. sodium hydrochloride
- 
14. A positive test for a base occurs when
- A. red litmus turns blue
  - B. blue litmus remains red
  - C. blue litmus turns red
  - D. red litmus remains red
- 



## Summary

You have come to the end of lesson 5. In this lesson you have learnt that:

- a base is any compound that yields hydroxide ions ( $\text{OH}^-$ ) when dissolved in water.
- a soluble base is referred to as an alkali if it contains and releases hydroxide ions ( $\text{OH}^-$ ) quantitatively.
- a strong base is a base which hydrolyses completely, raising the pH of the solution toward 14.
- bases have the following properties:
  - Slimy or soapy feel on fingers, due to saponification of the lipids in human skin.
  - Concentrated or strong bases are caustic on organic matter and react violently with acidic substances.
  - Aqueous solutions or molten bases dissociate in ions and conduct electricity.
  - Bases are electrolytes; because they form ions in solution and therefore the better it conducts electricity.
  - The pH level of a basic solution is higher than 7.
  - Bases are bitter in taste.
- indicators are chemical substances that are used to find out whether a given solution is acidic or alkaline by showing a colour change.
- the pH indicator indicates the nature as well as the strength of the given medium (solution). pH is a scale that measures the acidity or alkalinity (basicity) of a solution.
- weak bases is one which does not convert fully into hydroxide ions in solution.

---

|                                                     |
|-----------------------------------------------------|
| <b>NOW DO PRACTICE EXERCISE 7 ON THE NEXT PAGE.</b> |
|-----------------------------------------------------|



## Practice Exercise 7

---

**Circle the best answer.**

1. A base is a
  - A. hydrogen ion ( $\text{H}^+$ ).
  - B. hydrogen ion ( $\text{H}^+$ ) donor.
  - C. hydrogen ion ( $\text{H}^+$ ) destroyer.
  - D. hydrogen ion ( $\text{H}^+$ ) acceptor.

---
2. Bases cause phenolphthalein to turn
  - A. clear
  - B. pink
  - C. green
  - D. orange

---
3. The strongest bases are hydroxides of
  - A. halogens
  - B. noble gases
  - C. transition metals
  - D. group 1 & 2 metals

---
4. The characteristic ion of bases is
  - A. sodium ion ( $\text{Na}^+$ )
  - B. hydrogen ion ( $\text{H}^+$ )
  - C. carbonate ion  $\text{CO}_3^{2-}$
  - D. hydroxide ion ( $\text{OH}^-$ )

---
5. A salt derived from a strong base and a weak acid will give a salt that is
  - A. basic
  - B. acidic
  - C. neutral
  - D. volatile

6. Which is a soluble base in water?

- |                             |                             |
|-----------------------------|-----------------------------|
| A. NaOH                     | B. $\text{Fe}(\text{OH})_3$ |
| C. $\text{Cu}(\text{OH})_2$ | D. $\text{Zn}(\text{OH})_2$ |
- 

7. Which of the following is a weak base?

- |                             |                           |
|-----------------------------|---------------------------|
| A. KOH                      | B. NaOH                   |
| C. $\text{Ca}(\text{OH})_2$ | D. $\text{NH}_4\text{OH}$ |
- 

8. A test that could be safely used to distinguish a strong base from a weak base is

- |                 |                            |
|-----------------|----------------------------|
| A. taste        | B. touch                   |
| C. litmus paper | D. electrical conductivity |
- 

9. To distinguish between a strong acid and a strong base, an experimenter could use

- |                      |                    |
|----------------------|--------------------|
| A. odour             | B. magnesium       |
| C. conductivity test | D. common ion test |
- 

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 2.</b> |
|------------------------------------------------------------|

### Answers to Activity

- |      |      |      |       |       |
|------|------|------|-------|-------|
| 1. D | 4. B | 7. D | 10. C | 13. A |
| 2. A | 5. B | 8. D | 11. B | 14. A |
| 3. D | 6. D | 9. A | 12. C |       |

## Lesson 8: Neutralisation



Welcome to Lesson 8. In Lessons 6 and 7, you learned about acids and bases respectively. You have also learned that the acids and the bases react together forming the products salt and water. In this lesson, you will learn that a reaction between an acid and a base is called neutralisation.

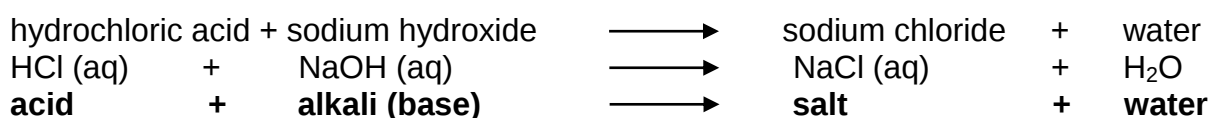


### Your Aims:

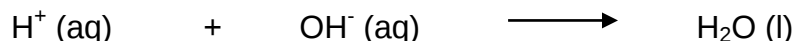
- define neutralisation
- describe different neutralisation reactions
- give examples of neutralisation reactions and balance them
- state and describe examples of everyday neutralisation

### Neutralisation and Different Reactions

What takes place in the reaction between an acid and a base? Consider the reaction between hydrochloric acid and the alkali (soluble base), sodium hydroxide solution:



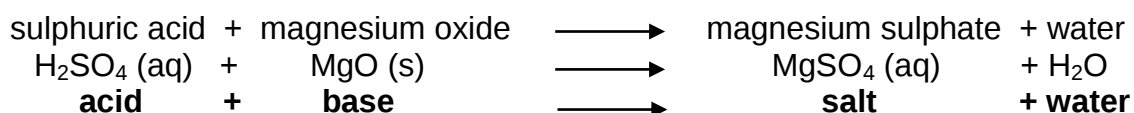
When the solutions of an acid and alkali are mixed, hydrogen ions, H<sup>+</sup> (aq), and hydroxide ions, OH<sup>-</sup> (aq), combine to form water molecules.



Sodium ions, Na<sup>+</sup> (aq), and chloride ions, Cl<sup>-</sup> (aq), remain in the solution, which become a solution of sodium chloride. Solid sodium chloride is obtained if the solution is evaporated.

The reaction between an acid and a base is called neutralisation. Or stated differently, neutralisation is the combination of hydrogen ions from an acid and hydroxide ions from a base to form water. In the process, water is formed.

What happens when an acid neutralizes an insoluble base? Consider the sulphuric acid magnesium oxide:

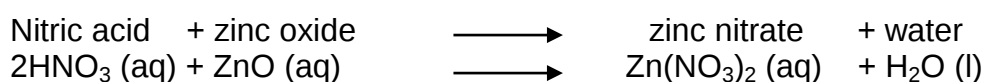
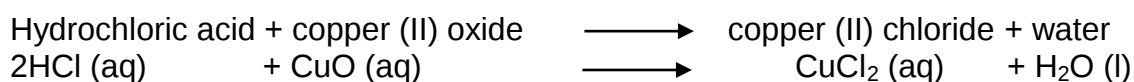
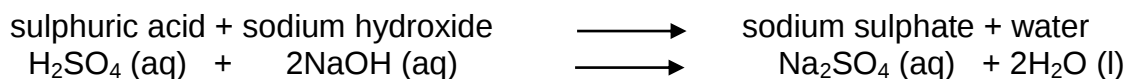
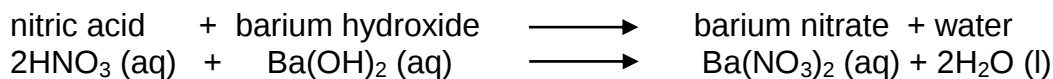


Hydrogen ions and oxide ions, O<sup>2-</sup>, combine to form water:



The resulting solution contains magnesium ions and sulphate ions, it is a solution of magnesium sulphate. Crystals of magnesium sulphate will be obtained if the solution is evaporated.

Some examples of neutralisation reactions:



**In a neutralisation reaction the hydrogen ion of acid is cancelled by a base.**

**The is regarded as what is left when the  $\text{H}^+$  of the acid is neutralised by the  $\text{OH}^-$  or  $\text{O}^{2-}$  of the base.**



## Summary

You have come to the end of lesson 8. In this lesson, you have learnt that:

- neutralisation is a reaction between an acid and a base.
- it is the combination of hydrogen ions from an acid and hydroxide or oxide ions from a base to form water.
- when the solutions of an acid and alkali are mixed, hydrogen ions,  $\text{H}^+$  (aq), and hydroxide ions,  $\text{OH}^-$  (aq), combine to form water molecules.
- hydrogen ions and oxide ions,  $\text{O}^{2-}$ , combine to form water.
- the salt may be regarded as what is left when the  $\text{H}^+$  of the acid is neutralised by the  $\text{OH}^-$  or  $\text{O}^{2-}$  of the base.

**NOW DO PRACTICE EXERCISE 8 ON THE NEXT PAGE**



## Practice Exercise 8

---

**Answer the following questions:**

1. Define neutralisation reaction?

\_\_\_\_\_

2. What happens during a neutralisation reaction?

\_\_\_\_\_

3. Write the chemical formulas for the following acids:

- i. Hydrochloric acid: \_\_\_\_\_
- ii. Nitric acid: \_\_\_\_\_
- iii. Sulphuric acid: \_\_\_\_\_

4. Write the chemical formulas of the following bases:

- i. Sodium hydroxide \_\_\_\_\_
- ii. Calcium hydroxide \_\_\_\_\_
- iii. Aluminium oxide: \_\_\_\_\_
- iv. Zinc oxide \_\_\_\_\_

5. Write the name of the salt formed by reacting:

- i. Q3(i) and Q4(ii) \_\_\_\_\_
- ii. Q3(iii) and Q4(iv) \_\_\_\_\_
- iii. Q3(ii) and Q4(iii) \_\_\_\_\_
- iv. Q3(iii) and Q((i) \_\_\_\_\_

6. Write balanced chemical equations for the reactions in Q5.

- i. \_\_\_\_\_
- ii. \_\_\_\_\_
- iii. \_\_\_\_\_
- iv. \_\_\_\_\_

---

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 2.</b> |
|------------------------------------------------------------|

## Lesson 9: Rate of Reaction



Welcome to lesson 9. In your last lesson you have learnt the reaction between an acid and a base. In this lesson you will learn about the rate of reaction.



### Your Aims:

- define the rate of reaction
- describe effective collisions
- explain factors influencing rate of reaction

### What is Rate?

Rate is a measure of how fast or slow something is. Here are some everyday examples.



This plane has just flown 2000 kilometres in 1 hour. It flew at a **rate** of 2000 kilometres per hour



This petrol pump can pump petrol at a **rate** of 50 litres per minute

**Rate is a measure of the change that happens in a single unit of time**

Any suitable unit of time can be used – a second, a minute, an hour, even a day.

### Collision Theory- How Chemical Reactions Occur

For a chemical reaction to occur, the reacting particles (reactants) must collide. The collision must also have enough energy so that the chemical bonds can be broken. Collision without enough energy will not lead to a reaction. An **effective reaction** is a reaction which does have enough energy and does lead to a reaction.

**Remember: Collisions with too little energy do not produce a reaction. The particles must have enough energy for the collision to be successful in producing a reaction where there is energy storage.**

Chemical reactions occur at different rates. Reactions that occur slowly have a low rate of reaction. Rusting is a slow reaction. Reactions that happen quickly have a high rate of reaction. Burning and explosions are very fast reactions: they have a high rate of reaction.



Rust forming on an old iron anchor near the sea. This is usually a very slow reaction



Concrete setting. This reaction is quite slow. It will take a couple of days for the concrete to harden



Burning is a fast reaction



An explosion is a very fast reaction

Particles need enough kinetic energy to break the bonds and cause a chemical reaction to occur. Particles may be atoms, ions or molecules. There is a minimum amount of kinetic energy which colliding particles need in order to react with each other. If the colliding particles have less than this minimum energy then they just bounce off each other and no reaction occurs. This minimum amount of kinetic energy that a reaction requires to occur is known as the **activation energy**.

So when the particles collide there must be enough kinetic energy to exceed the activation energy in order for a chemical reaction to occur. Slow reactions such as rusting generally have high activation energies, while explosive chemical reactions generally have low activation energies.

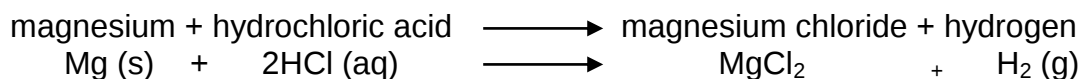
The rate of reaction depends on the rate of successful collisions between reactant particles. The more successful collisions there are, the faster the rate of reaction.

**The collision theory says that a chemical reaction can only occur between particles when they collide**

The rate of reaction can be found by measuring the amount of reactant used up, or the amount of product formed in a given time.

### Explaining Rates

Let us have a closer look at a reaction to see how it all happens.

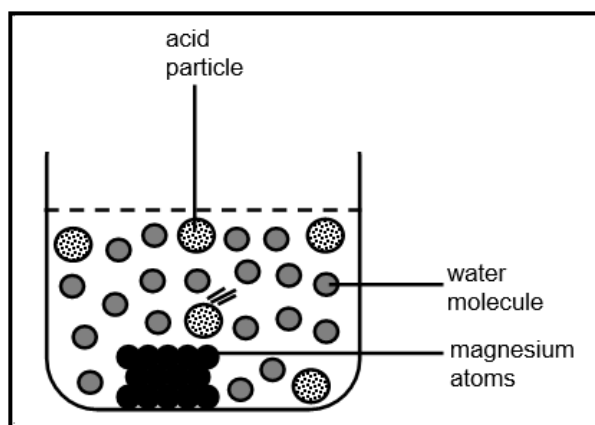


In order for the magnesium and acid particles to react together:

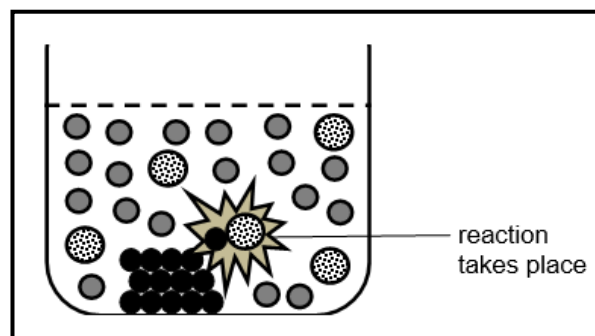
- **they must collide with each other.**
- **the collision must have enough energy.**

This is shown by the drawings below.

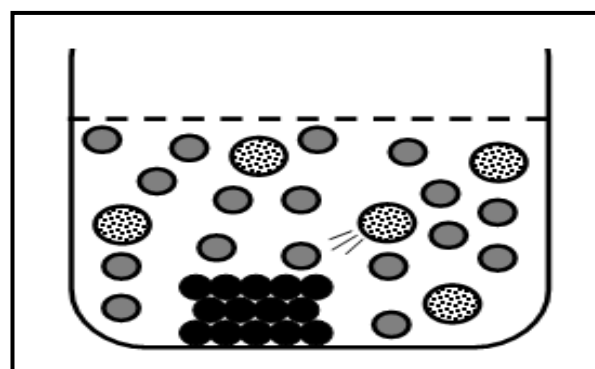
The particles in the liquid move around continually. Here an acid particle is about to collide with a magnesium atom.



If the collision has enough energy, reaction takes place. Magnesium chloride and hydrogen are formed.



If the collision does not have enough energy, no reaction occurs. The acid particle bounces away again.



If there are lots of successful collisions in a given minute, then a lot of hydrogen is produced in that minute. In other words, the reaction goes quickly – its rate is high. If there are not many, its rate is low.

**The rate of a reaction depends on how many successful collisions there are in a given unit of time.**

In a successful collision:

- old bonds are broken (these need energy).
- new bonds are formed (these give out energy).

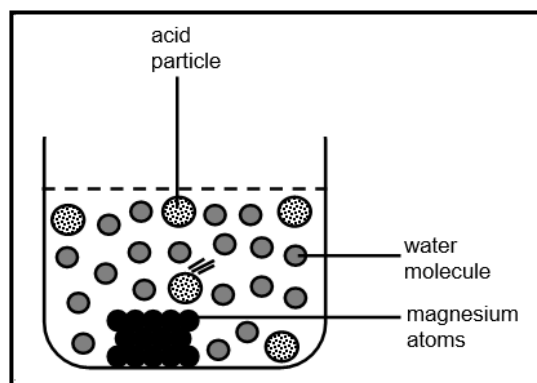
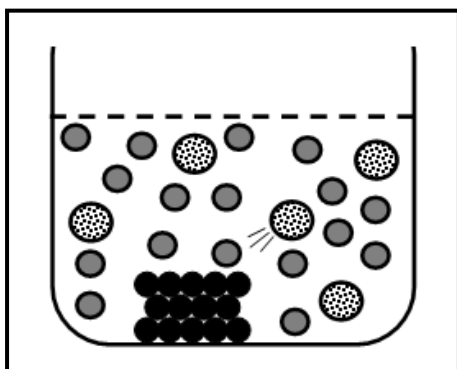
### Changing the rate of a reaction

It is useful to be able to predict whether an action will affect the rate at which a chemical reaction proceeds. There are several factors that can influence the rate of a chemical reaction. In general, a factor that increases the number of collisions between particles will increase the reaction rate and a factor that decreases the number of collisions between particles will decrease the chemical reaction rate.

### Why the rate increases with concentration

If the concentration of the acid is increased, the reaction goes faster. It is easy to see why:

In dilute acid, there are not so many acid particles. This means there is not much chance of an acid particle hitting a magnesium atom.



Here the acid is more concentrated – there are more acid particles in it. There is now more chance of a successful collision occurring

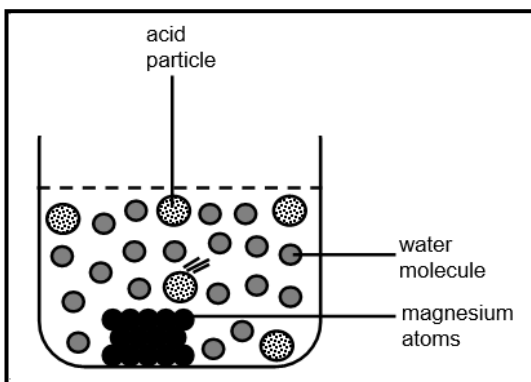
**Increasing the concentration of a reactant increases the rate**

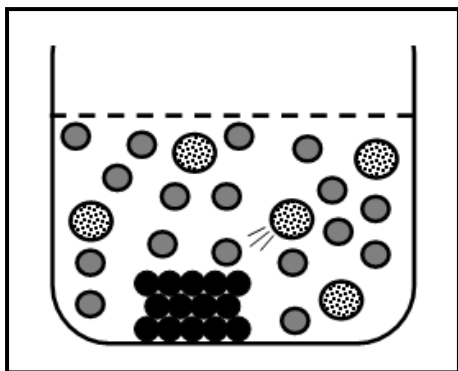
Increasing the concentration means that the particles are more crowded, so there will be more frequent effective collisions increasing the rate of reaction.

**The more successful collisions there are, the faster the reaction.**

This idea also explains why the reaction between magnesium and hydrochloric acid slows down as time goes by:

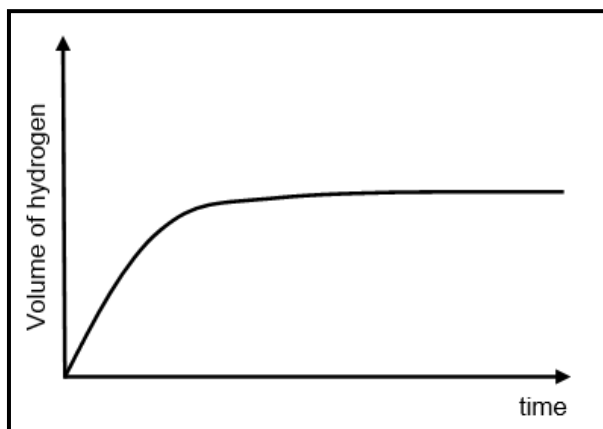
At the start, there are plenty of magnesium atoms and acid particles. But they get used up during successful collisions.





This means that the slope of the reaction curve decreases with time, as shown on the right

After a time, there are fewer magnesium atoms, and the acid is less concentrated. So the reaction slows down.



### Why the rate increases with temperature

At lower temperatures, particles of reacting substances have less kinetic energy, are moving much slower and so there are less effective collisions. Increasing the temperature increases the kinetic energy that the reactants have, which means they will move faster, collide more often and have more energy available to exceed the activation energy.

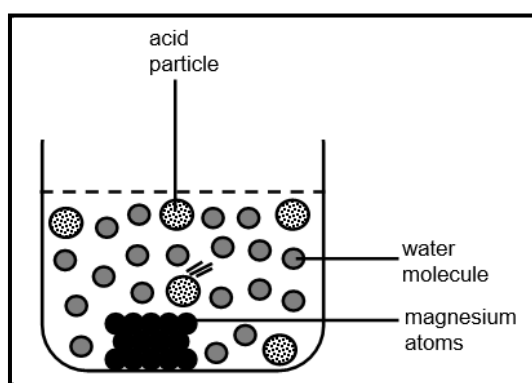
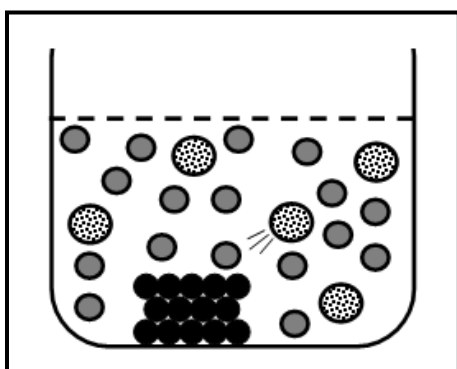
More energy means more successful effective collisions. Therefore the rate of reaction increases.

**Increasing the temperature of a reaction increases the rate**

### Why the rate increases with surface area

The reaction between the magnesium and acid is much faster when the metal is cut into smaller pieces or when it is powdered.

The acid particles can collide only with those magnesium atoms in the outer layer of the metal ribbon.



When the metal is powdered, many more atoms are exposed. So there is a greater chance of successful collisions.

The surface area of a solid reactant can be increased by cutting the solid into smaller pieces or by crushing the solid to a powdered form. Increasing the surface areas in these ways increases the number of particles that are exposed to the reactants which increases the number of collisions and so increases the number of effective reactions. So smaller pieces or a powder form of a reactant will have a higher rate of reaction than the same reactant in a block form.

### Why a catalyst increases its rate

Some reactions can be speeded up by adding a **catalyst**. A catalyst is a substance that increases the rate of a reaction but is not being used up itself. It does so by lowering the activation energy of a reaction. In the presence of a catalyst, a collision needs less energy in order to be successful. This means that more particles will have enough kinetic energy to overcome the activation energy level resulting in more successful effective collisions, so the reaction goes faster. Catalysts are very important in industry, because they speed up reactions even at low temperatures. This means that less fuel is needed, so money is saved.

### Why pressure increases the rate

In reactions involving gases, increasing the pressure on the gases has the same effect as increasing the concentration of solutions. Because more molecules are squeezed into the same volume, they will meet more often and react more quickly.

### Important points to remember:

- As the concentration of the reactants increases, the reaction rate increases
- As the surface area of the reactant increases, the reaction rate increases
- As the temperature of a system increases, the reaction rate increases
- The presence of a catalyst increases the reaction rate.
- Increasing the pressure of reactions involving gases increases the rate of reaction.



**Activity:** Now test yourself by doing this activity.

### Answer the following questions:

1. Here are some reactions that take place at home. Put them in order of decreasing rate (the fastest one first).

- |    |                              |    |       |
|----|------------------------------|----|-------|
| A. | a gloss paint drying         | 1. | _____ |
| B. | fruit going rotten           | 2. | _____ |
| C. | cooking gas burning          | 3. | _____ |
| D. | a cake baking                | 4. | _____ |
| E. | an old metal bicycle rusting | 5. | _____ |

2. Which of these rates of travel is the slowest? Underline the correct answer.

5 kilometres per second  
20 kilometres per minute  
60 kilometres per hour

---

3. Copy and complete:

Two particles can only react together if they \_\_\_\_\_ and if the \_\_\_\_\_ has enough \_\_\_\_\_.

---

4. What does the rate of any reaction depend on?
- 
- 

5. Why are catalysts important in industries?
- 
- 



## Summary

You have come to the end of lesson 9. In this lesson you have learnt that:

- rate is a measure of the change that happens in a single unit of time.
  - the collision theory says that a chemical reaction can only occur between particles when they collide.
  - the rate of a reaction depends on how many successful collisions there are in a given unit of time.
  - the rate of reaction can be found by measuring the amount of reactant used up, or the amount of product formed in a given time.
  - the rate of reaction can be controlled by changing the frequency of the collisions or changing the energy of the reactant particle.
  - a catalyst is a substance that increases the rate of a reaction but is not consumed in the reaction.
- 

|                                                    |
|----------------------------------------------------|
| <b>NOW DO PRACTICE EXERCISE 9 ON THE NEXT PAGE</b> |
|----------------------------------------------------|



## Practice Exercise 9

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**Answer the following questions:**

1. What is rate?  
\_\_\_\_\_  
\_\_\_\_\_
2. What must happen in order for a chemical reaction to take place?  
\_\_\_\_\_  
\_\_\_\_\_
3. What will happen to the rate of a reaction when the temperature is lowered?  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
4. In your own words, explain why the reaction between magnesium and acid goes faster when:
  - a. The temperature is raised  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
  - b. The magnesium is powdered  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
5. Explain why a catalyst can speed up a reaction, even at low temperatures?  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

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|                                                              |
|--------------------------------------------------------------|
| <b>CHECK YOUR ANSWERS. ANSWERS ARE AT THE END OF TOPIC 2</b> |
|--------------------------------------------------------------|

**Answers to Activity.**

1.
  - A. A cooking gas burning
  - B. A cake baking
  - C. A gloss paint drying
  - D. Fruit going rotten
  - E. An old metal bicycle rusting
2. 60 kilometres per hour
3. Two particles can only react together if they **collide** and if the **collision** has enough **energy**.
4. The rate of a reaction depends on how many successful collisions there are in a given unit of time.
5. Catalysts are very important in industries, because they speed up reactions even at low temperatures. This means that less fuel is needed, so money is saved.

## Lesson 10: Reactions Involving Enzymes

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Welcome to Lesson 10. In your previous lesson you learnt that in order for a chemical reaction to take place the reactants must collide and the collision must have enough energy. In this lesson you will learn about reactions involving enzymes.



### Your Aims:

- define enzymes and biotechnology
- describe how enzymes work
- discuss the importance of biotechnology

### What are Enzymes?

At any given moment, all the work being done inside every living cell in every plant and animal, including you is being done by enzymes.

Enzymes are **biological catalysts**. They speed up the chemical reactions which go on inside living things but are not changed during the reaction. Without them the reactions would be so slow that the organism would die. Maltase, lipase and protease are examples of enzymes. Notice that the name of an enzyme ends in the suffix- ase.

Enzymes are divided into groups depending on the job they do.

- **Amylases** break down starch. Cells in your mouth produce amylase and release it into saliva, where it catalyses the breakdown of starch in food when you chew.
- **Proteases** break down protein (for example when you digest food).
- **Lipases** break down fats and oils (lipids).

Amylases, proteases and lipases are just three of thousands of biological catalysts. As you can see from these three **enzymes** – each one does a specific job. They control reactions in our bodies and in food production.

### How enzymes work

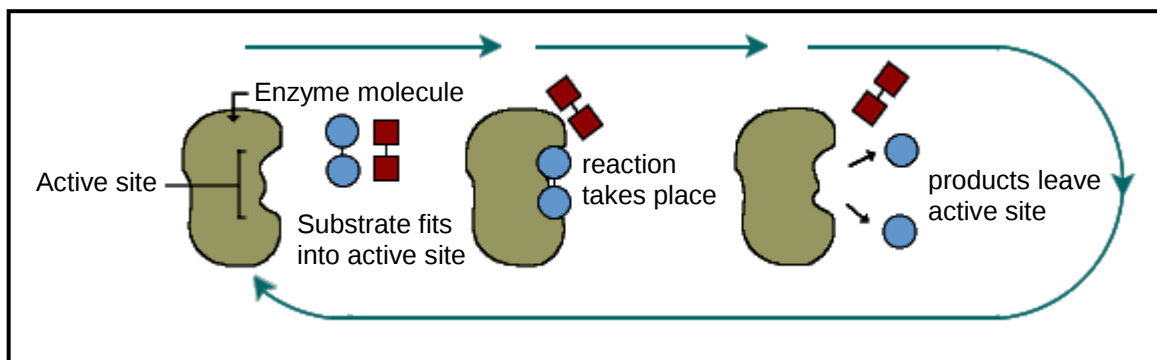
The lock-and-key model is used to explain how enzymes work. If we examine a lock and a key, we notice that the shape of the key is designed to fit into a lock. The key can be used to open and close the lock, and the key can be used again and again. Only one key can fit into the lock.



Enzymes are thought to have an area with a very particular shape. The shape of an enzyme allows it to carry out specific chemical reactions. An enzyme acts as a very efficient catalyst for a specific reaction. The enzyme speeds that reaction up tremendously.

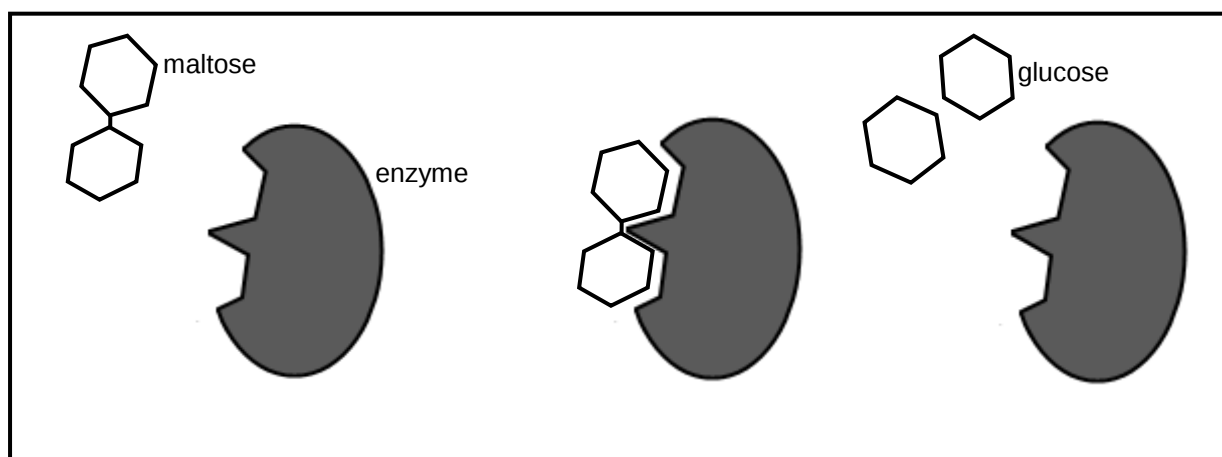
When a molecule of the right chemical for that enzyme comes along it will fit exactly into the shape. The area of particular shape is called the **active site** of the enzyme, as that is where the reaction takes place. The reacting molecule that binds to the enzyme is called the **substrate**. After the reaction has taken place, the products of the reaction leave the active site leaving it ready for another molecule of the chemical.

The active site of an enzyme has such a particular shape that only one kind of molecule will fit it, rather like a particular key fitting a lock. In organisms, the enzyme is the key, and the substrate is the lock. Only one kind of enzyme can be used for each type of chemical reaction. This is why enzymes are specific in their action.



Let us now study closely an example of how an enzyme works.

The sugar maltose is made from two glucose molecules bonded together. The enzyme maltase is shaped in such a way that it can break the bond and free the two glucose pieces. The only thing maltase can do is break maltose molecules, but it can do that very rapidly and efficiently. Other types of enzymes can put atoms and molecules together. Breaking molecules apart and putting molecules together is what enzymes do, and there is a specific enzyme for each chemical reaction to work properly.



Maltose is made of two glucose molecules bonded together (1). The maltase enzyme is a protein that is perfectly shaped to accept a maltose molecule and break the bond (2). The two glucose molecules are released (3). A single maltase enzyme can break in excess of 1000 maltose bonds per second, and will only accept maltose molecules.

You can see in the diagram above the basic action of an enzyme. A maltose molecule floats near and is captured at a specific site on the maltase enzyme. The **active site** on the enzyme breaks the bond, and then the two glucose molecules float away.

**In the active site the bonds are broken down easily and the products are released quickly leaving the enzyme free to accept another substrate.**

### Biotechnology

Enzymes have been used in biotechnology for thousands of years. Biotechnology means using plants, animals and microbes (bacteria and fungi) to produce useful substances. Without realising it, ancient Egyptians and Babylonians used the natural enzymes made by micro-organisms to turn milk into yoghurt and cheese, and for making beer, wine, vinegar and bread.

The biotechnology industry of today makes use of these ancient techniques plus new ones to produce a huge variety of useful things including fuels, foods for humans and animals, antibiotics and other medicines, plastics and industrial chemicals. It can also dispose of sewage, refuse and spilled oil. In these ways, biotechnology can help solve the world's food, health and energy problems.

Some other processes that depend on enzymes are given below.

- In biological detergents or washing powders – stains like sweat, grease, grass stains and blood contain proteins, starches and fats. So **proteases**, **amylases** and **lipases** are added to detergents – and the stains vanish in the wash.
- In making baby food – **Proteases** 'predigest' protein in the food to make it easier for babies to digest.
- In making soft-centred chocolate. Have you ever wondered how they got the runny fillings into the chocolates? Easy! The filling starts off as an almost solid paste. It contains some sugar cane (sucrose) and a little of the enzyme **invertase**. It is coated with chocolate and left for a couple of weeks. Inside, the enzyme gets to work on the sucrose and breaks it down into simpler sugars, making the paste go runny.
- To convert starch syrup (from potatoes for example, and not sweet) into sugar syrup (which is sweet) for use in baking, soft drinks, and making sweets. A **carbohydrase** is used for this.
- To convert glucose (a sugar) into fructose (another sugar) which is much sweeter. So you need less, which is why it is used in slimming foods. An enzyme called **isomerase** is used for this.
- To stonewash blue jeans for that washed out look. They use to put the jeans in a washing machine with pumice stones, to knock some of the indigo dye from the denim. A **cellulase** enzyme does the job now

It is possible that in the future we shall be able to get bacteria to make all sorts of things including antibiotics, medical drugs and even cheap fuels.

**Why so popular?**

Enzymes are becoming more widely used as industrial catalysts because:

- They are catalysts so they make reactions go easier. This increases productivity and yield
  - As catalysts they are not consumed by the reaction. They may be used over and over again
  - They are specific in their action and are therefore less likely to produce unwanted by-products
  - They are biodegradable and therefore cause less environmental pollution
  - They work in mild conditions, that is, low temperatures, neutral pH and normal atmospheric pressure, and therefore are energy saving
  - They are sensitive to their environment so you can control them easily and stop them working altogether by changing the temperature, the pH or the substrate concentration
- 



**Activity:** Now test yourself by doing this activity.

**Answer these questions correctly.**

1. What is an enzyme?

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2. What does amylase do?

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3. Enzymes are added to some washing powders.

- a. Explain why, and name the enzymes

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- b. You should not use them in very hot water. Why?

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4. Explain how the runny centres get into some chocolates.

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5. Some denim jeans were called **stonewashed**. Why?

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6. Why might this name **stonewashed** no longer be appropriate?

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## Summary

You have come to the end of lesson 10. In this lesson you have learnt that:

- all the work being done inside every living cell is being done by enzyme.
- enzymes are biological catalysts.
- enzymes speed up the chemical reactions which go on inside living things but are not changed during the reaction.
- the shape of an enzyme allows it to carry out specific chemical reactions.
- the area of a particular shape is called the **active site** of the enzyme and that is where the reaction takes place.
- the reacting molecule that binds to the enzyme is called the **substrate**.
- biotechnology means using plants, animals and microbes (bacteria and fungi) to produce useful substances.
- it is possible that in the future we shall be able to get bacteria to make all sorts of things including antibiotics, medical drugs and even cheap fuels.

**NOW DO PRACTICE EXERCISE 10 ON THE NEXT PAGE**



## Practice Exercise 10

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**Answer the following questions:**

1. What does biotechnology mean?

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2. What are the oldest examples of biotechnology?

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3. How could biotechnology help solve the world's food and energy problems?

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4. Why are enzymes important?

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5. Define the term substrate?

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6. Explain what is meant by saying "enzyme action is specific."

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7. What kind of molecule is kinase?

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|                                                              |
|--------------------------------------------------------------|
| <b>CHECK YOUR ANSWERS. ANSWERS ARE AT THE END OF TOPIC 2</b> |
|--------------------------------------------------------------|

**Answers to Activity**

1. Enzymes are proteins that act as catalysts
2. Amylase breaks down starches
3.
  - a. Some stains like sweat, grease, grass stains and blood contain proteins, starches and fats. So proteases, amylases and lipases are added to the detergents and the stains varnish in the wash.
  - b. Enzymes usually work best at quite low temperatures. Too hot and the enzyme can be destroyed.
4. The filling starts off as an almost solid paste. It contains some sugar cane (sucrose) and a little of the enzyme invertase. It is coated with chocolate and left for a couple of weeks. Inside, the enzyme gets to work on the sucrose and breaks it down into simpler sugars, making the paste go runny.
5. These denim jeans were called stonewashed because the jeans used to be put in a washing machine with pumice stones to knock some of the indigo dye from the denim to give the jeans the stonewashed look.
6. The name stonewashed is no longer appropriate as a cellulase enzyme does the job now.

## Answer to Practice Exercises 6 - 10

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### Practice Exercise 6

1.
  - a. corrosive to metals
  - b. turn blue litmus indicator red
  - c. have a pH value less than pH 7
  - d. have a sour taste
  - e. form electrolytic solutions
  - f. can neutralise an alkali

2.

|   |
|---|
| C |
| A |
| F |
| E |
| B |
| D |

3.
 

|    |                         |   |                  |                   |                            |   |                                     |
|----|-------------------------|---|------------------|-------------------|----------------------------|---|-------------------------------------|
| A. | $2\text{HCl}$           | + | $2\text{MgO}$    | $\longrightarrow$ | $2\text{MgCl}$             | + | $\text{H}_2\text{O}$                |
| B. | $2\text{HNO}_3$         | + | $\text{CaCO}_3$  | $\longrightarrow$ | $\text{Ca}(\text{NO}_3)_2$ | + | $\text{CO}_2 + \text{H}_2\text{O}$  |
| C. | $\text{H}_2\text{SO}_4$ | + | $\text{Ca}$      | $\longrightarrow$ | $\text{CaSO}_4$            | + | $\text{H}_2$                        |
| D. | $2\text{HNO}_3$         | + | $2\text{CuCO}_3$ | $\longrightarrow$ | $2\text{CuNO}_3$           | + | $2\text{CO}_2 + \text{H}_2\text{O}$ |
| E. | $2\text{HCl}$           | + | $2\text{KOH}$    | $\longrightarrow$ | $2\text{KCl}$              | + | $\text{H}_2\text{O}$                |
- 

### Practice Exercise 7

- |      |      |
|------|------|
| 1. A | 6. A |
| 2. B | 7. C |
| 3. C | 8. C |
| 4. D | 9. D |
| 5. C |      |

**Practice Exercise 8**

1. Neutralisation reaction is a reaction between an acid and a base.
  2. During a neutralisation reaction the hydrogen ions from an acid and hydroxide or oxide ions from a base combine to form water.
  3.
    - i.  $\text{HCl (aq)}$
    - ii.  $\text{HNO}_3 \text{ (aq)}$
    - iii.  $\text{H}_2\text{SO}_4 \text{ (aq)}$
  4.
    - i.  $\text{NaOH (aq)}$
    - ii.  $\text{Ca(OH)}_2 \text{ (aq)}$
    - iii.  $\text{Al}_2\text{O}_3 \text{ (aq)}$
    - iv.  $\text{ZnO (aq)}$
  5.
    - i. calcium chloride
    - ii. zinc sulphate
    - iii. aluminium nitrate
    - iv. sodium sulphate
  6.
    - i.  $2\text{HCl (aq)} + \text{Ca(OH)}_2 \text{ (aq)} \longrightarrow \text{CaCl}_2 \text{ (aq)} + 2\text{H}_2\text{O (l)}$
    - ii.  $\text{H}_2\text{SO}_4 \text{ (aq)} + \text{ZnO (aq)} \longrightarrow \text{ZnSO}_4 \text{ (aq)} + \text{H}_2\text{O (l)}$
    - iii.  $6\text{HNO}_3 \text{ (aq)} + \text{Al}_2\text{O}_3 \text{ (aq)} \longrightarrow 2\text{Al(NO}_3)_3 + 3\text{H}_2\text{O (l)}$
    - iv.  $\text{H}_2\text{SO}_4 \text{ (aq)} + 2\text{NaOH (aq)} \longrightarrow \text{Na}_2\text{SO}_4 \text{ (aq)} + 2\text{H}_2\text{O (l)}$
- 

**Practice Exercise 9**

1. Rate is a measure of the change that happens in a single unit of time.
2. For a chemical reaction to occur, the reacting particles (reactants) must collide.
3. When the temperature is lowered, the particles of the reacting substances will have less kinetic energy and will move much slower and so there will be less effective collisions.
4.
  - a. When the temperature is raised, the particles take in energy. This causes them to move faster and collide more often. The collisions have more energy, so more of them are successful. Therefore, the rate of reaction increases or goes faster.
  - b. When the magnesium is powdered, many more atoms are exposed. So there is a greater chance of successful collisions which will make the reaction go faster.

5. At low temperatures, particles of reacting substances do not have much energy so there is not much chance of a successful collision. But the reaction can be speeded up by adding a catalyst. In the presence of a catalyst, a collision needs less energy in order to be successful. The result is that more collisions become successful, so the reaction goes faster.
- 

### Practice Exercise 10

1. Biotechnology means using plants, animals and microbes (bacteria and fungi) to produce useful substances.
2. Ancient Egyptians and Babylonians used the natural enzymes made by micro-organisms to turn milk into yoghurt and cheese, and for making beer, wine, vinegar and bread.
3. It is possible that in the future we shall be able to get bacteria to make foods for humans and animals and even cheap fuels.
4. Enzymes speed up the rate of chemical reactions. Without enzymes, the chemical reactions that take place in an organism do not work and the organism dies.
5. The substrate is the substance that an enzyme works on.
6. Only one kind of enzyme can be used for each type of chemical reaction. For Example, maltase can be used to make or break down maltose or a lipase can be used to make or break down a lipid.
7. Kinase is an enzyme. All enzymes end in the suffix – ase.

## REVIEW OF TOPIC 2 :                      CHEMICAL CHANGES

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Now, revise all lessons in this Topic and then do **ASSIGNMENT 3**.  
Here are the main points to help you revise.

### Lesson 6:    A Closer Look at Acids

- Acids are some of the things that are found in the laboratory and at home. They can be irritant and corrosive.
- Corrosive which means they will attack and weaken many things including metals, paper, clothing and skin.
- Concentrated means without much or without any water added. Dilute means a lot of water added.
- Strong acid is an acid that has a very low pH (0-3). A weak acid is an acid that has a high pH close to 7 (4-6).
- Hydrogen ion causes acidity in acids.
- The pH scale measures how acidic or basic a liquid is. The pH scale is actually a measure of the number of Hydrogen ( $H^+$ ) ions in a solution.
- Stomach acidity can be described as a condition wherein there is an excess of acid secretion by the gastric glands of stomach.
- The term salt refers to any ionic compound resulting from a reaction involving acids.
- Acid + metal - a reaction that forms a metal salt and hydrogen as the only products.
- Acid + metal oxide - a reaction that forms a salt and water as the only products.
- Acid + carbonate - a reaction that forms salt, carbon dioxide and water as the only products.

### Lesson 7:    A Closer Look at Bases

- A base is any compound that yields hydroxide ions ( $OH^-$ ) when dissolved in water.
- A soluble base is referred to as an alkali if it contains and releases hydroxide ions ( $OH^-$ ) quantitatively.
- A strong base is a base which hydrolyzes completely, raising the pH of the solution toward 14.
- Bases have the following properties:
  - Slimy or soapy feel on fingers, due to saponification of the lipids in human skin.
  - Concentrated or strong bases are caustic on organic matter and react violently with acidic substances.
  - Aqueous solutions or molten bases dissociate in ions and conduct electricity.
  - Bases are electrolytes; because they form ions in solution and therefore the better it conducts electricity.
  - The pH level of a basic solution is higher than 7.
  - Bases are bitter in taste.
- Indicators are chemical substances that are used to find out whether a given solution is acidic or alkaline by showing a colour change.

**Lesson 8: Neutralisation**

- Neutralisation is a reaction between an acid and a base.
- It is the combination of hydrogen ions from an acid and hydroxide or oxide ions from a base to form water.
- When the solutions of an acid and alkali are mixed, hydrogen ions,  $\text{H}^+$  (aq), and hydroxide ions,  $\text{OH}^-$  (aq), combine to form water molecules.
- Hydrogen ions and oxide ions,  $\text{O}^{2-}$ , combine to form water.
- The salt may be regarded as what is left when the  $\text{H}^+$  of the acid is neutralised by the  $\text{OH}^-$  or  $\text{O}^{2-}$  of the base.

**Lesson 9: Rate of Reaction**

- Rate is a measure of the change that happens in a single unit of time.
- The collision theory says that a chemical reaction can only occur between particles when they collide.
- The rate of a reaction depends on how many successful collisions there are in a given unit of time.
- The rate of reaction can be found by measuring the amount of reactant used up, or the amount of product formed in a given time.
- The rate of reaction can be controlled by changing the frequency of the collisions or changing the energy of the reactant particle.
- A catalyst is a substance that increases the rate of a reaction but is not consumed in the reaction.

**Lesson 10: Reactions Involving Enzymes**

- All the work being done inside every living cell is being done by enzyme.
- Enzymes are biological catalysts.
- Enzymes speed up the chemical reactions which go on inside living things but are not changed during the reaction.
- The shape of an enzyme allows it to carry out specific chemical reactions.
- The area of particular shape is called the **active site** of the enzyme and that is where the reaction takes place.
- The reacting molecule that binds to the enzyme is called the **substrate**.
- Biotechnology means using plants, animals and microbes (bacteria and fungi) to produce useful substances.
- It is possible that in the future we shall be able to get bacteria to make all sorts of things including antibiotics, medical drugs and even cheap fuels.

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|                                                                   |
|-------------------------------------------------------------------|
| <b>REVISE WELL AND THEN DO TOPIC TEST 2 IN YOUR ASSIGNMENT 3.</b> |
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## **TOPIC 3**

# **REACTIONS OF ORGANIC SUBSTANCES**

**In this topic you will learn about:**

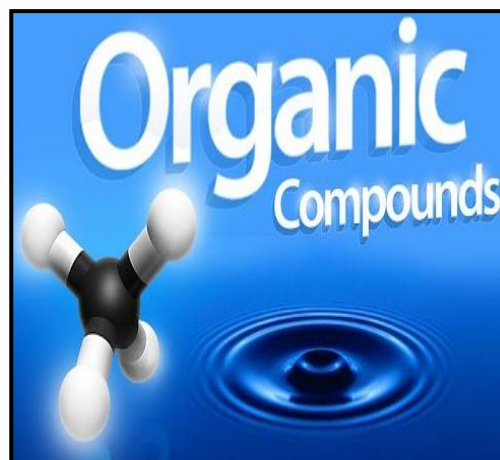
- **photosynthesis**
- **respiration**
- **burning fuel**
- **chemicals from crude oil**
- **cracking**

## INTRODUCTION TO TOPIC 3: REACTIONS OF ORGANIC SUBSTANCES

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Organic reactions are chemical reactions involving organic compounds. They are used in construction of new organic molecules. The production of many man-made chemicals such as drugs, plastics, food additives and fabrics depend on organic reactions.

**Organic chemistry** is the study of living things-not in the same way that biology is the study of life. Rather, organic chemistry takes a look at what composes the living things and how they are structured. Organic chemistry breaks down living things not only into organs seen in organisms but goes a step further to break down those organs into atoms and molecules.



It focuses mainly on carbon, which is highly essential in maintaining life, and particularly in on the hydrocarbon, which is a molecule composed of hydrogen and carbon.



Hydrocarbons not only compose what we are made of, but also what we consume, including carbohydrates, proteins, steroids, fats and more. As a matter of fact, you may be surprised to know that everyday things, such as caffeine, plastic and paint are all composed of hydrocarbons.

When we look at organic chemistry, we are mainly looking at molecules composed of carbon and hydrogen, however we may also see nitrogen, sulfur, oxygen, phosphorous, silicon and the halogens (F, Cl, Br, I and At) taking a part in our compounds and reactions. Organic compounds are generally composed of long carbon chains displaying covalent bonds.

Such questions will arise as:

- Which element is present in all organic compounds?
- What is the name of the compound that has the molecular formula  $C_6H_6$ ?
- What element is present in all organic compounds?

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**In this Topic, you will find the answers to these questions and other questions relating to reactions of organic substances.**

## Lesson 11: Photosynthesis



Welcome to Lesson 11. In the last lesson you learnt about reactions involving enzymes. In this lesson you will learn about photosynthesis, which is a reaction that also involves enzymes. Photosynthesis reaction is the process by which organisms capture energy from sunlight and use it to build food molecules rich in chemical energy.



### Your Aims:

- explain photosynthesis
- enumerate and explain the process of photosynthesis.
- draw and label diagrams of photosynthesis.

### Importance of Photosynthesis

Life on earth would be impossible without photosynthesis. Every oxygen atom in the air we breathe was once part of a water molecule, released by photosynthesis. The energy released by the burning of coal, firewood, gasoline, and natural gas, and by our bodies' burning of all the food we eat all, directly or indirectly, has been captured from the sunlight by photosynthesis. It is vitally important that we understand photosynthesis.

**All animals including human beings depend on plants for their food. Have you ever wondered from where plants get their food?**

Green plants, in fact, have to make or rather synthesise the food they need. All other living things depend on the plants for food and the other needs.

Green plants carry out **photosynthesis**, a chemical process by which they use light energy to make food. Eventually, all living forms on earth depend on sunlight for energy. The use of energy from sunlight by plants during photosynthesis is the foundation of life on earth.

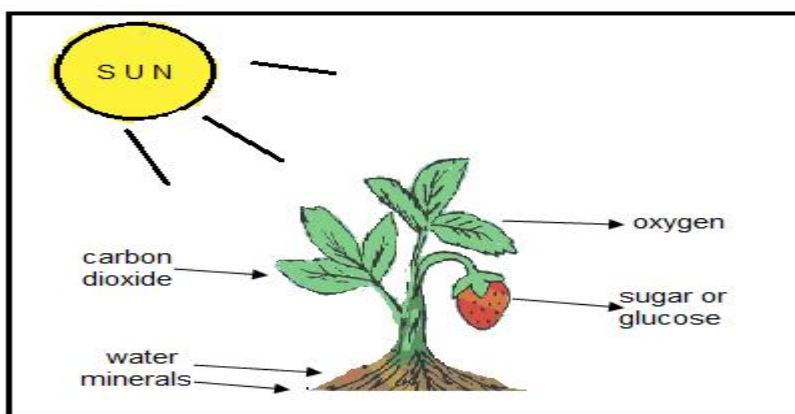
Photosynthesis is important due to two reasons:

1. It is the primary source of all food on earth.
2. It is also responsible for the release of oxygen into the atmosphere by green plants.

### How do green plants make or synthesise their food?

The process by which green plants make their food is called photosynthesis.

Photosynthesis occurs in the leaves and sometimes the stems of green plants. Photosynthesis also occurs in many kinds of bacteria and algae.



The photosynthesis process

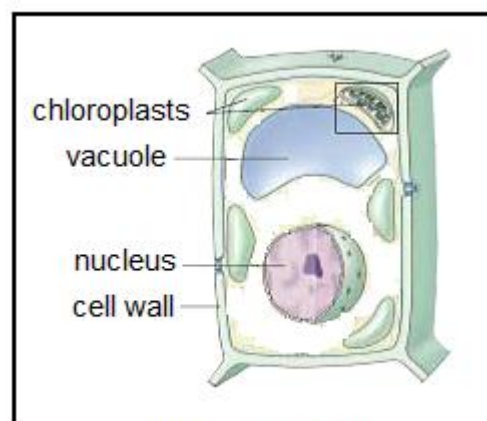
All green plants, bacteria and the algae which photosynthesise contain a substance called **chlorophyll**. It is the chlorophyll that traps the energy of the sunlight which is used to carry out the photosynthesis reaction.



Moss plants are growing on the surface of an old kunai grass house.

### Where in a green plant is chlorophyll found?

Inside the cells of all green plants there are parts or organelles called **chloroplasts**. Chlorophyll is found in the chloroplasts and the chloroplasts are the place in the cells where the photosynthesis reactions take place.

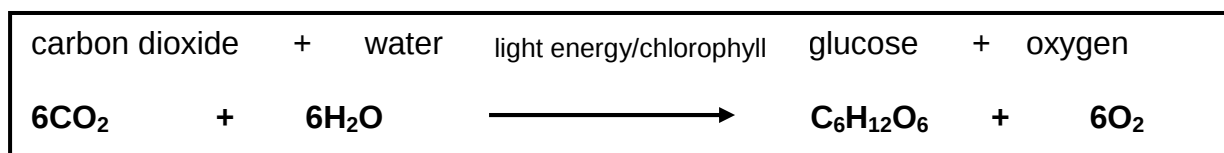


Parts of a plant cell

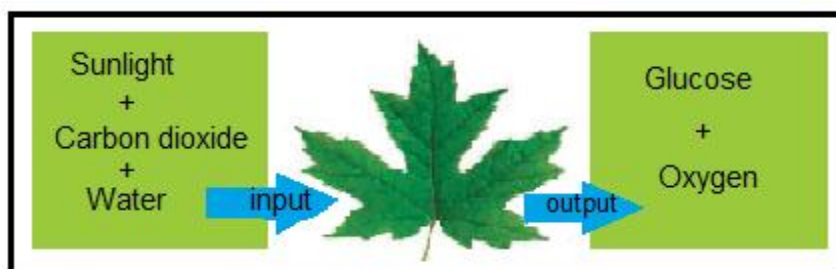
### What is photosynthesis?

The word photosynthesis literally means a putting together (synthesis) in the presence of light (photo). Photosynthesis is the process by which all green plants containing chlorophyll use sun's energy to make glucose sugar (food) from water and carbon dioxide and release oxygen as a by-product.

The process of photosynthesis can be summarised below:



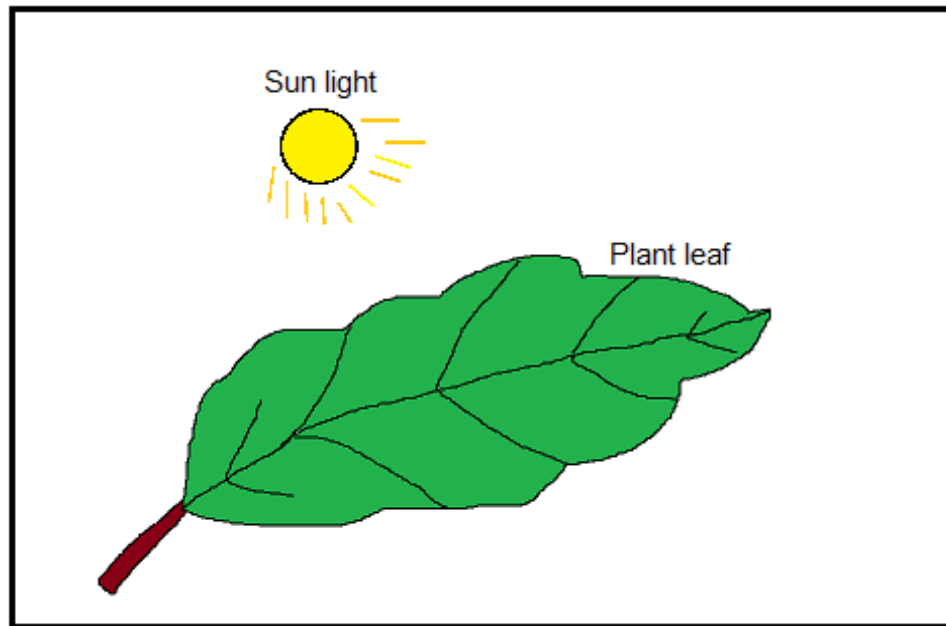
The sugar is the food that is produced by the plants. It is a very simple sugar called glucose.



Inputs and outputs during photosynthesis reaction.

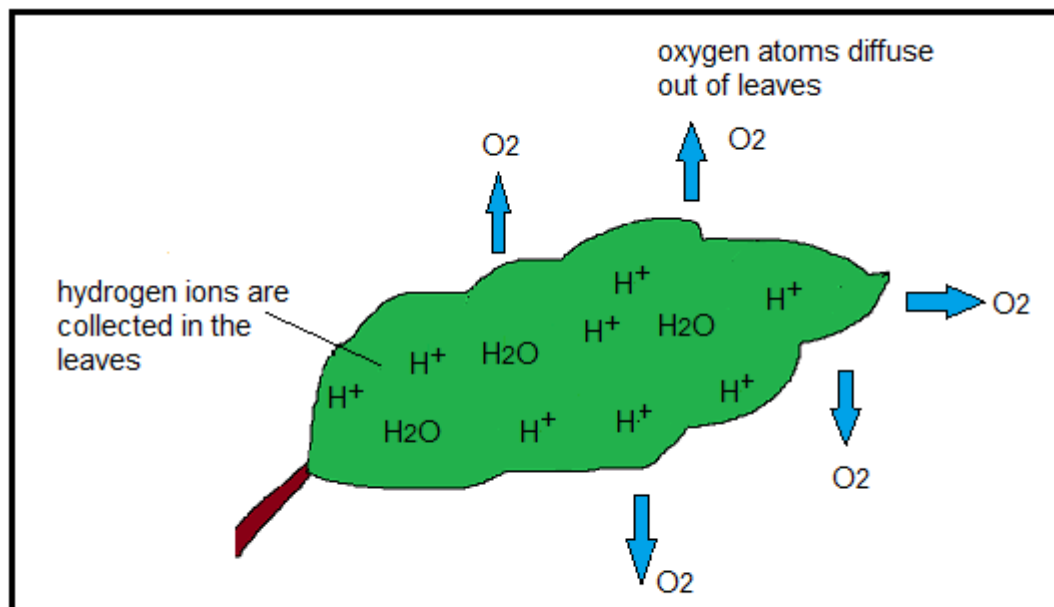
**A summary of the photosynthesis process:**

1. The leaves and green parts of the plants absorb energy. From the sunlight.



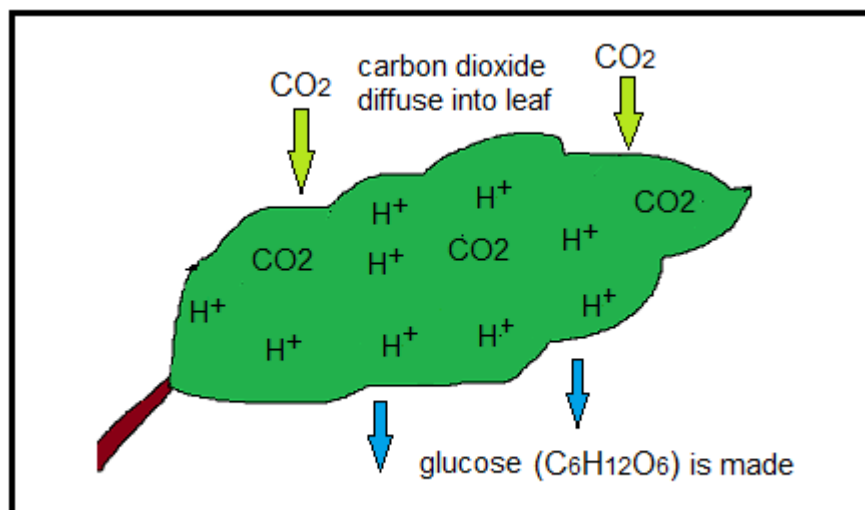
Chlorophyll in green plants absorb energy from sunlight

2. The water molecules in the leaf cells are split by the energy from the sunlight. The hydrogen ions are collected in the leaves while the oxygen atoms escape into the air through tiny openings on the surfaces of the leaves called **stomata**. These oxygen molecules are the by-products of the photosynthesis reaction and they are useful to all living things on earth.



Water molecules are split into hydrogen and oxygen atoms. Hydrogen ions remain in the leaves while oxygen gas diffuses into the atmosphere.

3. Carbon dioxide molecules from the atmosphere diffuse into the leaves through the stomata. By the action of enzymes these carbon dioxide molecules chemically combine with the hydrogen ions collected in the leaves to produce sugar or glucose.



Carbon dioxide gas combines with hydrogen ions to produce glucose

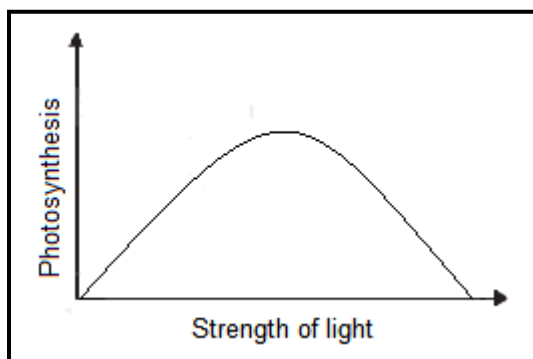
The glucose made is stored in different parts of the plant which is collected and eaten by animals as food. The above process of photosynthesis repeats all the time in all green plants. This provides food and oxygen to all living things on earth therefore plants are known as the food factory.

### Factors affecting the rate of photosynthesis

The rate of photosynthesis is under the influence of several factors, both internal (inside the plant) and external (outside of the plant). The internal factors include the number, size, age and arrangement of leaves, internal carbon dioxide concentration and the amount of chlorophyll present. The external factors would include the availability of sunlight, temperature, carbon dioxide concentration and water. As a plant photosynthesises, all these factors will affect the rate of photosynthesis.

### Light

Experiments have shown that as the strength of light or light intensity increases the rate of photosynthesis also increase. That means the brighter the light the faster the rate of photosynthesis. However if the light intensity increases so high that it reaches beyond a point, it causes the breakdown of chlorophyll and a decrease in photosynthesis. Plants in the open will photosynthesise faster than those that are growing in the shade. However, different types of plants have their own adaptations that help them to grow best in certain conditions.



### Carbon dioxide

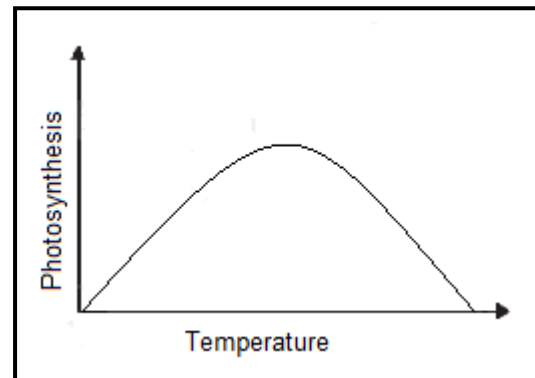
This is one of the major raw materials for photosynthesis and because air contains relatively little (about 0.3%) very small changes in carbon dioxide concentration can make a big difference in the rate of photosynthesis.

### Water

This is also raw material, and plants that are wilting from lack of water will photosynthesise slowly.

### Temperature

Because chemical reactions tend to occur faster at higher temperature, the rate of photosynthesis generally increases as temperature rises. At 10°C the photosynthesis reaction rate may double. Above 40°C the temperature is so high that the heat destroys the enzymes which control photosynthesis therefore the rate drops rapidly. Photosynthesis is more effective in the tropical rainforests where the temperature is more suitable.



### Chlorophyll concentration in chloroplasts

Chlorophyll is required for photosynthesis and the more chlorophyll the faster the rate of photosynthesis. Chlorophyll contains the element magnesium. In plants lacking magnesium, the leaves turn yellow because not enough chlorophyll is present. The growth rate of this particular plant would be very slow.

### Wave lengths of light

The rate of photosynthesis is greatest with red and blue light because chlorophyll absorbs these colours.

### Leaves of plants are adapted for photosynthesis in many ways.

1. Their **broad, flat shape** gives a large surface area for absorption of sunlight and carbon dioxide.
2. Most leaves are **thin** and carbon dioxide has to diffuse across only short distances to reach the inner cells.
3. There are many **stomata** (pores) in the lower surface of the leaf. This allows the exchange of carbon dioxide and oxygen.
4. There are more **chloroplasts** in the upper cells of the leaves which trap sunlight energy.
5. The **branching network of veins** provides a good water supply to the photosynthesising cells. No cell is very far from a water- conducting vessel in one of these veins.

In daylight, respiration and photosynthesis will be taking place in a leaf, in darkness, only respiration will be taking place. In daylight, a plant will be taking in carbon dioxide and giving out oxygen. In darkness a plant will be taking in oxygen and giving out carbon dioxide.



**Activity:** Now test yourself by doing this activity.

### Part A

Fill in the blank spaces with the most correct words.

1. Photosynthesis comes from the word **photo** which means \_\_\_\_\_ and **synthesis** which means \_\_\_\_\_.
2. The two substances needed by plants for photosynthesis are \_\_\_\_\_ and \_\_\_\_\_.
3. The two substances produced during photosynthesis are \_\_\_\_\_ and \_\_\_\_\_.
4. All green plants contain \_\_\_\_\_ which they use to capture the sun's energy.
5. In plant cells there are cell parts called \_\_\_\_\_ which contains the chlorophyll.
6. Gases move into and out of leaves through openings called \_\_\_\_\_.

### Part B

State whether the statement is true or false by writing the correct answers in the box provided.

- |                                                                 |       |
|-----------------------------------------------------------------|-------|
| 1. Carbon dioxide gas is produced                               | _____ |
| 2. Sunlight provides the energy                                 | _____ |
| 3. Chloroplasts absorb the sunlight energy                      | _____ |
| 4. Water molecules are split into oxygen and hydrogen           | _____ |
| 5. Oxygen and hydrogen are released into the air                | _____ |
| 6. Glucose is produced when hydrogen reacts with carbon dioxide | _____ |
| 7. Glucose is a form of sugar                                   | _____ |

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|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|



## Summary

You have come to the end of lesson 11. In this lesson you have learnt that:

- plants make food for all other living things using energy of the sunlight.
- sunlight energy is the primary source of all other forms of energy on earth.
- photosynthesis is the process whereby green plants use chlorophyll
- to capture energy of the sunlight to produce glucose (food) from water and carbon dioxide and release oxygen as a waste product.
- chlorophyll is found in the chloroplasts of all plant cells.
- increase in light intensity increases photosynthesis, however if the light is so much that it reaches beyond a point photosynthesis reaction stops.
- photosynthesis reaction increases with an increase in temperature, however if the temperature exceeds a point the reaction stops also.
- the process of photosynthesis are as follows:
  - \* chlorophyll in plants absorb energy of sunlight
  - \* this energy is used to split water molecules in the leaves into oxygen atoms and hydrogen ions.
  - \* the oxygen gas escapes into the atmosphere while the hydrogen ions are collected in the leaves.
  - \* carbon dioxide molecules diffuse into the leaves through stomata openings.
  - \* carbon dioxide reacts with the hydrogen ions to produce glucose (sugar).
- leaves have adaptations for photosynthesis such as: flat shape, thinness, many stomata, presence of chlorophyll, having many branching veins.

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**NOW DO PRACTICE EXERCISE 11 ON THE NEXT PAGE.**



## Practice Exercise 11

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**Answer the following questions:**

1. Define the word photosynthesis.

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2. Write down the complete word and chemical equation for photosynthesis process.

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3. Oxygen is produced during photosynthesis and is released by the leaves. Where do the oxygen molecules come from?

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4. The glucose is formed when two substances react together. Name the substances.

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5. Through what track do the carbon dioxide and oxygen gases move in and out of the cells of plant leaves?

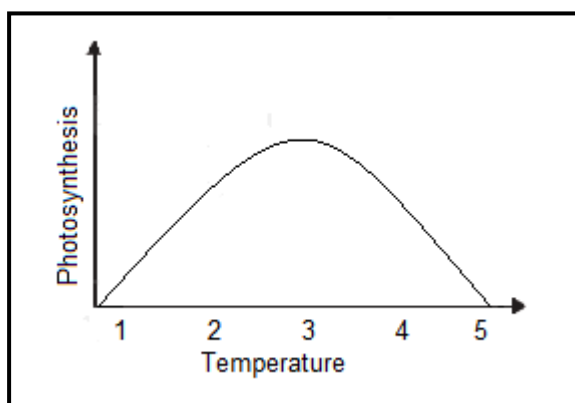
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**Refer to the graph below to answer the Questions 6 to 9.**

The graph below shows the changes in the photosynthesis reaction in a plant as the temperature changes from point 1 to point 5.



Study the graph and answer the following questions.

6. At which temperature points 1 to 5 is the rate of photosynthesis at its

- a. Highest? \_\_\_\_\_  
b. Medium? \_\_\_\_\_  
c. Lowest? \_\_\_\_\_

7. At temperature points 1 and 5, the photosynthesis reaction is very low. What are the differences in the temperature at those two points?
- 
- 
8. Write a statement to summarise the relationship between the temperature and the photosynthesis as shown by the graph.
- 
- 
9. What do you think would happen to the plants if the temperature rises to point 6?
- 
- 
10. What happens to the plants which lack the element magnesium?
- 
- 
- 

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|

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### Answers to Activities

#### Part A

1. Light, putting together
2. Water and carbon dioxide
3. Glucose and oxygen
4. Chlorophyll
5. Chloroplasts

#### Part B

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

## Lesson 12: Respiration



Welcome to Lesson 12. In the last lesson, you have learnt about photosynthesis reaction that takes place in green plants and certain organisms. In this lesson you will learn about another reaction called respiration. Respiration takes place in all living things, plants as well as in animals.



### Your Aims:

- define respiration.
- explain the process of respiration.
- draw and label diagrams of respiration.

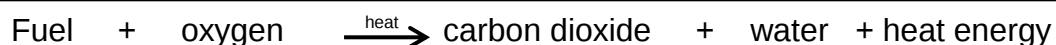
### What is Respiration?

**Respiration** is a chemical process by which living things take up oxygen, release carbon dioxide and produce energy from food inside cells. It is a process that goes on all the time in every living cell.

Food is slowly burnt up using oxygen from the air. This releases energy, which keeps the organism working. Food and oxygen are used up inside the cells and carbon dioxide and water are produced. Carbon dioxide is a waste substance and so it must be removed.

Chemical changes that use up oxygen to release energy are called **oxidation**. Respiration is the oxidation of food. In respiration oxygen reacts with food to form energy and new substances. Oxidation can be fast or slow. Burning a fuel such as kerosene is a fast oxidation. Respiration is a slow oxidation.

Fast oxidation, for example burning a fuel:



Slow oxidation, for example respiration:



### Exchange of gases

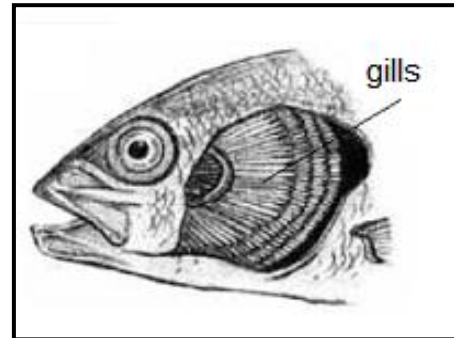
Cells need oxygen to get energy from food. In order to get oxygen to cells and to get carbon dioxide away from cells, these gases must be exchanged with gases in the environment. Gas exchange takes place through surfaces that are thin, moist and well-supplied with blood vessels known as capillaries.

Very small animals exchange gases directly with the environment. This is because all parts of their bodies are close to the source of oxygen.

In most vertebrates the exchange of gases takes place in special organs inside the body and special methods of achieving this have developed.

### Gas exchange in fish

Fish need water to pass over special organs called gills all the time. They take in oxygen from the water which contains dissolved oxygen, the oxygen pass into the blood and the blood carries the oxygen to the cells. The faster a fish swims the more oxygen it needs.



Fish take in oxygen as water pass through their gills

In amphibians, reptiles, birds and mammals air is pumped into and out of special organs called **lungs**. The pumping of air in and out of the lungs is called **breathing**. Breathing is not respiration as it is sometimes called. It is only the action which brings oxygen to the lungs to be transported to the body cells.

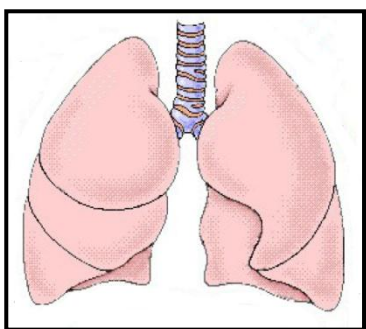
Both gills and lungs have a thin, moist surface which is well supplied with blood vessels. This means that oxygen can easily pass from the water or air onto the blood. Also carbon dioxide can easily pass out of the blood into the water or air. Gills and lungs are not smooth but have lots of folds. This means that there is a large surface area. A large surface area means that lots of gas can be transferred at the same time.



In order for effective exchange of carbon dioxide and oxygen between the air and the animals' body, the following must be true: The surface area must be thin, moist, it must be large and be well supplied with blood vessels.

### Breathing in humans

As in all vertebrates, humans have two lungs which they use to breathe in oxygen and breathe out carbon dioxide (CO<sub>2</sub>).



Humans have two lungs

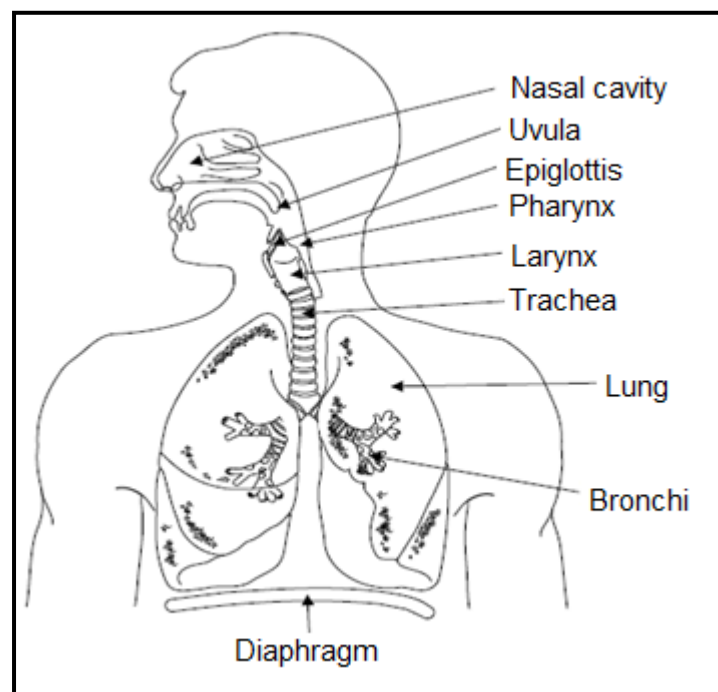
The normal adult human lung weighs about 100 grams and consists of about 50% blood and 50% tissue by weight.

About 10% of the total lung volume is composed of various types of conducting airways and some connective tissue. The remaining 90% is the respiratory or gas exchange portion of the lung, composed of alveoli and supporting blood capillaries.

### The respiratory processes

Let us now look at the respiratory system and study the parts of the track which air moves through during breathing in and out.

1. The **nose cavity**. There are two nose cavities, which are lined by special cells and contain small hairs. The cells produce watery fluid called mucus. The small hairs and watery fluid help to trap germs and dust particles and prevent them going any further into the air passages. When the small hairs are irritated by dust particles, people sneeze to get rid of them.
2. The **throat** or **pharynx**. Both the mouth cavity and two nose cavities open into the throat. At the lower end, the throat divides into two openings: the food pipe or oesophagus at the back, and the windpipe or trachea at the front.
3. The **voice box** or **larynx**. This is at the top end of the windpipe. It is made of cartilage and gets larger in boys at puberty. It is sometimes called the Adam's apple. Inside the voice box are the vocal cords, which make the sounds we speak. Air must pass over the vocal cords for sounds to be made.
4. The **windpipe** or **trachea**. In adults the windpipe is about 10 centimetres long. It is made up of rings of cartilage joined together by muscle. At the lower end the windpipe divides into two bronchi, with one bronchus going into each lung. All these air passages are lined with the same kind of cells as on the nose. These cells also make the watery fluid called mucus.

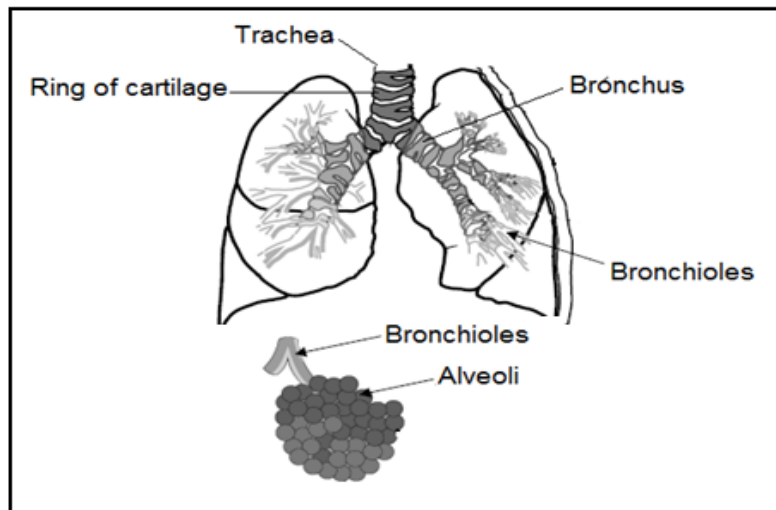


The human respiratory system

5. Each **bronchus** divides and divides again inside the lung until each lung contains hundreds of tiny air passages. At the end of the smallest of these air passages there are several round hollow sacs called alveoli.
6. Each sac or **alveolus** is like a small balloon containing air. It has a thin wall and is covered by small blood capillaries.

In humans, there are about 300 million alveoli in each of the two lungs, and the total surface area available for diffusion can be as much as 80 square metres, or about 42 times the surface area of the body.

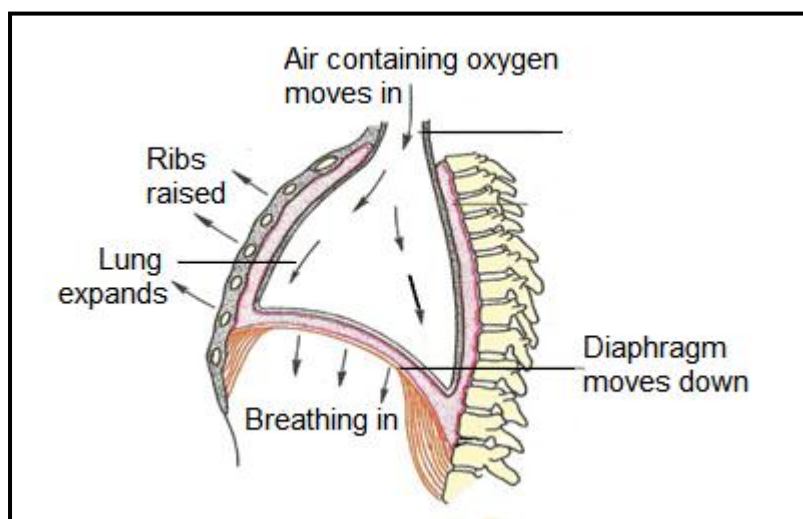
When air is breathed in, the air sacs fill with air. The oxygen in the air then passes through the walls of the air sacs and enters the blood in the capillary. The oxygen rich blood then flows away from the air sac and goes back to the heart. The blood that flows towards the air sacs has extra carbon dioxide. This carbon dioxide passes through the wall of the air sac and is breathed out on the exhaled air.



Structure of the lungs in increasing magnification

### Breathing in (inhaling)

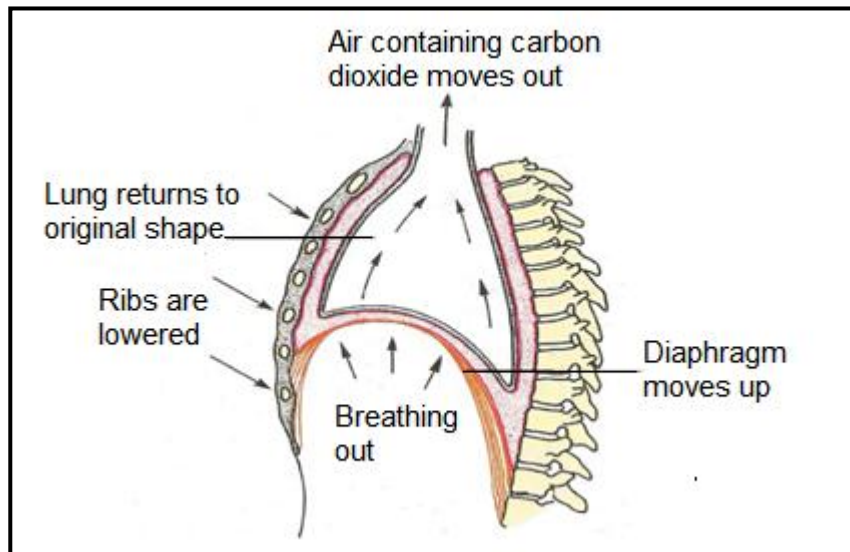
Air enters the lungs since the air pressure inside the lungs is less than the air pressure of the atmosphere. When breathing in, muscles between the ribs contract, the ribs move out and up, and the diaphragm muscle moves down. The chest increases in size, more air flows in to fill the lungs and the lungs expand.



Breathing in (inhaling)

**Breathing out (exhaling)**

When breathing out, the ribs move down and in, the diaphragm moves up, and the lungs go back to their normal size. The chest returns to its normal size and the air is pushed out of the lungs. Work is done when breathing in because the muscles contract. No work is done when breathing out.



Breathing out (exhaling)

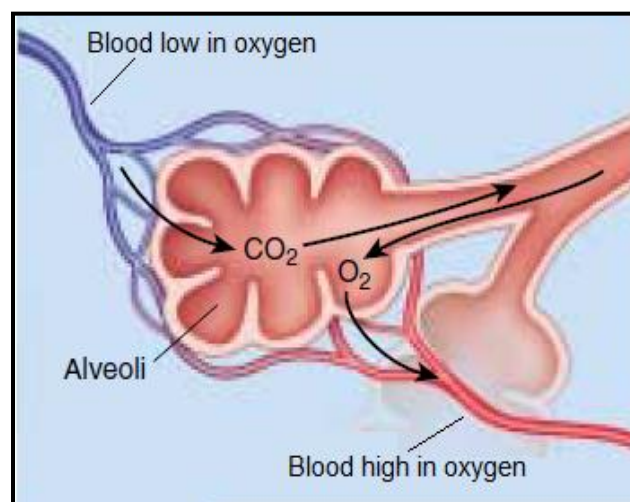
Humans are breathing all the time, although people do not normally take any notice of it. Everyone begins to breathe immediately after they are born and continues to do so until they die. There are three main stages of respiration: external, internal and cellular.

**External respiration**

Air enters the nose and after the trachea, the air passes through the bronchi and into the lungs. In the lungs, it follows narrower and narrower bronchioles until it reaches the alveoli.

As air enters the alveoli, the oxygen concentration of the alveoli becomes higher than the oxygen concentration of the blood in the lung capillaries. This allows the oxygen to pass or diffuse across the membrane of the alveoli into the blood. This is called external respiration.

The haemoglobin in these blood capillaries has very little oxygen and a lot of carbon dioxide bound to it. Haemoglobin has an attraction for oxygen so it releases carbon dioxide and takes up the oxygen.



Gas exchange takes place at the alveoli

**Haemoglobin is a substance found in the red blood cells. It transports oxygen from the lungs to the body cells and the carbon dioxide from the cells to the lungs. Haemoglobin is very useful for respiration.**

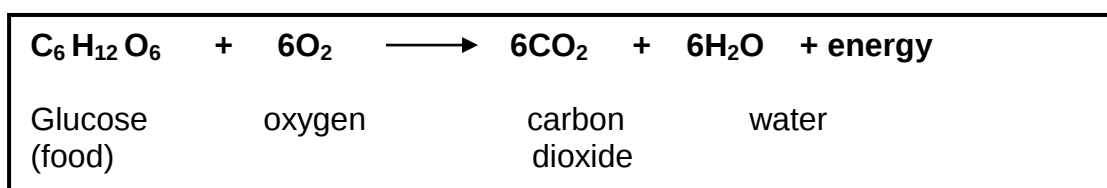
### Internal respiration

The haemoglobin carrying oxygen is transported in the blood throughout the body. Body tissues that are low in oxygen and high in carbon dioxide will take oxygen from and give carbon dioxide to the haemoglobin. This is called internal respiration.

### Cellular respiration

The oxygen and glucose are used by the cells in the tissue to produce energy. This is called cellular respiration. The energy produced is in the form of some compounds called ATP (adenosine tri phosphate).

The balanced equation for cellular respiration is:



The carbon dioxide gas produced by cellular respiration attaches to haemoglobin in the blood during internal respiration. The blood carries it to the alveoli in the lungs. Carbon dioxide leaves the blood and enters the alveoli during external respiration and is expelled when humans exhale. The entire process of respiration happens very quickly within seconds.



**Activity:**      **Now test yourself by doing this activity.**

### Part A

Match the words with their definitions by writing in the correct numbers in the blank boxes.

|   |             |  |                                    |
|---|-------------|--|------------------------------------|
| 1 | Larynx      |  | Substance found in red blood cells |
| 2 | Pharynx     |  | Organ used for taking in oxygen    |
| 3 | Haemoglobin |  | Voice box                          |
| 4 | Trachea     |  | Throat                             |
| 5 | Gill        |  | Wind pipe                          |

**Part B**

Write **true** or **false** beside the following statements.

- a) \_\_\_\_\_ The diaphragm moves up during exhalation.
- b) \_\_\_\_\_ The ribs are raised during inhalation.
- c) \_\_\_\_\_ The bronchiole is bigger than bronchus.
- d) \_\_\_\_\_ Cellular respiration takes place at the alveoli.
- e) \_\_\_\_\_ Nitrogen gas is used up during respiration.

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.**

**Summary**

You have come to the end of lesson 12. In this lesson you have learnt that:

- respiration is a chemical process by which living organisms use up oxygen, release carbon dioxide and produce energy from the food inside cells.
- chemical changes that use up oxygen to release energy are called oxidation.
- the inputs for the respiration reaction are glucose and oxygen while the outputs are carbon dioxide, water and energy.
- gas exchange takes place through surfaces that are thin, moist and well-supplied with blood vessels.
- fish take in oxygen dissolved in water through special organs called the gills.
- mammals take in oxygen from the air into their body by breathing through their lungs.
- for effective gas exchange to take place, the surface in contact must be thin, moist, large and be well supplied with blood vessels.
- the track through which oxygen moves from the air into the lungs is summarised as:
  - nose cavity
  - larynx
  - pharynx
  - trachea
  - bronchus
  - bronchiole
  - alveolus.
- amount of oxygen in inspired air is reduced in expired air while carbon dioxide is increased in expired air.
- at the alveoli the haemoglobin in the blood capillaries break down and release the carbon dioxide and pick up the oxygen which is carried away to the body tissues.
- the three stages of respiration are:
  - external respiration is the exchange of oxygen and carbon dioxide in the alveoli.
  - internal respiration is the exchange of oxygen and carbon

- dioxide in the body tissues.
- cellular respiration is the use of oxygen by body cells to produce energy.

---

**NOW DO PRACTICE EXERCISE 12 ON THE NEXT**



## Practice Exercise 12

---

**Answer the following questions:**

1. What is haemoglobin? Describe its function.  
\_\_\_\_\_  
\_\_\_\_\_
2. What is respiration?  
\_\_\_\_\_  
\_\_\_\_\_
3. What is oxidation?  
\_\_\_\_\_  
\_\_\_\_\_
4. Lungs and gills are organs for gas exchange. List down four things that make these organs suitable for effective gas exchange.
  - a) \_\_\_\_\_
  - b) \_\_\_\_\_
  - c) \_\_\_\_\_
  - d) \_\_\_\_\_
5. Where in the body do the following take place?
  - a) External respiration: \_\_\_\_\_
  - b) Internal respiration: \_\_\_\_\_
6. Describe the process of cellular respiration.  
\_\_\_\_\_  
\_\_\_\_\_
7. Write down the balanced equation for cellular respiration.  
\_\_\_\_\_
8. In the nose cavity there are small hairs and mucous found. In what ways do they help the air passage?  
\_\_\_\_\_  
\_\_\_\_\_
9. What is breath rate?  
\_\_\_\_\_

10. What type of people have high breath rate and why?

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11. Describe the position of the lungs, ribs and diaphragm as a person inhales.

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|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|

### Answers to Activities

#### Part A

|   |             |   |                                    |
|---|-------------|---|------------------------------------|
| 1 | Larynx      | 3 | Substance found in red blood cells |
| 2 | Pharynx     | 5 | Organ used for taking in oxygen    |
| 3 | Haemoglobin | 1 | Voice box                          |
| 4 | Trachea     | 2 | Throat                             |
| 5 | Gill        | 4 | Wind pipe                          |

#### Part B

- a) True
- b) True
- c) False
- d) False
- e) False

## Lesson 13: Burning of Fuel



Welcome to Lesson 13. In your last lesson you learnt about the process of respiration. In this lesson we will investigate of fuel in particular combustion. Combustion and respiration are similar processes in the sense that they produce energy. Fuel is any material or substance that has a stored chemical energy.



### Your Aims:

- define fuel
- describe the burning of fuel
- state the equation for the burning of fuel

### Chemical Fuels

**Chemical fuels** are substances that release energy by reacting with other substances around them and are easily noticeable. An example is burning of wood. This reaction occurs because of the presence of oxygen therefore, the process is specifically called **oxidation**.



There are two types of chemical fuels, they are fossil and bio fuels.

1. **Fossil fuels** are usually **hydrocarbons** and are formed from the remains of dead plants and animals exposed to high heat and pressure in the absence of oxygen in the earth's crust for over millions of years.

Eventually, they form fossil fuels as in coal and crude oil. Crude oil is composed of petroleum and natural gas. They are used up in a chemical reaction process called **combustion or burning** to release heat energy.

The general equation for this process is:



2. **Bio fuels** can be another alternative source of fuel if we run out of fossil fuels. They are found in nature in the form of solids, liquids and gases and consist of or derived from **biomass**. Bio fuels are produced from any carbon source that is renewed quickly; for example **plants**. Many different plants and plant-derived materials are used for bio fuel manufacturing.

Some countries have already ventured into the use of bio-fuels. Example;

1. In Malaysia, oil from oil palm is used to fuel petrol engine vehicles.
2. In Brazil, alcohol produced from sugar cane is used to fuel petrol engine vehicles.
3. In Bougainville, Papua New Guinea coconut oil is used as petrol engines.

Another possible source of fuel is **bio gas**. Bio gas is produced when organic matter, which is the waste materials from plants and animals, is allowed to decay in the absence of air. Bio-gas contains 50% of methane. Methane is a useful household gas.

### Some common examples of fuels

- wood
- coal
- petroleum
- natural gas
- kerosene
- charcoal

It is also important to know that a good fuel is the one that possess the following vital properties; it must

1. be easy to ignite but not easily flammable
2. be easy to store and transport
3. produce as little pollution as possible and
4. produce a lot of heat energy during combustion.

Using the above properties, we can to compare and contrast between the types of common fuels we use today.

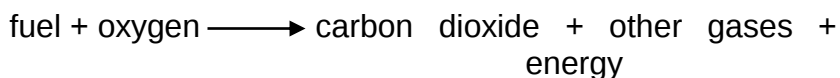
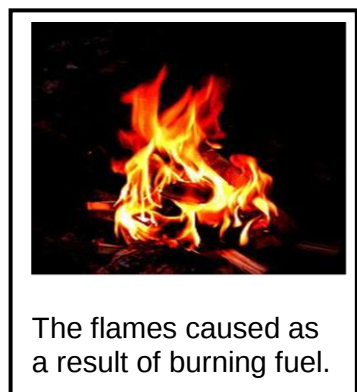
This is shown in the table below.

| Properties                    | Coal                                                                     | Petroleum                                                                       | Natural gas                                                                |
|-------------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Physical state                | Solid                                                                    | Liquid                                                                          | Gas                                                                        |
| Ease of storage and transport | Not easily stored or transported                                         | Can be stored and transported easily by tankers. Can flow through a pipe easily | Can be liquefied easily and stored in tanks. Can flow through pipes easily |
| Polluting effects             | Extremely polluting. Large amount of soot and sulfur dioxide is produced | Moderately polluting. Some sulfur dioxide and soot is produced                  | Almost no pollutants. No soot or sulfur dioxide is produced.               |

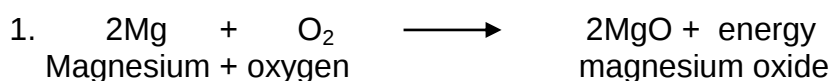
## Combustion

We use an enormous amount of energy in our homes, schools and factories. We use energy to power our cars. We need energy in factories to turn raw materials into manufactured goods. Most energy required is produced from the combustion of fuels.

During combustion a substance reacts with oxygen in the air. The release of heat from the reaction results in the production of light in the form of either glowing or a flame as seen in the diagram below. Most fuels we use today are carbon compounds. The common fuels are kerosene, diesel, petrol, charcoal, coal and wood. The general equation for this chemical reaction is:



Here are some specific examples of combustion:



This reaction gives out heat, white light and a fizzing noise.

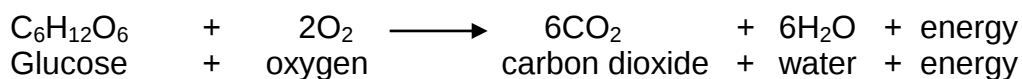


All these reactions are exothermic reactions. They give off more energy than energy used in the reactions.

## Respiration

Respiration also a kind of burning and is used to describe the oxidation process that takes place in the tissues of the body. When cells in the tissues use up food, oxidation has taken place and energy is produced. The energy produced is used by the cells to function properly. This process is specifically called cellular respiration.

The chemical equation for this process is:



Two things happen to the food we eat; it is either used up by the cells of tissues or stored in our bodies.

Therefore:

$$\text{energy intake} = \text{energy used up} + \text{energy stored}$$

$$\text{energy used up} = \text{energy output}$$

Our bodies use this energy for maintaining metabolism and physical activities. Metabolism is the chemical processes occurring in our bodies to keep us alive. If the body's energy intake is less than the energy output, weight is lost.

The food used by our bodies in respiration include sugar, amino acids and fatty acids, and oxygen ( $O_2$ ). Each type of food has a caloric value measured in kilocalories or kcal, which is converted to kilojoules (Kj) once energy is used and work is done.

For example:

- (a) carbohydrates - 4.0 kcal = 17kj of energy per gram
- (b) proteins - 4.0 kcal = 17kj of energy per gram
- (c) fats - 9.0 kcal = 38 KJ of energy per gram

Therefore, respiration is one of the key ways a cell gains useful energy to fuel cellular activities.



**Activity:** Now test yourself by doing this activity.

**Circle the letter of the correct answer.**

1. Another word that means the same as combustion is \_\_\_\_\_.

- A. respiration                      C. decaying  
B. reaction                          D. burning

2. Substances or materials which undergo combustion are called \_\_\_\_\_.

- A. hydrocarbons                      B. fuels  
C. products                              D. coals

- ### 3. What is ATP?

- A. A chemical enzyme.
- B. A chemical that transport energy.
- C. A chemical used to burn food substances.
- D. A chemically stored energy from burned food.

4. Exothermic reaction is a \_\_\_\_\_ reaction that \_\_\_\_\_ heat and energy.

- A. chemical, releases
- B. physical, releases
- C. physical, receives
- D. chemical, receives

## 5. Nuclear fission

- A. creates larger elements.
  - B. occurs for lighter elements only.
  - C. occurs for heavy elements only.
  - D. occurs for both light and heavy elements.
- 

## 6. A hydrocarbon is

- A. both B and C.
  - B. an organic compound.
  - C. an inorganic compound.
  - D. is made up of hydrogen and carbon.
- 

## B. Following are reactants of combustion.

Complete their balanced chemical equations correctly:

## 1. magnesium and oxygen

\_\_\_\_\_ → \_\_\_\_\_

## 2. methane and oxygen

\_\_\_\_\_ → \_\_\_\_\_

## 3. glucose and oxygen

\_\_\_\_\_ → \_\_\_\_\_

---

## C. Describe the following terms:

## 1. Combustion:

\_\_\_\_\_  
\_\_\_\_\_

## 2. Cellular respiration:

\_\_\_\_\_  
\_\_\_\_\_

## 3. Hydrocarbon:

\_\_\_\_\_  
\_\_\_\_\_

---

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|



## Summary

You have come to the end of lesson 12. In this lesson you have learnt that:

- fuels are the most important source of energy. they are found in nature as chemical fuels and nuclear fuels.
- there are two types of chemical fuels namely; fossil fuels and bio fuels.
- nuclear fuels are derived from nuclear fission and nuclear fusion.
- most chemical fuels are made up of carbon and hydrogen elements and by catenation process, they build up complex compounds called hydrocarbons.
- combustion or burning is the process used to derive energy from chemical fuels. these reactions are referred to as exothermic reaction.
- in exothermic reactions, more energy is given off compared to the amount of energy required for the reaction itself.
- during cellular respiration, digested and absorbed food molecules are burned in tissues of the body with oxygen to produce the energy needed to power the activities of the cells in the body.
- sugar, amino acids and fatty acids are nutrients that are used by cells in our bodies for respiration. The molecular oxygen ( $O_2$ ) is the common oxidizing agent in cellular respiration.

---

|                                                |
|------------------------------------------------|
| <b>NOW DO PRACTICE EXERCISE 12 ON THE NEXT</b> |
|------------------------------------------------|



## Practice Exercise 13

Answer the following questions:

1. Compare and contrast between

a) bio fuel and bio gas

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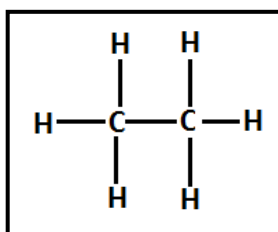
b) combustion and respiration

---



---

2. Study the following structural diagram of an alkane.



a) Write its molecular formula

---

b) What is the name of this alkane?

---

3. Match Column A with Column B. Write the letter of the correct answer on the space provided.

| ↓ | Column A        |
|---|-----------------|
|   | Fossil fuel     |
|   | Bio fuel        |
|   | Nuclear fission |
|   | Nuclear fusion  |

|   | Column B                                                      |
|---|---------------------------------------------------------------|
| A | Heavier elements are divided into lighter elements            |
| B | Derived from plants                                           |
| C | Lighter elements combine to form heavier elements when fused. |
| D | Derived from dead plants and animals.                         |

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.**

**Answers to Activities****Part A**

1. D
2. B
3. D
4. A
5. C
6. B

**Part B**

1.  $2\text{Mg} + \text{O}_2 \longrightarrow 2\text{MgO}$
2.  $\text{CH}_4 + 2\text{O}_2 \longrightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
3.  $\text{C}_6\text{H}_{12}\text{O}_6 + 2\text{O}_2 \longrightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$

**Part C**

1. Another word which means the same as burning. It is the process by which substances are burned in the presence of oxygen.
2. A metabolic process that takes place in the cells of all living organisms that converts biochemical energy from nutrients into adenosine triphosphate (ATP), and then release waste products.
3. Hydrocarbons are organic compounds consisting of carbon and hydrogen. They form the basis for chemical fuels.

## Lesson 14: Chemicals from Crude Oil



Welcome to Lesson 14. In our last lesson we looked at burning of fuel as a functional phenomenon that plays a vital role in our survival. In this lesson, we will investigate and deliberate on crude oil, its chemical components and importance. Crude oil is the term for unprocessed oil, that is, the stuff that comes out of the ground. It is also known as petroleum.

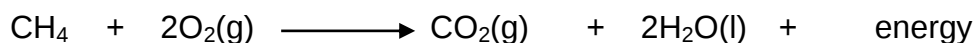


### Your Aims:

- define crude oil
- state the different uses of compounds from crude oil
- identify the process of refining crude oil

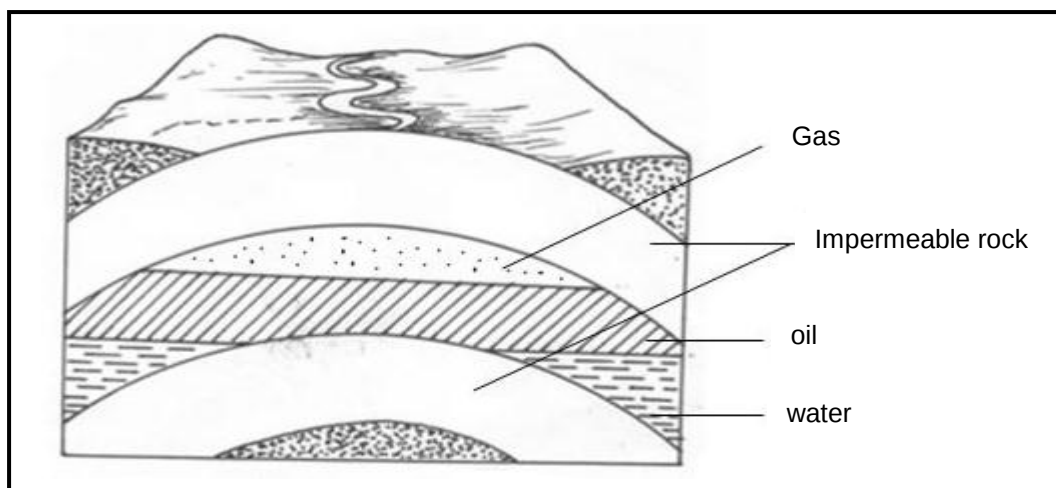
### Petroleum (Crude Oil)

Crude oil and natural gas are fossil fuels formed from the soft remains of sea plants and animals that fall to the ocean floor. They are fossil fuels because they are the remains of plants and animals that lived millions of years ago. They are very good fuel because they give out plenty of heat energy when they burn. They also produce carbon dioxide and water vapour. For example, the methane gas of the North Seas, with oxygen, burns like this:



Crude oil is such a useful starting point for so many different substances because it contains hydrocarbon. Hydrocarbons are molecules that contain hydrogen and carbon and come in various lengths and structures, from straight chains, to branching chains to rings. The development of crude oil goes back to its origin and formation.

Below is the timeline to show how it is formed. When the ancient plants and animals perish and settle on the sea bed.



Formation of Crude Oil

- the remains decay then stop to decay because dissolved oxygen in water becomes depleted and they are buried in sediments that prevents further decaying.
- as more sediments are added on, the deeper the remains are buried and pressure and temperature increases. Chemical change begins here.
- the first change is a solid waxy substance called **kerogen**. At depths of about 2-4 km and temperature of 50-100°C, break down of these materials begin to simpler substances eventually forming crude oil and gases.
- as they are lighter than water, these substances begin to drift upwards through permeable rocks like **limestone**.
- eventually, when they heat permeable rocks, they are collected and trapped in the reservoir rock like water in a sponge.

Petroleum or crude oil is a naturally occurring, flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds that are found in geological formations beneath the Earth's surface. Oil is recovered only through drilling then refined and separated by their boiling points into a large number of consumer products like petrol (gasoline) and kerosene, to asphalt and chemical reagents used to make plastics and pharmaceuticals. Uses of petroleum also have negative impacts on the Earth's biosphere.

### Composition and Structure

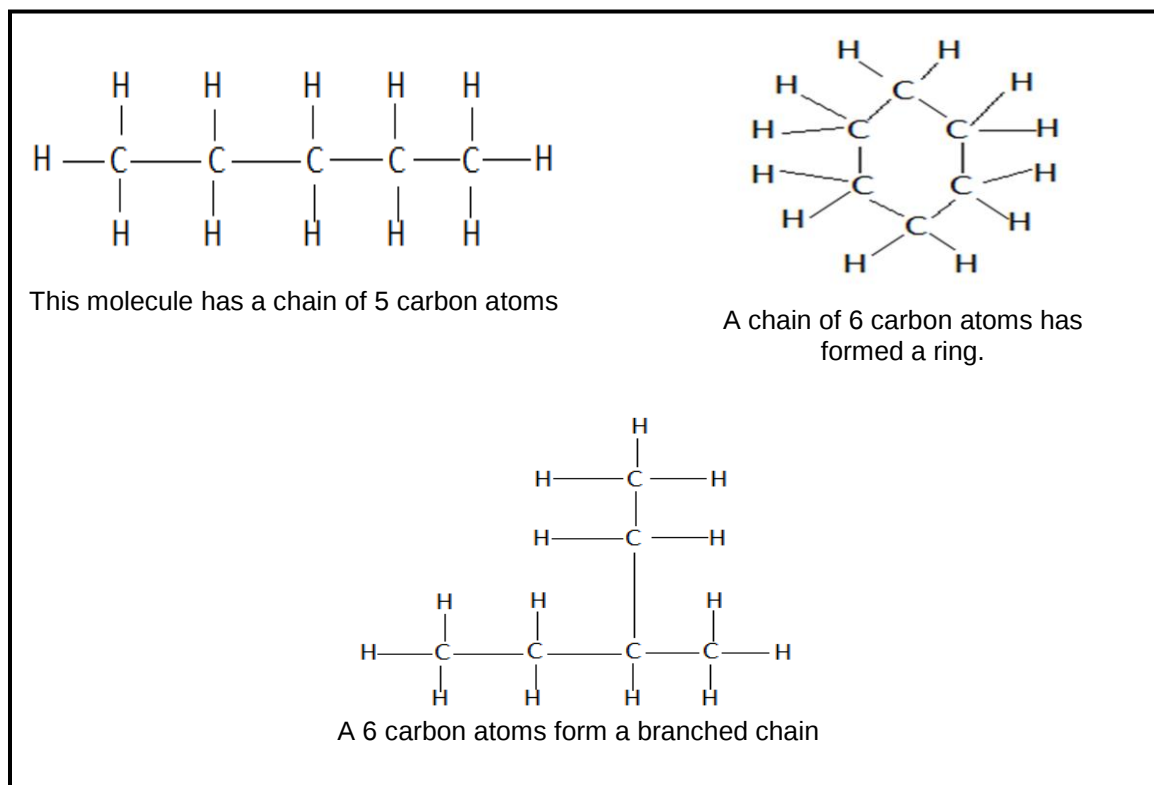
Petroleum includes crude oil, natural gas and hydrocarbons. It varies in color from clear to tar-black and in viscosity from water to almost solid. The table below shows the composition of elements in crude oil.

The crude oil components by weight:

| Element  | Percentage Range |
|----------|------------------|
| Carbon   | 83 to 87%        |
| Hydrogen | 10 to 14%        |
| Nitrogen | 0.1 to 2%        |
| Oxygen   | 0.05 to 1.5%     |
| Sulfur   | 0.05 to 6.0%     |
| Metals   | <0.1%            |

Crude oil varies greatly in appearance depending on its composition. It is usually black or dark brown and found in association with natural gas in the reservoir.

In itself, oil is a mixture of hundreds of different carbon compounds. Their structure is such that the molecules of the compound consist of chains or rings of carbon atoms bonded with other atoms bonded on them. For example, study the three diagrams of the carbon compounds below;



You will notice from these diagrams that hydrocarbon molecules contain hydrogen and carbon atoms and come in various lengths and structures; from straight chains to branching chains to rings.

Two interesting things that make hydrocarbons exciting to study is that hydrocarbons:

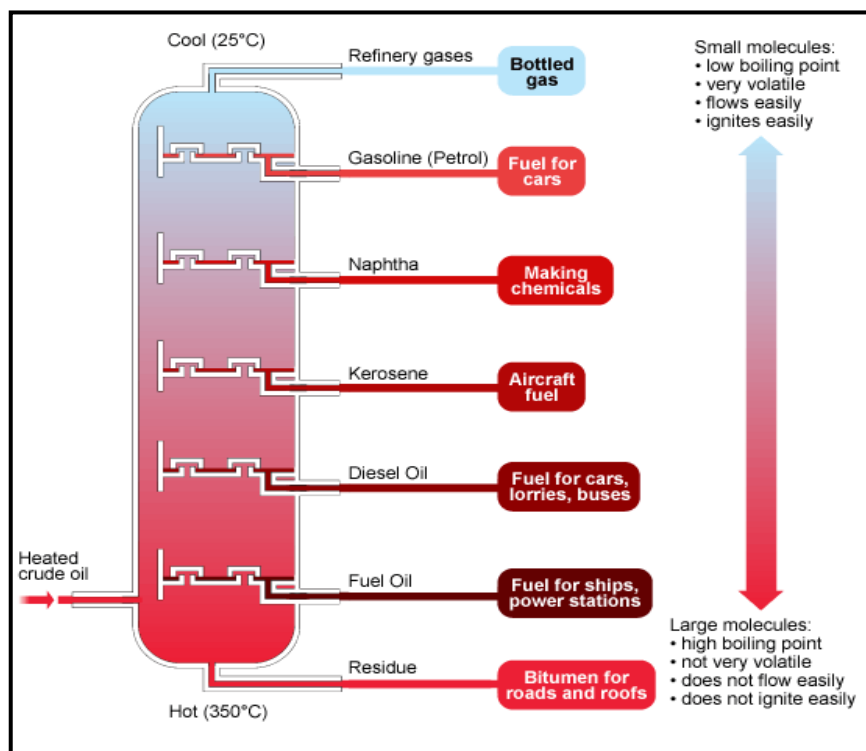
- contain a lot of energy and
- can take on many different forms (the smallest hydrocarbon is methane).

The fractions at this stage are not the final products. They will still have to go through another process called cracking, which will be discussed in detail in our next lesson, to simplify them to usable compounds.

### Process of getting crude oil

Crude oil, once extracted from the reservoir rock or oil trap, is taken to a refinery where it goes through a series of processes to turn it into useful materials. This process is called refining and it is separated into groups of compounds. Some compounds are cracked and others are reformed. Because of the variations in size of the molecules making up crude oil, crude oil is separated into groups of compounds according to the number of carbon atoms in each compound or molecule. This is the first step in refining crude oil and the groups of compounds are called **fractions**.

**Separation** is carried out by a process called **fractional distillation** as shown in the diagram below.



In a tall tower, fractional distillation is carried out with the base kept hot and getting cooler towards the top. As crude oil is pumped in at the base, it starts to boil off. Compounds with smallest molecule size boils off first and rise to the top because they have the lowest boiling point. Others boil and rise half way depending on their boiling points and then condense. The larger molecules, on the other hand, have very high melting points and are too heavy that they do

not rise but settle at the bottom. By then they are separated from the other compounds. These compounds are more vicious and less flammable. Once fractions are separated, further treatments are given before they can be used.

### Products and Uses

After crude oil is refined the following fractions are extracted:

1. Petroleum gas.
  - Used for heating, cooking and making plastics. The common petroleum gases are methane, ethane, propane and butane
  - Boiling range is less 40 degree Celsius
2. Gasoline
  - Used for motor fueling
  - Boiling range is 40 to 205 Degree Celsius
3. Kerosene
  - Fueling jet engines and tractors
  - Boiling range is 175 to 325 degree Celsius
4. Lubricating oil
  - Used for motor oil, grease and other lubricants
  - Boiling range is 300 to 370 degree Celsius
5. Heavy gas or fuel oil
  - Used for industrial fuel
  - Boiling range is 370 to 600 degree Celsius
6. Residuals
  - Residuals include coke, asphalt, tar, waxes,
  - Boiling range is greater than 600 degree Celsius

You may notice that all of these products have different boiling ranges. This property enables their separation from crude oil.

**The problems with use of fuels**

One of the common problems with the use of these products is that it causes an upset in the natural balance in the amount of carbon dioxide in the atmosphere. This could lead to global warming. As the amount of carbon dioxide accumulates, more heat is trapped in the atmosphere causing increase an increase in average global temperature. This problem is not a new one, it is ongoing.

Another important point to point out is that crude oil and its products are non-renewable resources. Therefore, sustainable use of this important resource must be strongly encouraged to preserve and prolong its uses and find alternative renewal resources.

---



**Activity:**      **Now test yourself by doing this activity.**

**A.      Circle the letter of the best answer.**

1.      All energy used, stored and recycled is derived from

- A.      plants.
  - B.      the sun.
  - C.      animals.
  - D.      hydrocarbons.
- 

2.      Which of the following is derived from gasoline?

- A.      Petrol
  - B.      Methane
  - C.      Polythene bags
  - D.      Fuel for power stations and ships
- 

3.      Crude oil mostly comprised of the element \_\_\_\_\_.

- A.      sulfur
- B.      carbon
- C.      oxygen
- D.      hydrogen

4. The chemical formula for methane is \_\_\_\_\_.

- A.  $\text{CH}_4$
  - B.  $\text{C}_2\text{H}_4$
  - C.  $2\text{CH}_4$
  - D.  $\text{C}_6\text{H}_{12}\text{O}_6$
- 

5. What is the process used for refining crude oil?

- A. distillation
  - B. separation
  - C. column distillation
  - D. fractional distillation
- 

6. Which factor is important in the separation of hydrocarbons?

- A. size
  - B. density
  - C. boiling point
  - D. molecular structure
- 

**B. Write a balanced chemical equation for the following:**

Methane + Oxygen  $\longrightarrow$  Carbon dioxide + water + energy

\_\_\_\_\_  $\longrightarrow$  \_\_\_\_\_

---

**C. Complete the table below.**

| Fraction          | Temperature range of Separation |
|-------------------|---------------------------------|
| Gasoline (Petrol) |                                 |
| Kerosene          |                                 |
| Diesel oil        |                                 |
| Fuel oil          |                                 |
| Paraffin, asphalt |                                 |

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|



## Summary

You have come to the end of lesson 14. In this lesson you have learnt that:

- crude oil is a fossil fuel formed from dead plants and animals of ancient times.
- the main composition of crude oil is hydrocarbons and natural gas.
- fraction distillation is the process used to separate crude oil into fractions. these fractions are further simplified cracking process converting hydrocarbons to usable products.
- hydrocarbons have different boiling ranges that make it possible for the separation during separation.
- fractions derived from fractional distillation are gas, gasoline (petrol), naphtha, kerosene, diesel oil, fuel oil and residues.
- crude oil is a non-renewable resource because it takes millions of years to form.
- one of the negative effects of use of petroleum products is that too much carbon dioxide is emitted into the atmosphere causing an imbalance in carbon dioxide concentration ultimately increasing the rate of global warming.

---

**NOW DO PRACTICE EXERCISE 14 ON THE NEXT PAGE.**



## Practice Exercise 14

---

**Answer the following questions:**

1. Crude oil must be refined before it can be used. Refining involves three main processes. Name them.
- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

- 
2. Explain why crude oil is considered a non-renewable resource?
- \_\_\_\_\_
- \_\_\_\_\_

- 
3. A crude oil sample was separated into four fractions in a laboratory. These fractions were collected in the temperature ranges below:

| Fraction | Temperature range/°C |
|----------|----------------------|
| A        | 25-70                |
| B        | 70-115               |
| C        | 115-200              |
| D        | 200-380              |

Which fraction:

- A. Has the lowest range of boiling point?

\_\_\_\_\_

- B. burns more readily?

\_\_\_\_\_

- C. has molecules with the longest chain?

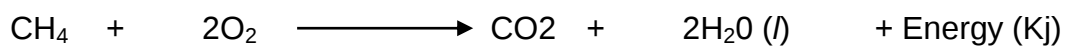
\_\_\_\_\_

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|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|

**Answers to Activities****Part A**

1. B
  2. A
  3. B
  4. A
  5. D
  6. C
- 

**Part B****Part C**

| <b>Fraction<br/>Summary</b> | <b>Temperature range of<br/>Separation</b> |
|-----------------------------|--------------------------------------------|
| Gasoline (Petrol)           | 40°C to 205°C                              |
| Kerosene                    | 175°C to 325°C                             |
| Diesel oil                  | 300°C to 370°C                             |
| Fuel oil                    | 370°C to 600°C                             |
| Paraffin, asphalt           | > 600°C                                    |

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## Lesson 15: CRACKING



Welcome to Lesson 15. In your last lesson you learnt about chemical from crude oil and the process of refining crude oil. In this lesson, you will study about cracking of hydrocarbons.

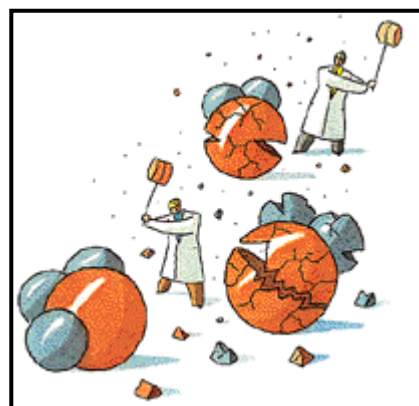
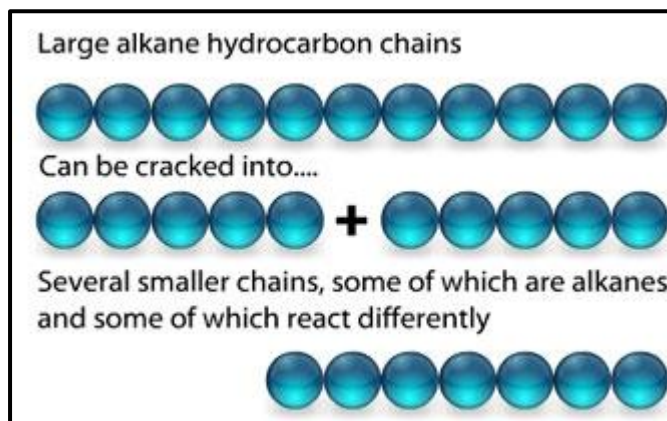


### Your Aims:

- define cracking
- explain the process of cracking
- differentiate saturated from unsaturated hydrocarbon

### What is Cracking?

**Cracking** is a reaction of how a hydrocarbon such as alkane molecules and more useful substances are broken into smaller molecules, using heat and a catalyst. The most widely used conversion method is called **cracking**, which uses heat and pressure to literally 'crack' heavy hydrocarbon molecules into lighter ones.



It is very important in the oil industry, for two reasons:

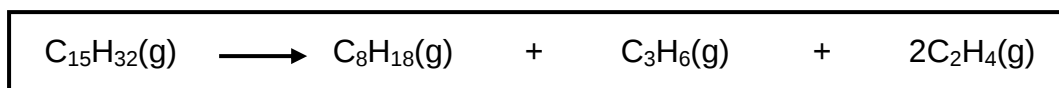
1. Some fractions from oil are more useful than others. For example, there is a greater demand for petrol than for diesel oil or lubricating oil. So cracking is used to convert part of these fractions to petrol.
2. Cracking produces short-chains alkanes, like ethane and propane. These are reactive because of their double bonds, so they can be used to make other substance. For example, ethane is made into polythene and ethanol.



Oil finery in Napa Napa in PNG

The process whereby a catalyst enables long-chain hydrocarbon molecules from petroleum to be broken into shorter chain, more useful molecules. Short-chain hydrocarbons are more useful industrially as feed-stocks for the petrochemical industries and as fuels for cars and trucks than the long-chain molecules, which find uses as lubricants. The catalysts allow for considerable selectivity in where and how the hydrocarbon chain may be broken under conditions of temperature and pressure that are much milder than for **thermal cracking**.

A typical reaction is shown:



Thermal cracking utilizes high temperatures and pressures to break long-chain hydrocarbon components of petroleum, such as heavy industrial oils, into more useful, smaller chains suitable for use as petrol and diesel fuel.

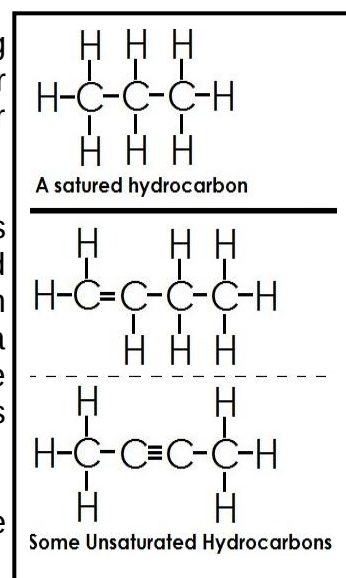
Thermal cracking is effectively the same technique as coke formation, though conditions are milder and are not sustained for as long.

**Crude oil** is a mixture of hundreds of different compounds called hydrocarbons, which contain only carbon and hydrogen. They consist of chains or rings of carbon atoms with hydrogen bonded on. The diagram below shows how a hydrocarbon could be cracked:

A **hydrocarbon** is an organic compound made of nothing more than carbons and hydrogen. It is possible for double or triple bonds to form between carbon atoms and even for structures, such as rings, to form.

**Saturated hydrocarbons** have as many hydrogen atoms as possible attached to every carbon. For carbons on the end of a molecular chain, three can be attached. For carbons in the middle of a chain or a ring, two can be attached. For a carbon atom all by itself, four hydrogen atoms can be attached. Saturated hydrocarbons have only single bonds between adjacent carbon atoms.

**Unsaturated hydrocarbons** have double and/or triple bonds between some of the carbon atoms.



### Common hydrocarbons

Examples of common saturated hydrocarbons are: plastics, gasoline, diesel fuels, lighter fluid, propane, home heating oil (kerosene/diesel mixture), marine and motor oil, fuels, and cleaning solvents.

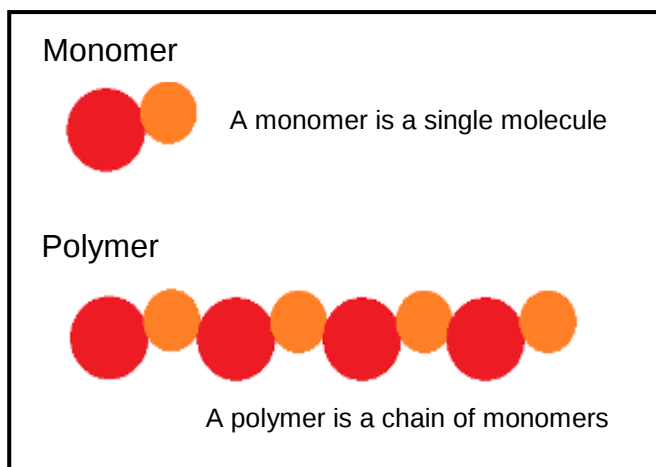
**Monomers** are the building blocks of more complex molecules, called polymers. Polymers consist of repeating molecular units which usually are joined by covalent bonds. Here is a closer look at the chemistry of monomers and polymers.

Monomers are small molecules which may be joined together in a repeating fashion to form more complex molecules called polymers.

A polymer may be a natural or synthetic macromolecule comprised of repeating units of a smaller molecule (monomers).

While many people use the term 'polymer' and 'plastic' interchangeably, **polymers** are much larger class of molecules which includes plastics, plus many other materials, such as cellulose, amber, and natural rubber.

Examples of polymers are plastics such as polyethylene, silicones such as silly putty, biopolymers such as cellulose and DNA, natural polymers such as rubber and shellac, and many other important macromolecules.



### How are polymers formed?

**Polymerisation** is the process of covalently bonding the smaller monomers into the polymer. During polymerisation, chemical groups are lost from the monomers so that they may join together. In the case of biopolymers, this is a dehydration reaction in which water is formed.

### Characteristics of polymers

1. **Polymers can be very resistant to chemicals.** Consider all the cleaning fluids in your home that are packaged in plastic. Reading the warning labels that describe what happens when the chemical comes in contact with skin or eyes or is ingested will emphasize the need for chemical resistance in the plastic packaging. While solvents easily dissolve some plastics, other plastics provide safe, non-breakable packages for aggressive solvents.
2. **Polymers can be both thermal and electrical insulators.** A walk through your house will reinforce this concept, as you consider all the appliances, cords, electrical outlets and wiring that are made or covered with polymeric materials. Thermal resistance is evident in the kitchen with pot and pan handles made of polymers, the coffee pot handles, the foam core of refrigerators and freezers, insulated cups, coolers, and microwave cookware. The thermal underwear that many skiers wear is made of polypropylene and the fiberfill in winter jackets is acrylic and polyester.
3. **Generally, polymers are very light in weight with significant degrees of strength.** Consider the range of applications, from toys to the frame structure of space stations, or from delicate nylon fiber in pantyhose to Kevlar, which is used in bulletproof vests. Some polymers float in water while others sink. But, compared to the density of stone, concrete, steel, copper, or aluminum, all plastics are lightweight materials.
4. **Polymers can be processed in various ways.** Extrusion produces thin fibers or heavy pipes or films or food bottles. Injection molding can produce very intricate parts or large car body panels. Plastics can be molded into drums or be

mixed with solvents to become adhesives or paints. Elastomers and some plastics stretch and are very flexible. Some plastics are stretched in processing to hold their shape, such as soft drink bottles. Other polymers can be foamed like polystyrene (Styrofoam™), polyurethane and polyethylene.

5. **Polymers are materials with a seemingly limitless range of characteristics and colors.** Polymers have many inherent properties that can be further enhanced by a wide range of additives to broaden their uses and applications. Polymers can be made to mimic cotton, silk, and wool fibers; porcelain and marble; and aluminum and zinc. Polymers can also make possible products that do not readily come from the natural world, such as clear sheets and flexible films.
6. **Polymers are usually made of petroleum, but not always.** Many polymers are made of repeat units derived from natural gas or coal or crude oil. But building block repeat units can sometimes be made from renewable materials such as polylactic acid from corn or cellulose from cotton linters. Some plastics have always been made from renewable materials such as cellulose acetate used for screwdriver handles and gift ribbon. When the building blocks can be made more economically from renewable materials than from fossil fuels, either old plastics find new raw materials or new plastics are introduced.
7. **Polymers can be used to make items that have no alternatives from other materials.** Polymers can be made into clear, waterproof films. PVC is used to make medical tubing and blood bags that extend the shelf life of blood and blood products. PVC safely delivers flammable oxygen in non-burning flexible tubing. And anti-thrombogenic material, such as heparin, can be incorporated into flexible PVC catheters for open heart surgery, dialysis, and blood collection. Many medical devices rely on polymers to permit effective functioning.



**Activity:** Now test yourself by doing this activity.

**Fill in the blank.**

1. \_\_\_\_\_ is a mixture of hundreds of different compounds called hydrocarbons, which contain only carbon and hydrogen.
2. \_\_\_\_\_ is a reaction of how an alkane molecule can be broken into smaller molecules.
3. \_\_\_\_\_ hydrocarbons have double and/or triple bonds between some of the carbon atoms.
4. \_\_\_\_\_ is a single molecule.
5. \_\_\_\_\_ is a chain of monomers.

---

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|



## Summary

You have come to the end of lesson 15. In this lesson you have learnt that:

- cracking is a reaction of how an alkane molecule can be broken into smaller molecules, using heat and a catalyst.
- polymerisation is the process of covalently bonding the smaller monomers into the polymer.
- a hydrocarbon is an organic compound made of nothing more than carbons and hydrogen.
- monomers are the building blocks of more complex molecules, called polymers.
- unsaturated hydrocarbons have double and/or triple bonds between some of the carbon atoms.

---

**NOW DO PRACTICE EXERCISE 15 ON THE NEXT PAGE.**



## Practice Exercise 15

**A. Define the following terms:**

1. Polymerisation
  2. Saturated hydrocarbons
  3. Hydrocarbon
- 

**B. Give three characteristics of polymers and examples.**

- (i) \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
- (ii) \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
- (iii) \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
- 

|                                                            |
|------------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 3.</b> |
|------------------------------------------------------------|

**Answers to Activity**

1. Crude oil
2. Cracking
3. Saturated
4. Monomer
5. Polymer



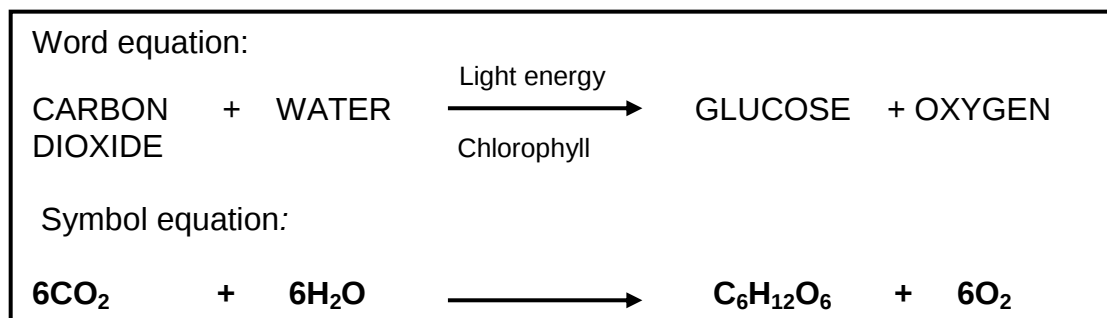
## ANSWERS TO PRACTICE EXERCISES 15

1. **Polymerisation** is the process of covalently bonding the smaller monomers into the polymer.
  2. **Saturated hydrocarbons** have as many hydrogen atoms as possible attached to every carbon.
  3. A **hydrocarbon** is an organic compound made of nothing more than carbons
- 
- B.**
1. **Polymers can be very resistant to chemicals.** Consider all the cleaning fluids in your home that are packaged in plastic.
  2. **Polymers can be both thermal and electrical insulators.** A walk through your house will reinforce this concept, as you consider all the appliances, cords, electrical outlets and wiring that are made or covered with polymeric materials.
  3. **Generally, polymers are very light in weight with significant degrees of strength.** Consider the range of applications, from toys to the frame structure of space stations, or from delicate nylon fiber in pantyhose to Kevlar, which is used in bulletproof vests.
  4. **Polymers can be processed in various ways.** Extrusion produces thin fibers or heavy pipes or films or food bottles.
  5. **Polymers are materials with a seemingly limitless range of characteristics and colors.** Polymers can be made to mimic cotton, silk, and wool fibers; porcelain and marble; and aluminum and zinc.
  6. **Polymers are usually made of petroleum, but not always.** Many polymers are made of repeat units derived from natural gas or coal or crude oil.
  7. **Polymers can be used to make items that have no alternatives from other materials.** Polymers can be made into clear, waterproof films. PVC is used to make medical tubing and blood bags that extend the shelf life of blood and blood products.

## Answer to Practice Exercises 11 - 15

### Practice Exercise 11

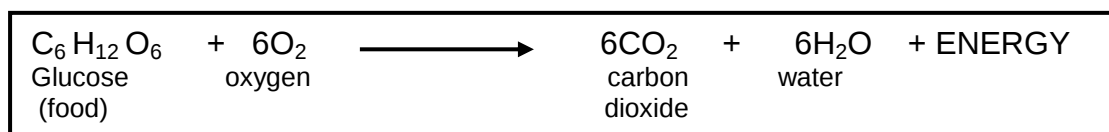
1. Photosynthesis is the process by which all green plants containing chlorophyll use sun's energy to make glucose sugar (food) from water and carbon dioxide and release oxygen as a by-product.
- 2.



3. From the water ( $\text{H}_2\text{O}$ ) molecules.
4. Hydrogen ions and carbon dioxide molecules.
5. Openings (pores) on leaf surface called stomata.
6. a) point 3                      b) point 2 and 4                      c) point 1 and 5
7. Temperature at point 1 is very low while at point 5 is very high.
8. A photosynthesis reaction stops because the enzymes are destroyed by the temperature. The plant may wilt and die.
9. Photosynthesis reaction increases as the temperature of the environment increases. If the temperature increases beyond a point, photosynthesis reaction stops and the plant dies.
10. The plant will lack chlorophyll so it will not photosynthesise well. As a result the growth rate of the plant will be too slow.

### Practice Exercise 12

1. A substance found in the body cells and carbon dioxide from the cells to the lungs. It transports oxygen from the lungs the body cells and carbon dioxide from the cells to the lungs.
2. Respiration is a chemical process by which living organisms take up oxygen, release carbon dioxide and produce energy from food inside cells.
3. Any chemical reactions that use up oxygen gas the release energy.
4. (a) large surface area    (b) Moist    (c) Thin walls    (d) many blood vessels
5. (a) at the lungs    (b) at the body tissues and cells
6. Oxygen and glucose are used up by cells at the tissues to produce energy.
- 7.



8. Trap germs and dust particles and prevent them going any further into the air passages.

9. It is the number of breaths taken by an individual in one minute.
  10. Infants and children have high breath rate because their growth rate is faster and they are also active.
  11. Ribs are raised, diaphragm moves down and the lungs expand during inhalation.
- 

### Practice Exercise 13

1.
  - a. Bio fuels can be seen as another alternative source of fuels if we run out of fossil fuels while bio gas is produces when organic matter, which is the waste of materials from plants and animals, is allowed to decay the absence or air.
  - b. Combustion is the release of heat from the reaction results in the production of light in the form of either glowing or a flame.
2.
  - a.  $C_2H^6$
  - b. ethane
- 3.

|   |
|---|
| D |
| B |
| A |
| C |

---

### Practice Exercise 14

1.
    - a. Fractional distillation
    - b. Separation
    - c. Distillation
  2. Crude oil is a non-renewable resource because it takes millions of years to form.
  3.
    - a. A
    - b. D
    - c. C
- 

### Practice Exercise 15

1.
  - a. Fractional distillation
  - b. Separation
  - c. Distillation
2. Crude oil is a non-renewable resource because it takes millions of years to form.
3.
  - a. A
  - b. D
  - c. C

## REVIEW OF TOPIC 3: REACTIONS OF ORGANIC SUBSTANCES

---

Now, revise all lessons in this Topic and then do **ASSIGNMENT 3**.  
Here are the main points to help you revise.

### Lesson 11: Photosynthesis

- Plants make food for all other living things using energy of the sunlight.
- Sunlight is the primary source of all other forms of energy on earth.
- Photosynthesis is the process whereby green plants use chlorophyll
- To capture energy of the sunlight to produce glucose (food) from water and carbon dioxide and release oxygen as a waste product.
- Chlorophyll is found in the chloroplasts of all plant cells.
- Increase in light intensity increases photosynthesis, however if the light is so much that it reaches beyond a point photosynthesis reaction stops.
- Photosynthesis reaction increases with an increase in temperature, however if the temperature exceeds a point the reaction stops also.
- The process of photosynthesis are as follows:
  - \* Chlorophyll in plants absorb energy of sunlight
  - \* This energy is used to split water molecules in the leaves into oxygen atoms and hydrogen ions.
  - \* The oxygen gas escapes into the atmosphere while the hydrogen ions are collected in the leaves.
  - \* Carbon dioxide molecules diffuse into the leaves through stomata openings.
  - \* Carbon dioxide reacts with the hydrogen ions to produce glucose (sugar).
- Leaves have adaptations for photosynthesis such as: flat shape, thinness, many stomata, presence of chlorophyll, having many branching veins.

### Lesson 12: Respiration

- Respiration is a chemical process by which living organisms take up oxygen, release carbon dioxide and produce energy from food inside cells.
- Chemical changes that use up oxygen to release energy are called oxidation.
- The inputs for respiration reaction are glucose and oxygen while the outputs are carbon dioxide, water and energy.
- Gas exchange takes place through surfaces that are thin, moist and well-supplied with blood vessels.
- Fish take in oxygen dissolved in water through special organs called gills.
- Mammals take in oxygen from the air into their body by breathing through their lungs.

**Lesson 13: Neutralisation**

- Fuels are the most important source of energy. They are found in nature as chemical fuels and nuclear fuels.
- There are two types of chemical fuels namely; fossil fuels and bio fuels.
- Nuclear fuels are derived from nuclear fission and nuclear fusion.
- Most chemical fuels are made up of carbon and hydrogen elements and by catenation process, they build up complex compounds called hydrocarbons.
- Combustion or burning is the process used to derive energy from chemical fuels. these reactions are referred to as exothermic reaction.
- In exothermic reactions, more energy is given off compared to the amount of energy required for the reaction itself.
- During cellular respiration, digested and absorbed food.
- Molecules are burned in tissues of the body with oxygen to produce the energy needed to power the activities of the cells in the body.
- Sugar, amino acids and fatty acids are nutrients that are used by cells in our bodies for respiration. The molecular oxygen ( $O_2$ ) is the common oxidizing agent in cellular respiration.

**Lesson 14: Rate of Reaction**

- Crude oil is a fossil fuel formed from dead plants and animals of ancient times.
- The main composition of crude oil is hydrocarbons and natural gas.
- Fraction distillation is the process used to separate crude oil into fractions. These fractions are further simplified cracking process converting hydrocarbons to usable products.
- Hydrocarbons have different boiling ranges that make it possible for the separation during separation.
- Fractions derived from fractional distillation are gas, gasoline(petrol), naphtha, kerosene, diesel oil, fuel oil and residues.
- Crude oil is a non-renewable resource because it takes millions of years to form.
- One of the negative effects of use of petroleum products is that too much carbon dioxide is emitted into the atmosphere causing an imbalance in carbon dioxide concentration ultimately increasing the rate of global warming.

---

**REVISE WELL AND THEN DO TOPIC TEST 1 IN YOUR ASSIGNMENT 3.**

## **TOPIC 4**

### **ANALYSING MATTER**

**In this topic you will learn about:**

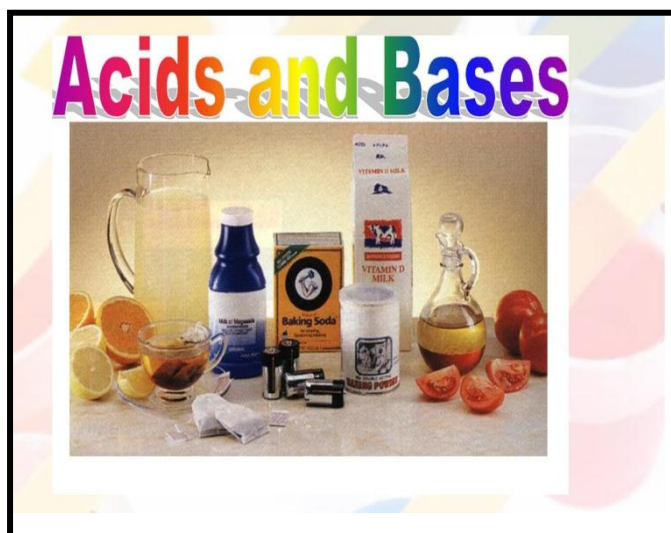
- **testing acids and bases with litmus**
- **testing of carbonates and carbon dioxide with acid and limewater**
- **splint and flame tests**

## INTRODUCTION TO TOPIC 4: ANALYSING MATTER

There are millions of chemical substances in the world. Some of them have acidic properties, others basic properties. Acids are substances which free hydrogen ions ( $H^+$ ), when they are mixed with water. Bases are substances which free hydroxide ions ( $OH^-$ ) when they are mixed with water.



(This freeing of ions is called dissociation in both cases). Free hydroxide ions react with the hydrogen ions producing water molecules:  $H^+ + OH^- = H_2O$ . In this way, bases diminish the concentration of hydrogen ions.



A solution rich in hydrogen ions is acidic, a solution poor in hydrogen ions is basic. Some acids dissociate only in part and they are called **weak acids**; others dissociate completely, freeing large amounts of hydrogen ions, and they are called **strong acids**. In the same way, the bases can be stronger or weaker. **Diluted acids and bases** are less aggressive in their actions. The acidic or basic degree of substances is measured in pH units. The scale used spans from 0 to 14. Substances with **pH lower than 7**

are considered **acids**, those with **pH equal to 7** are considered **neutral**, and those with **pH higher than 7** are considered **bases**. Substances with low pH are very acidic, while those with high pH are highly basic. Concentrated acidic and basic substances are very corrosive and dangerous.

Some questions will arise such as:

- What is the evidence that a chemical reaction has taken place in the reaction of an acid with a carbonate?
- When a carbonate is added to an acid, what is the reaction and symbol of the carbonate?
- So, is an acid + carbonate a neutralisation? Or does the reaction type fall under a different category?

**In this Topic, you will find the answers to these questions and all other questions relating to analysing matter.**

## Lesson 16: Testing Acids and Bases with Litmus



Welcome to Lesson 16. Many common substances are either acids or bases. Some acids, like stomach acid are necessary for our health, while others, like sulfuric acid are dangerous and can cause burns and other injuries. Baking soda is a common, weak base used in our homes, while sodium hydroxide, a strong base, is hazardous to skin and eyes.



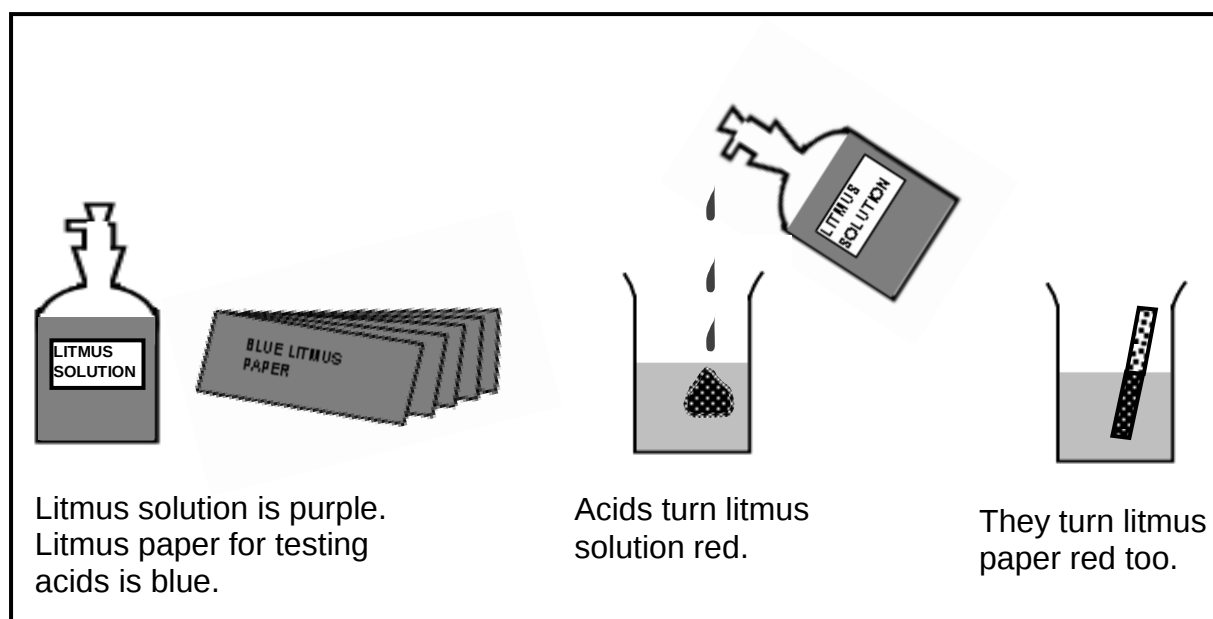
### Your Aims:

- investigate and observe simple activities in testing acids and bases
- describe the results using given table

### Indicators

An indicator, when added to an acid, a neutral substance or a base, will change into different colours. Indicators will help you see if a solution is acidic or basic.

You can tell if something is an acid, by its effect on **litmus**. Litmus is an indicator that is extracted from lichen and is commonly used to distinguish between acids and bases. It is a purple dye and is used as a solution, or on paper.



Litmus solution is purple.  
Litmus paper for testing acids is blue.

Acids turn litmus solution red.

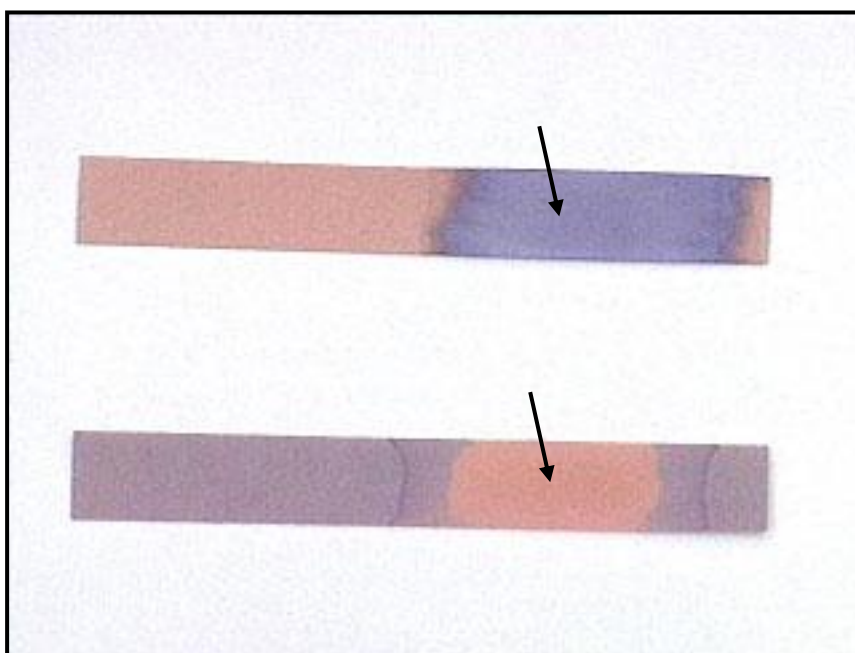
They turn litmus paper red too.

When an indicator is placed on paper, it provides a fast way to determine if a substance has acidic or basic properties. The most common acid/base indicator paper is called litmus paper, so a litmus test is the first test used to determine acidic or basic properties. If the litmus paper does not change colour, the substance is neutral.

**What is a litmus paper?**

**Litmus paper** is a pH indicator paper coated with an organic dye (extracted from lichen) which changes colour in the presence of acids and bases. Litmus paper is used when determining whether a solution is acidic or basic. You simply dip the paper in a solution and it will change colour depending on whether it is acidic or basic.

Litmus paper does not provide accurate information regarding the strength of the acid or base. There are two types of litmus paper that are commonly used. **Red litmus paper** is used to check for bases and **blue litmus paper** is used to check for acids. Red litmus paper turns blue when exposed to bases and blue litmus paper turns red when exposed to acids.



Red litmus paper (above); blue litmus paper (below)

You can follow this rule:

- Red litmus **turns** blue in base
- Blue litmus **turns** red in acid

You can also use something called a memory tool to help you memorise and become familiar with this rule:

- **blue for basic** - this simply means red litmus turns **blue** in **base**). If you can just memorise blue for basic then you will have no problem with the other part which is blue litmus turns **red** in **acid**. You can also have a memory tool for the second part.
- **red for acid** - it is better you familiarise yourself with a memory tool that you find easy to remember and you will have no problem remembering the other part.

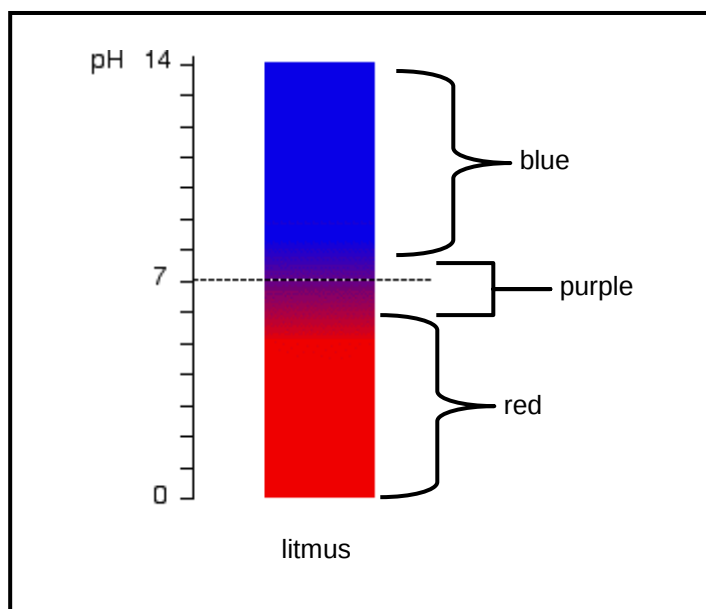
Often, both types of litmus paper are used during the same experiment. A basic solution will wet a piece of blue litmus paper, and no colour change will be observed. (The paper may appear bluer because it is wet, but there will be no colour change.) However, the lack of a colour change does not conclusively indicate that the solution is basic since neutral solutions will not cause a colour change. (Likewise, an acid will wet red litmus paper, with no colour change observed).

When no colour change is observed, the solution should be tested with the opposite colour litmus paper to confirm acidity or basicity.

The table below shows the colour changes litmus paper can make.

|                          | Red Litmus | Blue Litmus |
|--------------------------|------------|-------------|
| <b>Acidic solution</b>   | Stays red  | Turns red   |
| <b>Neutral solution</b>  | Stays red  | Stays blue  |
| <b>Alkaline solution</b> | Turns blue | Stays blue  |

Notice how we say 'stays red'. This is better than saying 'nothing' or 'stayed the same', because it tells us the colour we actually see.



Colour changes of litmus paper

This is more easily seen diagrammatically.

The litmus colour change happens over an unusually wide range, but it is useful for detecting acids and alkalis in the lab because it changes colour around pH 7. It is red in acids ( $\text{pH} < 7$ ), purple in neutral solutions and blue in alkaline solutions ( $\text{pH} > 7$ ).

### Examples of litmus paper colour changes

Sulphuric acid is obviously acidic in nature. It turns blue litmus paper red.

Sodium hydroxide is a base. It turns red litmus paper blue.

#### Points to remember

- Acids turn litmus solution red, and blue litmus paper red
- Alkalis turn litmus solution blue, and red litmus paper blue
- Many substances do not affect the colour of litmus the solution, so they are not acids or alkalis. They are neutral.



**Activity: Now test yourself by doing this activity.**

**Write true if the statement is correct and false if the statement is incorrect.**

**Part A**

1. Bases change litmus paper to blue. \_\_\_\_\_
2. Base solutions have a pH below 7. \_\_\_\_\_
3. An alkali is an acid. \_\_\_\_\_
4. Neutral solutions have a pH of 0. \_\_\_\_\_
5. Acids change litmus paper to red. \_\_\_\_\_
6. Acid solutions have a pH above 7. \_\_\_\_\_
7. Ammonia is an acid. \_\_\_\_\_
8. The chemical formula for sulphuric acid is  $\text{H}_2\text{SO}_4$ . \_\_\_\_\_
9. The chemical formula for sodium hydroxide is  $\text{NaOH}$ . \_\_\_\_\_
10. Sodium hydroxide is known as a weak base. \_\_\_\_\_

**Part B**

Complete the table below to show the colour changes litmus paper can make.

|                   | Red Litmus | Blue Litmus |
|-------------------|------------|-------------|
| Acidic solution   |            |             |
| Neutral solution  |            |             |
| Alkaline solution |            |             |

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF LESSON 16.**



## Summary

You have come to the end of lesson 16. In this lesson you have learnt that:

- indicators are natural or chemical dyes that are one colour in acidic solutions, but change to a different colour in basic solutions.
- litmus is an indicator that is extracted from lichen and is commonly used to distinguish between acids and bases.
- litmus can be used as a solution or on paper.
- acids turn litmus indicator red.
- bases turn litmus indicator blue.
- many substances do not affect the colour of the litmus solution, so they are not acids or alkalis. They are neutral.

---

**NOW DO PRACTICE EXERCISE 16 ON THE NEXT PAGE.**



## Practice Exercise 16

1. How would you test a substance to see if it is an acid?

\_\_\_\_\_

\_\_\_\_\_

2. What effect do alkalis have on litmus solution?

\_\_\_\_\_

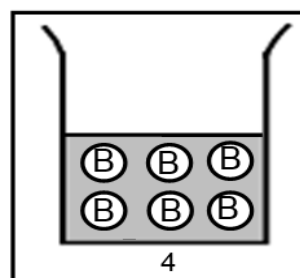
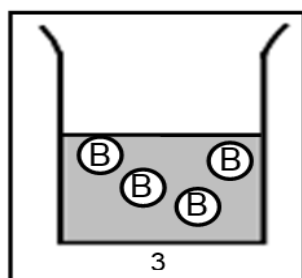
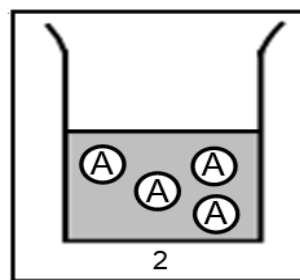
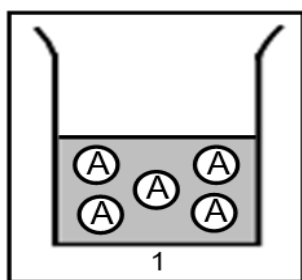
\_\_\_\_\_

3. What colour is litmus in:

- a. Vinegar? \_\_\_\_\_
- b. A solution of ammonia? \_\_\_\_\_

4. Study the diagrams below showing the beakers of hydrochloric acid particles A and sodium hydroxide base particles B. Describe the solutions obtained as acidic, neutral or basic, when the following beakers are mixed.

- a. 1 and 3. \_\_\_\_\_
- b. 1 and 4. \_\_\_\_\_
- c. 2 and 3. \_\_\_\_\_
- d. 2 and 4. \_\_\_\_\_
- e. 1, 2, 3 and 4. \_\_\_\_\_



**CHECK YOUR ANSWERS. ANSWERS ARE AT THE END OF TOPIC 4.**

**Answers to Activity****Part A**

1. True
2. False
3. False
4. False
5. True
6. False
7. False
8. True
9. False
10. False

**Part B**

|                          | <b>Red Litmus</b> | <b>Blue Litmus</b> |
|--------------------------|-------------------|--------------------|
| <b>Acidic solution</b>   | Stays red         | Turns red          |
| <b>Neutral solution</b>  | Stays red         | Stays blue         |
| <b>Alkaline solution</b> | Turns blue        | Stays blue         |

## Lesson 17: Testing of Carbonates and Carbon dioxide with Acid and Limewater



Welcome to Lesson 17. In the previous lesson you learnt about simple activities that can be performed to test for acids and bases. Then you discussed acids and bases using given tables. You were able to draw and label diagrams of testing for acids and bases.



### Your Aims:

- investigate and observe simple activities in testing carbonates and carbon dioxide
- describe the carbonates and carbon dioxide results

### Acids and Carbonates

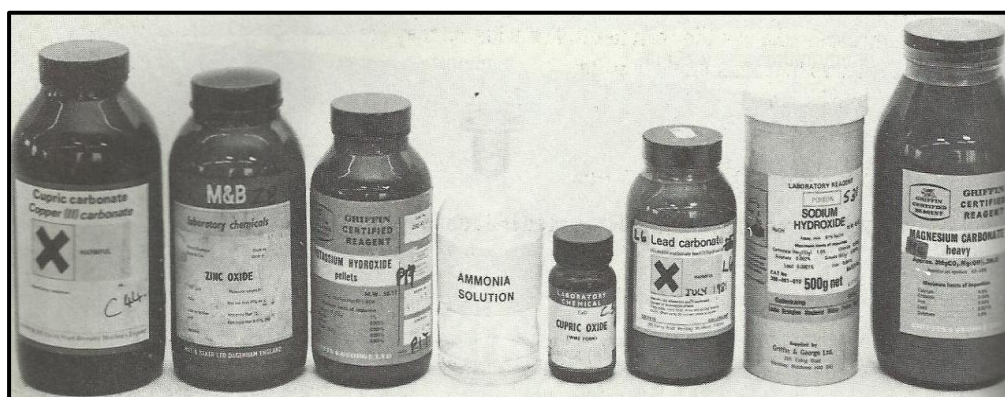
Carbonates form an important range of compounds. They are all salts of carbonic acid ( $\text{H}_2\text{CO}_3$ ) and contain the carbonate ion ( $\text{CO}_3^{2-}$ ). Many of them occur naturally in rock formations.

Most plants grow best when the pH of the soil is close to 7. If the soil is too acidic or basic (alkaline), the plants grow. Chemicals can be added to soil to adjust its pH. Most often it is too acidic, so it is treated with quick lime (calcium oxide), slaked lime (calcium hydroxide), or chalk (calcium carbonate). These are all bases, and are quite cheap.

Carbonates have a range of chemical and physical properties. Most mineral carbonates when heated decompose to form the metal oxide and carbon dioxide gas. Carbonates are generally insoluble in water except for those of sodium, potassium and ammonium.

Acids react with carbonates, forming a salt, water and carbon dioxide. When an acid reacts with a metal carbonate, which is a base, it fizzes and bubbles rapidly. A salt, carbon dioxide and water are produced. The general equation for the reaction is written as follows:

**Metal carbonate + Acid → Salt + Water + Carbon dioxide**



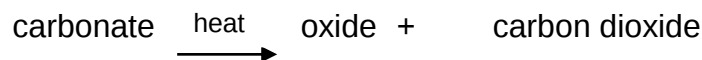
Carbonates are also bases. Above are examples of some bases

## Laboratory preparation of carbon dioxide

There are three main ways of preparing carbon dioxide:

### 1. Action of heat on Carbonates

When carbonates are heated, carbon dioxide is evolved and an oxide is left.



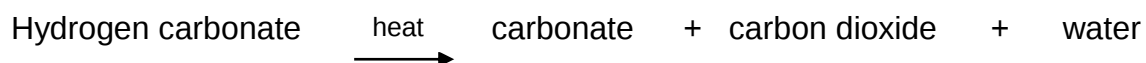
Here are two examples:



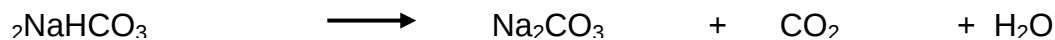
Two exceptions are sodium carbonate and potassium carbonate which will not decompose when heated in a Bunsen flame, because they are too stable.

### 2. Action of heat on hydrogen carbonates

When hydrogen carbonates are heated, carbon dioxide is evolved. A carbonate and water are produced:



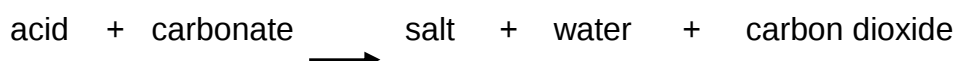
For example:



Sodium hydrogen carbonate is used in baking powder. When a cake mixture containing baking powder is heated in the oven, the sodium hydrogen carbonate decomposes, and the carbon dioxide makes the cake.

### 3. Action of dilute acids on carbonates

When acids are added to carbonates, carbon dioxide is given off; salt and water remain:



This is shown in three examples. The third example is the usual laboratory preparation.

1. Copper (II) carbonate + Sulphuric acid → Copper (II) sulphate + Water + Carbon dioxide

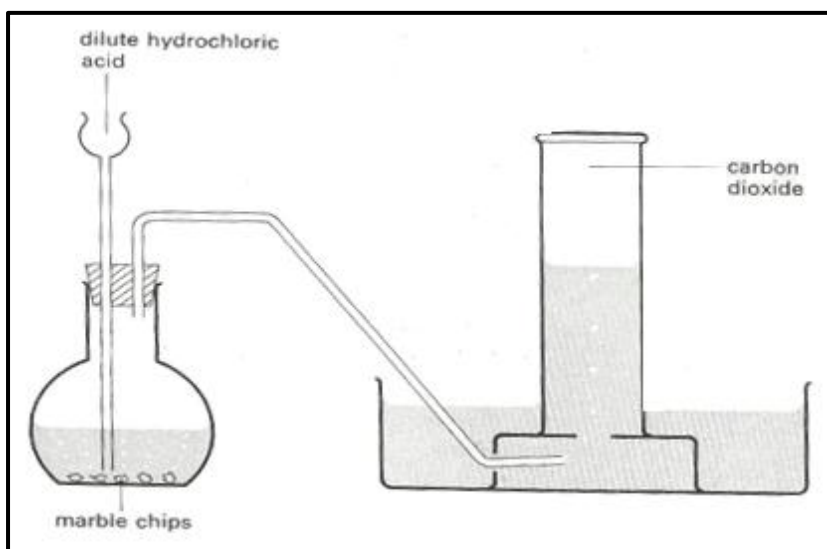


2. Sodium carbonate + Hydrochloric acid → Sodium chloride + Water + Carbon dioxide



3. Usual laboratory preparation. Carbon dioxide is usually prepared in the laboratory from marble chips and dilute hydrochloric acid.

Calcium carbonate + Hydrochloric acid (dilute) → Calcium chloride + Water + Carbon dioxide



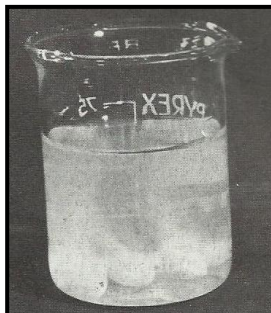
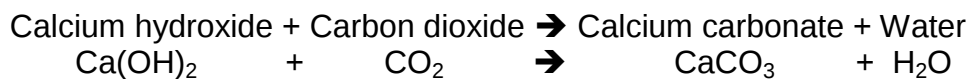
The preparation and collection of carbon dioxide

When the acid is added through the thistle funnel, the marble chips fizz and dissolve. the carbon dioxide is collected over water.

**This reaction is used in the laboratory preparation of carbon dioxide. It is also used as a test for carbonate because the reaction produces carbon dioxide which bubbles and if passed through lime water turns it chalky white.**

**Carbon dioxide turns lime water milky**

A weak solution of calcium hydroxide is called limewater. It is used to test for carbon dioxide gas, as a white solid of calcium carbonate is formed.



Carbon dioxide turns limewater milky

If carbon dioxide is bubbled for a further length of time when then the white precipitate of calcium carbonate dissolves and a solution of calcium hydrogen carbonate is produced.



Carbon dioxide  
turns limewater  
milky when



**Activity:** Now test yourself by doing this activity.

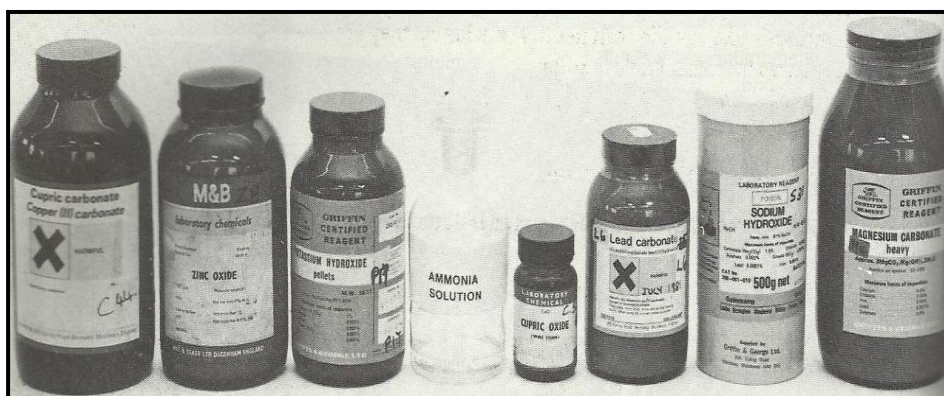
**Answer the following questions:**

1. Write a word equation for the reaction of dilute sulphuric acid with sodium carbonate.

\_\_\_\_\_ + \_\_\_\_\_ → \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_

2. Write the symbol of the carbonate ion present in all metal carbonates.

3. Refer to the diagram below.



List all the metal carbonates present in the diagram above.

a. \_\_\_\_\_ b. \_\_\_\_\_ c. \_\_\_\_\_

4. When hydrochloric acid is added to calcium carbonate, calcium chloride, water and carbon dioxide are produced. This reaction is used in the laboratory to make carbon dioxide gas.

- a) What are the names of the reactants? \_\_\_\_\_  
 b) What are the names of the products? \_\_\_\_\_  
 c) Write a word equation for this reaction.

\_\_\_\_\_ + \_\_\_\_\_ → \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 4.**



## Summary

You have come to the end of lesson 17. In this lesson you have learnt that:

- Carbonates form an important range of compounds. They are all salts of carbonic acid ( $\text{H}_2\text{CO}_3$ ) and contain the carbonate ion ( $\text{CO}_3^{2-}$ ).
- Most mineral carbonates when heated decompose to form the metal oxide and carbon dioxide gas.
- Acids react with carbonates, forming a salt, water and carbon dioxide.
- There are three main ways of preparing carbon dioxide: heating carbonates or hydrogen carbonates, and by the action of dilute acids on carbonates.
- Carbon dioxide is usually prepared in the laboratory from marble chips and dilute hydrochloric acid.
- The above reaction is also used as a test for carbonate because the reaction produces carbon dioxide which bubbles out and if passed through lime water turns it chalky white.

- Carbon dioxide turns limewater milky when reacted.
- 

**NOW DO PRACTICE EXERCISE 17 ON THE NEXT PAGE.**



## Practice Exercise 17

1. Read the following passage and draw a box around the correct word from each pair in brackets.

Acids are compounds which dissolve in water giving (hydrogen/hydroxide) ions. Sulphuric acid is one example. It is a (strong/weak) acid, which can be neutralised by (acids/alkalis), to form salts called (nitrates/sulphates). Many (metals/non-metals) react with acids to give a gas called (hydrogen/carbon dioxide). Acids also react with (chlorides/carbonates) to give (chlorine/carbon dioxide).

2. When coral is heated, the equation for the reaction is as follows:



Write the word equation of the above reaction.

\_\_\_\_\_ → \_\_\_\_\_ + \_\_\_\_\_

3. The table below is about the preparation of salts. Fill in the missing details.

| Method of preparation | Reactants       | Salt formed         | Other products           |
|-----------------------|-----------------|---------------------|--------------------------|
| a. acid + carbonate   | _____ and _____ | sodium chloride     | water and _____          |
| b. acid + carbonate   | _____ and _____ | copper(II) sulphate | carbon dioxide and _____ |

4. Write the chemical symbols of the following carbonates.

- a. Calcium carbonate \_\_\_\_\_  
 b. Barium carbonate \_\_\_\_\_  
 c. Sodium carbonate \_\_\_\_\_

5. Carbon dioxide turns limewater milky when reacted.

Write the word equation of this process.

\_\_\_\_\_ + \_\_\_\_\_ → \_\_\_\_\_ + \_\_\_\_\_

**CHECK YOUR WORK. ANSWERS ARE AT THE END TOPIC 4**

**Answers to Activity**

1. Sodium carbonate + Sulphuric acid → Sodium sulphate + Carbon dioxide + Water
2.  $\text{CO}_3^{2-}$
3.
  - a. Copper(II) carbonate
  - b. Magnesium carbonate
  - c. Lead carbonate
4.
  - a. Hydrochloric acid and Calcium carbonate
  - b. Calcium chloride, carbon dioxide and water
  - c. Hydrochloric acid + Calcium carbonate → Calcium chloride + carbon dioxide + water

## Lesson 18: Splint and Flame Test



Welcome to Lesson 18. In the previous lesson you learnt about simple activities that can be performed in testing carbonates and carbon dioxide using limewater and acid. Then you discussed the testing of carbonates and carbon dioxide and investigated drawings and diagrams of the laboratory set up of the tests involved.



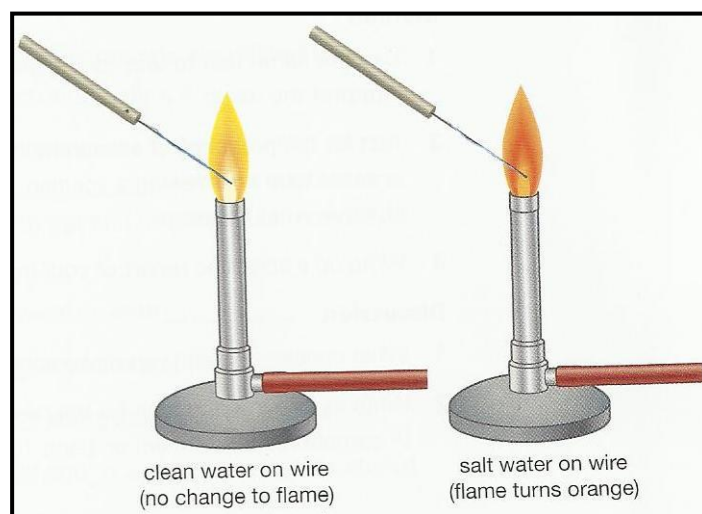
### Your Aims:

- describe splint and flame tests
- investigate and observe simple activities using splint and flame tests
- distinguish the different flame colours or metals
- identify elements in unknown solution

### Testing for Metals

One way of identifying which metal is present in a sample of an unknown compound is to carry out the flame test. This test uses a loop of wire mounted in a handle. The wire is dipped in hydrochloric acid then into a blue Bunsen flame in order to clean it. There should be no change in the colour of the flame when the wire loop is put in the flame.

The wire loop is dipped into the acid and then into the sample to pick up a small amount and back into the flame. The colour of the flame shows which metal is present. A wooden splint can also be used to pick up a small amount of the sample instead of a wire loop although when the wood begins to burn the colour of the flame from the wood will affect the result. When table salt is tested the flame is deep yellow because table salt contains sodium. All sodium compounds give a yellow flame colour.



The flame test is used to identify the presence of metal elements present in a sample

**Investigation: Identifying elements**

Here is an explanation of an investigation for the identification of elements. In this procedure, the following equipment would be required.

Wire loop mounted on handle, Bunsen burner, cement mat, hydrochloric acid and calcium carbonate

The following methods are closely followed in order to attain good results in the investigation.

Firstly, a wire loop is dipped into the acid and then into a blue Bunsen flame to clean it. There will be no change in the colour of the flame when the wire loop is clean. Secondly, the wire loop is dipped into the acid and then into the calcium carbonate so that some powder sticks to the loop. Thirdly, the loop is held in the flame and the colour of the flame when the powder burns is observed. The same method is repeated for any other samples.

The table below contains some common metallic elements and their characteristic flame colour.

| Metal of element | Flame colour |
|------------------|--------------|
| Barium           | Pale green   |
| Calcium          | Red          |
| Copper           | Blue-green   |
| Iron             | Pale yellow  |
| Potassium        | Purple       |
| Sodium           | Deep yellow  |



Different samples contain different metals and therefore will give different flame colours throughout the test.

**Flame colours**

If a clean nichrome wire is dipped into a metal compound and then held in the hot part of a Bunsen flame, the flame can become coloured. Certain metal ions may be detected in their compounds by observing their flame colours. Below is a table of some characteristic flame colours of some metal ions.

|                | Metal     | Flame colour  |
|----------------|-----------|---------------|
| <b>Group 1</b> | Lithium   | Crimson       |
|                | Sodium    | Golden yellow |
|                | Potassium | Lilac/ Purple |
|                | Rubidium  | Red           |
|                | Caesium   | Blue          |
| <b>Group 2</b> | Calcium   | Brick red     |
|                | Strontium | Crimson       |
|                | Barium    | Apple green   |
| <b>Others</b>  | Lead      | Blue-white    |
|                | Copper    | Green         |

**A flame colour is obtained as a result of the electrons in the particular ions being excited when they absorb energy from the flame which is then emitted as visible light.**



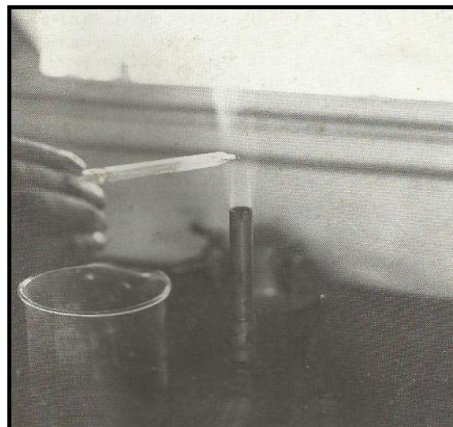
The different electron configurations of the different ions, therefore, give rise to the different

Different metal ions are used to produce the colours seen in fireworks.

### Identifying an unknown substance with two different tests

If you are given a blue powder and asked to identify it, the following testing procedure could be used:

Firstly try to identify if there is a metal in the compound by using the flame test. When the sample is heated on a wire in a Bunsen burner flame, the colour of the flame is blue-green. This shows that the metal copper is present. The compound could be a number of things, such as copper oxide, copper chloride, copper sulphate or copper nitrate. Your knowledge of copper compounds may lead you to predict that the blue powder you have is copper sulphate.



The flame test

Secondly try to prove this by adding barium chloride solution to a solution of the blue powder. The white precipitate of barium sulphate formed indicates that a sulphate is present.



A white precipitate shows that a sulphate is present

The chemical reaction that takes place can be represented by the following chemical equation:

Copper sulphate + Barium chloride → Copper chloride + Barium sulphate



You have now identified that the blue powder is copper sulphate, so no more testing needs to be done on this compound.

### Testing for elements in unknown solutions

There are many tests which can be carried out on unknown solutions, to find out which elements are present.

#### Iron

When sodium hydroxide solution is added to a solution containing iron, a green or brown precipitate forms.

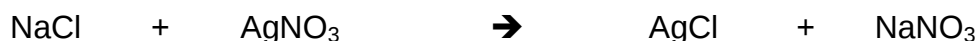
#### Zinc

When a solution of a base such as dilute ammonium hydroxide or sodium hydroxide is added to a solution containing zinc, a white precipitate forms. If more base is added, then the precipitate dissolves.

#### Chloride

When silver nitrate solution is added to an unknown solution, the appearance of a white precipitate shows that a chloride is present. If the unknown solution was sodium chloride, for example, the chemical reaction that takes place can be represented by the following chemical equation:

Sodium chloride + Silver nitrate → Silver chloride + Sodium nitrate (Precipitate)



#### Sulphate

When barium nitrate or barium chloride solution is added to an unknown solution, the appearance of a white precipitate shows that a sulphate is present. If the unknown solution was sodium sulphate, for example, the chemical reaction that takes place can be represented by the following chemical equation:

Sodium sulphate + Barium chloride → Sodium chloride + Barium sulphate



**Activity:** Now test yourself by doing this activity.

- Below is a list of metal carbonates. Write the appropriate colour that may appear if the flame test was done on each of the samples.

- Calcium carbonate
- Potassium carbonate

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- c. Copper carbonate
- d. Barium carbonate
- e. Iron carbonate
- f. Sodium carbonate

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2. If you tested limestone in a flame, what colour would the flame be?

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3. What in an element causes the different flame colours to be produced when tested in a flame?

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4. When barium nitrate or barium chloride solution is added to an unknown solution, the appearance of a white precipitate shows that a sulphate is present. Complete the word equation of the reaction.

Sodium sulphate + \_\_\_\_\_ → Sodium chloride + \_\_\_\_\_

---

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 4.**



### Summary

You have come to the end of lesson 18. In this lesson you have learnt that:

- chemical tests can be carried out to find out which elements and compounds are present in substances.
- tests used to identify particular elements and compounds are related to a chemical or physical property of the particular substance.
- one way of identifying which metal is present in a sample of an unknown compound is to carry out the flame test.
- a flame colour is obtained as a result of the electrons in the particular ions being excited when they absorb energy from the flame which is then emitted as visible light.
- the different electron configurations of the different ions, therefore, give rise to the different colours.
- different precipitates formed in different samples can also be used to identify elements in an unknown solution.

---

**NOW DO PRACTICE EXERCISE 18 ON THE NEXT PAGE.**



## Practice Exercise 18

1. There are many tests which are carried out on unknown solutions, to find out which elements are present.

Identify the colour of the different precipitates formed when tested for the presence of various substances.

- a. Sodium hydroxide solution is added to a solution containing iron.

- b. A solution of a base such as dilute ammonium hydroxide or sodium hydroxide is added to a solution containing zinc.

- c. Silver nitrate solution is added to an unknown solution containing chloride ions.

- d. Barium nitrate or barium chloride solution is added to an unknown solution containing sulphate ions.

2. Complete the precipitation reactions of the above reactions (1) and identify the precipitate formed.

- a. Sodium hydroxide + Iron nitrate → \_\_\_\_\_ + \_\_\_\_\_

Precipitate formed: \_\_\_\_\_

- b. Ammonium hydroxide + Zinc nitrate → \_\_\_\_\_ + \_\_\_\_\_

Precipitate formed: \_\_\_\_\_

- c. Silver nitrate + Barium chloride → \_\_\_\_\_ + \_\_\_\_\_

Precipitate formed: \_\_\_\_\_

- d. Barium nitrate + Zinc chloride → \_\_\_\_\_ + \_\_\_\_\_

Precipitate formed: \_\_\_\_\_

**CHECK YOUR WORK. ANSWERS ARE AT THE END TOPIC 4.**

**Answers to Activity 1**

1.
  - a. Red
  - b. Purple
  - c. Green
  - d. Green
  - e. Yellow
  - f. Yellow
2. Red flame
3. The different electron configurations of the different ions, therefore, give rise to the different colours
4. Sodium sulphate + Barium chloride → Sodium chloride + Barium sulphate

## Answer to Practice Exercises 16 – 18

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### Practice Exercise 16

1. Dip blue litmus paper into a solution and if the solution is acidic the blue litmus paper will turn red
  2. Alkalis turn litmus solution blue
  3.
    - a. Red.
    - b. Blue
  4.
    - a. Acidic
    - b. Basic
    - c. Neutral
    - d. Basic
    - e. Basic
- 

### Practice Exercise 17

1. Acids are compounds which dissolve in water giving (hydrogen/ hydroxide) ions. Sulphuric acid is one example. It is a (strong / weak) acid, which can be neutralised by (acids / alkalis), to form salts called (nitrates/ sulphates). Many (metals/ non-metals) react with acids to give a gas called (hydrogen/ carbon dioxide). Acids also react with (chlorides/ carbonates) to give (chlorine/ carbon dioxide).
2. Calcium carbonate → Calcium oxide + Carbon dioxide
3. The table below is about the preparation of salts. Fill in the missing details.

| Method of preparation | Reactants                               | Salt formed         | Other products           |
|-----------------------|-----------------------------------------|---------------------|--------------------------|
| a. acid + carbonate   | hydrochloric acid and sodium carbonate  | sodium chloride     | water and carbon dioxide |
| b. acid + carbonate   | copper(II) carbonate and sulphuric acid | copper(II) sulphate | carbon dioxide and water |

4.
  - a.  $\text{CaCO}_3$
  - b.  $\text{BaCO}_3$
  - c.  $\text{Na}_2\text{CO}_3$
5. Calcium hydroxide + Carbon dioxide → Calcium carbonate + Water

**Practice Exercise 18**

1.
    - a. A green or brown precipitate forms
    - b. A white precipitate is formed
    - c. A white precipitate is formed
    - d. A white precipitate is formed
- 

2.
    - a. Sodium hydroxide + Iron nitrate  $\rightarrow$  Sodium nitrate + Iron hydroxide  
Precipitate formed: Iron hydroxide
    - b. Ammonium hydroxide + Zinc nitrate  $\rightarrow$  Ammonium nitrate + Zinc hydroxide  
Precipitate formed: Zinc hydroxide
    - c. Silver nitrate + Barium chloride  $\rightarrow$  Barium nitrate + Silver chloride  
Precipitate formed: Silver chloride
    - d. Barium nitrate + Zinc chloride  $\rightarrow$  Zinc nitrate + Barium chloride  
Precipitate formed: Barium chloride
-

## REVIEW OF TOPIC 4 : ANALYSING MATTER

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Now, revise all lessons in this Topic and then do **ASSIGNMENT 3**.  
Here are the main points to help you revise.

### Lesson 16: Testing Acids and Bases with Litmus

- Indicators are natural or chemical dyes that are one colour in acidic solutions, but change to a different colour in basic solutions.
- Litmus is an indicator that is extracted from lichen and is commonly used to distinguish between acids and bases.
- Litmus can be used as a solution or on paper.
- Acids turn litmus indicator red
- Bases turn litmus indicator blue
- Many substances do not affect the colour of litmus solution, so they are not acids or alkalis. they are neutral.

### Lesson 17: Testing of Carbonates and Carbon Dioxide with Acid and Limewater

- Carbonates form an important range of compounds. They are all salts of carbonic acid ( $\text{H}_2\text{CO}_3$ ) and contain the carbonate ion ( $\text{CO}_3^{2-}$ )
- Most mineral carbonates when heated decompose to form the metal oxide and carbon dioxide gas.
- Acids react with carbonates, forming a salt, water and carbon dioxide.
- There are three main ways of preparing carbon dioxide: heating carbonates or hydrogen carbonates, and by the action of dilutes acids on carbonates.
- Carbon dioxide is usually prepared in the laboratory from marble chips and dilute hydrochloric acid.
- The above reaction is also used as a test for carbonate because the reaction produces carbon dioxide which bubbles out and if passed through lime water turns it chalky white.
- Carbon dioxide turns limewater milky when reacted.

### Lesson 18: Splint and Flame Tests

- Chemical tests are carried out to find out which elements and compounds are present in substances.
- Tests used to identify particular elements and compounds are related to a chemical or physical property of the particular substance.
- One way of identifying which metal is present in a sample of an unknown compound is to carry out the flame test.
- A flame colour is obtained as a result of the electrons in the particular ions being excited when they absorb energy from the flame which is then emitted as visible light.
- The different electron configurations of the different ions, therefore, give rise to the different colours.
- Different precipitates formed in different samples can also be used to identify elements in an unknown solution.

## **TOPIC 5**

### **CORROSION**

**In this topic you will learn about:**

- **cause and prevention of corrosion**
- **simple reactivity series**

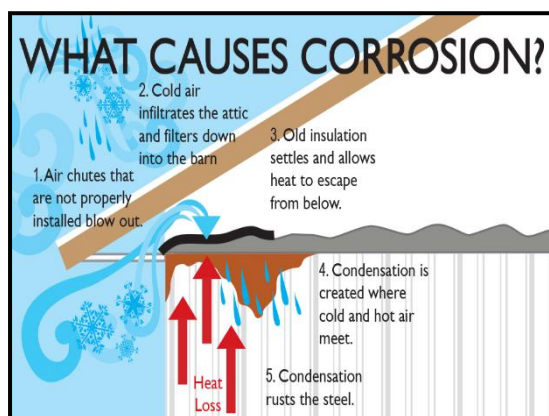
## INTRODUCTION TO TOPIC 5: CORROSION

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Corrosion is a general term used to describe various inter-action between a material and its environment leading to a degradation in the material properties. Interaction with oxygen can cause the formation of oxide layers through diffusion controlled growth. These may reduce chemical reactivity of the material against oxidation.



In a wet environment, aqueous corrosion can occur due to electrochemical processes which depend upon metal ion transport and reaction. Gradients of metallic and electrolytic ion concentrations, temperature, pressure and the presence of other metals, bacteria or active cells, all influence the corrosion rate.



Electric fields applied to corroding systems can accelerate or inhibit the rate of corrosion or material deposition. Galvanic corrosion between different materials in an aqueous environment is due to the electric field arising from the different electrode potential of the two materials.

External fields may enhance or suppress the corrosion. In all of these reactions, electron and ionic transport occurs. The following

sections will be concerned with these processes and the effect of conditions on the corrosion rates.

Such questions will arise such as:

- How long does it take vinegar to rust a nail?
- What chemical reaction is rust?
- How to remove rust from steel?
- What is metal corrosion?
- How to remove rust?

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**In this Topic, you will find the answers to these questions and other questions relating to corrosion.**

## Lesson 19: Cause and Prevention of Corrosion

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Welcome to Lesson 19. In this lesson, you will learn about the cause and prevention of corrosion.



### Your Aims:

- describe the corrosion of iron and steel
- make inference from a given diagram
- identify the methods of rust prevention

### Corrosion of Metals

Metals are needed by all people. A few metals such as lead and mercury are poisonous but we need small amount of some metals inside our bodies in order to survive.

For example, calcium is found in our bones and sodium and potassium are needed in the nervous system and for the muscles to contract. For this reason many metals are needed in small quantities in our diets. Dairy foods are good source of calcium, sodium is in salt and bananas are good source of potassium.

Metals are used to make many different products and are found in many of the things that we use every day because of their useful properties. Many household appliances, furniture, telephones, computers and motor vehicles made of or contain metal. However, one of the problems of metals is that they slowly change over long periods of time so that they no longer have the same properties.

When metals change or slowly break down the process is known as **corrosion**, which is a kind of chemical reaction. Corrosion cause metals to become weak or break so, for example, metals that are part of an electrical circuit may stop conducting an electric current, causing it to stop working. It then costs money to replace or repair these objects to get them working again.



Iron corrodes in damp air. So do most steels. The result is rust and the process is called rusting. In time, this vessel will fall apart.

**Rust** is the most common type of corrosion. Iron and steel rust very easily when they are exposed to the air and water and once the reaction has started it is difficult to slow down or stop. Rust is a reddish- brown iron oxide that forms the reaction of iron with oxygen, as shown in the following word equation:

Iron + oxygen → iron oxide



Objects made from iron or steel can be completely eaten away by rust

### Factors that cause corrosion

Both air and water are needed for iron and steel to rust. Dry air alone has no effect on iron and steel. In desert areas where the humidity is very low objects made from iron and steel will not rust easily.

People who live close to the sea find that things that are made of iron and steel go rusty more quickly than those owned by people who live further inland. This is due to the amount of salt in the air. The rate of corrosion decreases rapidly within the first kilometre from the sea. In countries such as the United States of America and the United Kingdom, where there is a lot of snow and ice in the winter, salt is often spread on roads. Salt helps to melt the ice but also causes cars and trucks to corrode more quickly.

**In big cities there is also greater corrosion near some industrial plants because of the sulphur dioxide gas that is given off in the air.**



The corrosion of iron and steel is called rusting. The iron is oxidised. It needs both air and water to oxidise.

### How to stop rust

When iron is made into stainless steel, it does not rust. But stainless steel is too expensive to use in large amounts. So other methods of rust prevention are needed. They mostly involve coating the metal with something, to keep out air and water.

1. Paint  
Steel bridges and railings are usually painted. Paints that contain lead or zinc are mostly used, because these are especially good at preventing rust.



Steel girders for building bridges are first sprayed with special paints

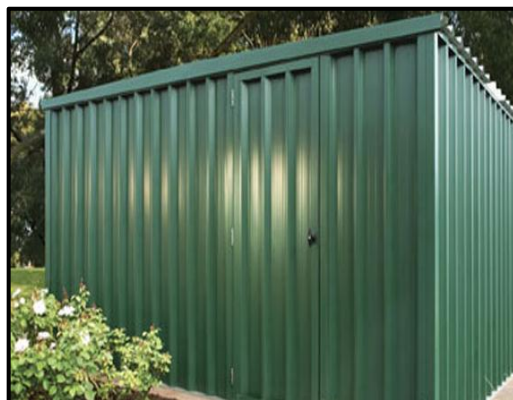
2. Grease  
Tools and machine parts, are coated with grease or oil.



3. Plastic  
Steel is coated with plastic for use in garden chairs, bicycle baskets and dish rack. Plastic is cheap and can be made to look attractive.



4. Galvanising  
Irons for sheds and dustbins are usually coated with zinc. It is called galvanised iron.

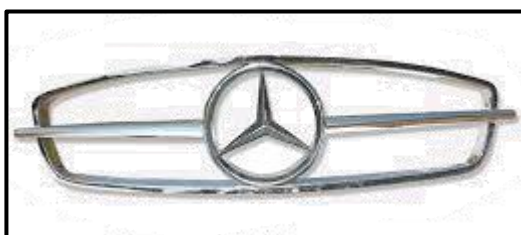


5. Tin plating  
Baked beans come in 'tins' which are made from steel coated on both sides with a fine layer of tin. Tin is used because it is unreactive, and non-toxic. It is deposited on the steel by electrolysis, in a process called tin plating.

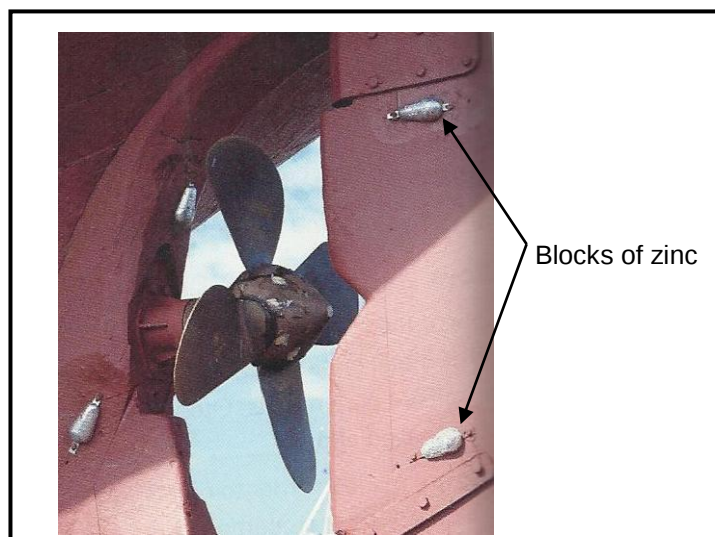


Steel cans for food are plated with tin

6. Chromium plating.  
Chromium is used to coat steel with a shiny protective layer, for example for car bumpers. Like tin the chromium is deposited by electrolysis.



7. Sacrificial protection.  
Magnesium is more reactive than iron. When a bar of magnesium is attached to the side of a steel ship, it corrodes instead of the steel. When it is nearly eaten away it can be replaced by a fresh bar. This is called sacrificial protection, because the magnesium is sacrificed to protect the steel. Zinc can be used in the same way.



Blocks of zinc attached to the hull of a ship help to prevent corrosion



Because magnesium and zinc are both more reactive than steel the blocks will corrode, which protects the steel from corrosion. The blocks will slowly disappear and are then replaced so the protection is continuous. It is much easier and cheaper to replace sacrificial blocks than it is to replace a ship, oil rig or pipe line.



**Activity:** Now test yourself by doing this activity.

Complete the following sentences using the most suitable word or words.

1. When metals change or slowly break down the process is known as , which is a kind \_\_\_\_\_ of chemical reaction.
2. \_\_\_\_\_ is the most common type of corrosion.
3. Iron and steel rust very easily when they are \_\_\_\_\_ to the air and water and once the reaction has started it is difficult to slow down or stop.
4. Some metals are more likely to take part in a chemical reaction than others. In other words, some metals are more \_\_\_\_\_ than others.
5. Rust can be \_\_\_\_\_ by making sure the iron or steel does not come in contact with air and water.

**CHECK YOUR WORK. ANSWERS ARE AT THE END TOPIC 4**



## Summary

You have come to the end of lesson 19. In this lesson you have learnt that:

- After a period of time, objects made of iron or steel will become coated with rust.
- The rusting of iron is a serious problem and wastes enormous amounts of money in PNG.
- Rust is an orange-red powder consisting mainly of hydrated iron (III) oxide.
- Both water and oxygen are essential for iron to rust, and if one of these two substances is not present then rusting will not take place.
- The rusting of iron is encouraged by salt.
- To prevent iron rusting, it is necessary to stop oxygen (from the air) and water coming into contact with it.
- There are several methods used to prevent rust and they are painting, greasing, plastic covering, galvanising, tin plating, chromium plating and sacrificial protection.

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|                                                      |
|------------------------------------------------------|
| <b>NOW DO PRACTICE EXERCISE 19 ON THE NEXT PAGE.</b> |
|------------------------------------------------------|



## Practice Exercise 19

Answer the following questions:

1. What is corrosion?

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2. What two substances cause rusting?  
\_\_\_\_\_ and \_\_\_\_\_

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3. Iron that is tin-plated does not rust. Why?

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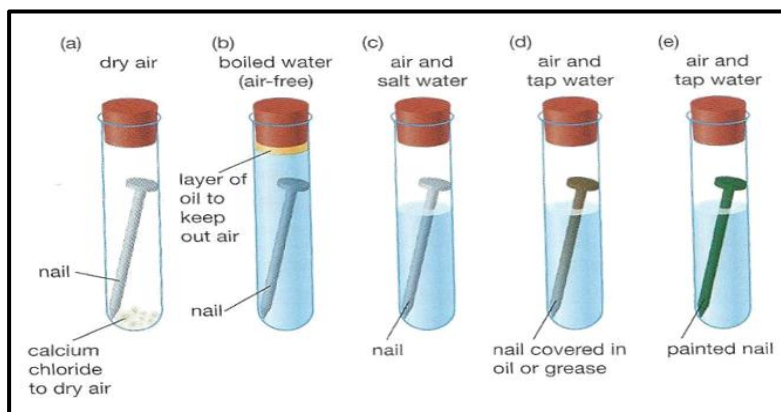
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4. In one method of rust prevention, the iron is not coated with anything. Which method is this?

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5. Refer to the diagram below.



Experiment set up illustrating conditions needed for rusting

a. List the three (3) conditions in the experiment needed for rusting.

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b. List two methods of rust prevention illustrated in the diagram.  
\_\_\_\_\_ and \_\_\_\_\_

---

c. List the test tubes (a-e) from the most corroded to the least.

---

**CHECK YOUR WORK. ANSWERS ARE AT THE END TOPIC 5.**

**Answers to Activity**

1. corrosion
2. Rusting
3. exposed
4. reactive
5. prevented

## Lesson 20: Simple Reactivity Series



Welcome to Lesson 20, Simple Reactivity Series. In the previous lesson you learnt about the corrosion of iron and steel. You were able to relate with diagrams of experimental set up of required conditions for corrosion. Then you listed and discussed the methods of rust prevention.



### Your Aims:

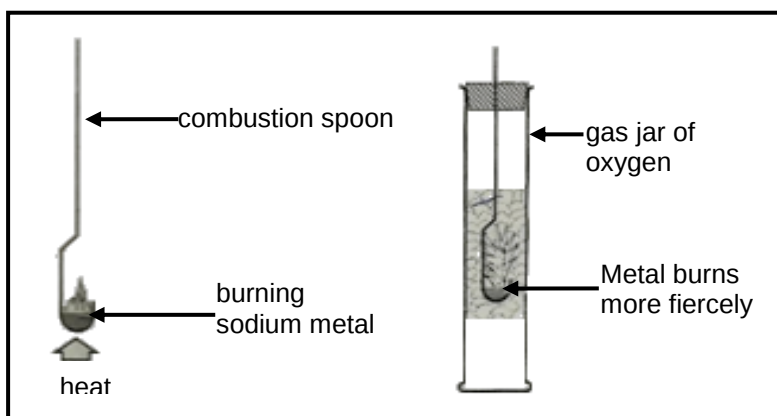
- describe the reactivity of metals in air, water and acid
- describe the table of reactivity
- enumerate rules about the reactivity series

### The Reactivity of Metals

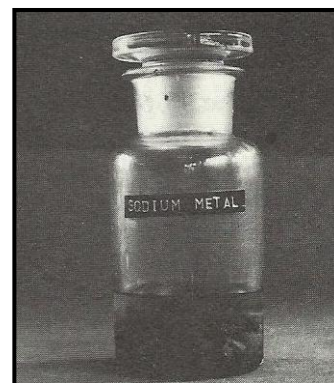
Some metals are more likely to take part in a chemical reaction than others. In other words, some metals are more reactive than others. A reactive metal will always take the place of, or displace, a less reactive metal from a compound. For example, if you put an iron nail into a blue solution of copper sulphate, the solution will turn green and brown copper metal will be deposited on the nail. This happens because iron is more reactive than copper. There is a competition between the iron and the copper to be the compound in solution.

### The Reaction between Metals and Oxygen

Look at the way sodium reacts with oxygen:



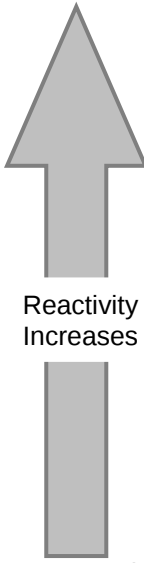
The reaction of sodium metal in a combustion spoon



Because it reacts with oxygen, sodium is stored under oil

A small piece of sodium is put in a combustion spoon and heated over a Bunsen flame. It melts quickly, and catches fire. Then the spoon is plunged into a jar of oxygen. The metal burns even more fiercely, with a bright yellow flame.

When the above reaction is repeated for other metals, the table below shows what happens:

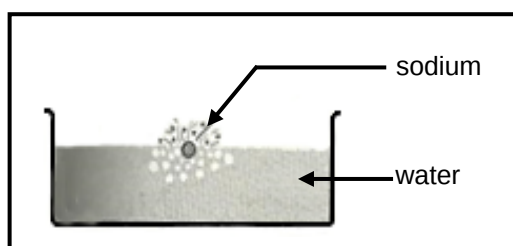
| Metal     | Behaviour                                                                               | Order of reactivity                                                                                                                                                    | Product                                                         |
|-----------|-----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| Sodium    | Catches fire with only a little heating. Burns fiercely with a bright yellow flame.     | <div style="text-align: center;"> <p>Most reactive</p>  <p>Least reactive</p> </div> | Sodium peroxide, $\text{Na}_2\text{O}_2$ , a pale yellow powder |
| Magnesium | Catches fire easily. Burns with a blinding white flame                                  |                                                                                                                                                                        | Magnesium oxide, $\text{MgO}$ a white powder                    |
| Iron      | Does not burn, but the hot metal glows brightly in oxygen, and gives off yellow sparks. |                                                                                                                                                                        | Iron oxide, $\text{Fe}_3\text{O}_4$ a black powder.             |
| Copper    | Does not burn, but the hot metal became coated with a black substance.                  |                                                                                                                                                                        | Copper oxide, $\text{CuO}$ a black powder.                      |
| Gold      | No reaction, no matter how much the metal is heated.                                    |                                                                                                                                                                        | _____                                                           |

If a reaction takes place, the product is an oxide. Sodium reacts the most vigorously with oxygen. It is the most reactive of the five metals. Gold does not react at all- it is the least reactive of them.

### The Reaction between Metals and Water

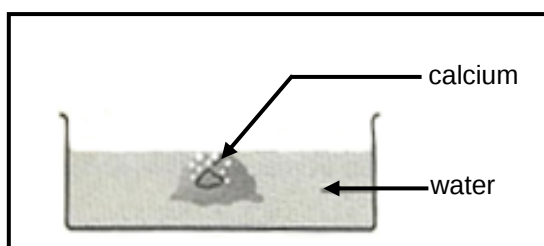
Metals also show differences in the way they react with water.

Sodium reacts violently with cold water, whizzing over the surface. Hydrogen gas and a clear solution of sodium hydroxide are formed.



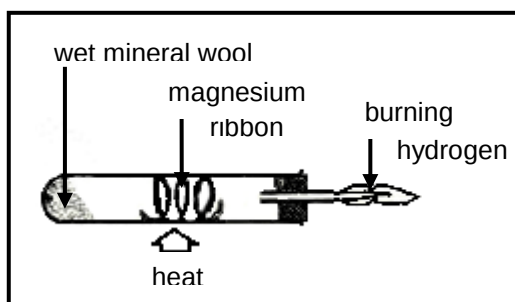
Sodium reacts violently with cold water

With calcium, the reaction is slower. Hydrogen bubbles off, and a cloudy solution of calcium hydroxide forms.



With calcium, the reaction is slower

Magnesium reacts only very slowly with cold water. But it reacts vigorously when heated in steam. It glows brightly, and hydrogen and solid magnesium oxide are formed.



Magnesium reacts very slowly with cold water, but vigorously when heated in steam



Both Sodium and Potassium are so reactive that they have to be stored under oil to prevent them from coming into contact with water or air

The table below shows the results for other metals.

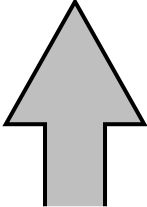
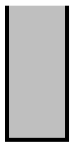
| Metal          | Reaction                                           | Order of reactivity                                                                 | Product                                                                                   |
|----------------|----------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Potassium      | Very violently with cold water. Catches fire       | <div style="text-align: center;"> <p>Most reactive</p> <p>Least reactive</p> </div> | Hydrogen and solution of potassium hydroxide, KOH                                         |
| Sodium         | Violent with cold water                            |                                                                                     | Hydrogen and a solution of sodium hydroxide, NaOH                                         |
| Calcium        | Less violent with cold water                       |                                                                                     | Hydrogen and calcium hydroxide, $\text{Ca}(\text{OH})_2$ , which is only slightly soluble |
| Magnesium      | Very slow with cold water, but vigorous with steam |                                                                                     | Hydrogen and solid magnesium oxide, MgO                                                   |
| Zinc           | Quite slow with steam                              |                                                                                     | Hydrogen and solid zinc oxide, ZnO                                                        |
| Iron           | Slow with steam                                    |                                                                                     | Hydrogen and solid iron oxide, $\text{Fe}_3\text{O}_4$                                    |
| Copper<br>Gold | No reaction                                        |                                                                                     | _____                                                                                     |

Notice that the first three metals in the list produce hydroxides. The others produce oxides, if they react.

### Reaction with acids (hydrochloric acid)

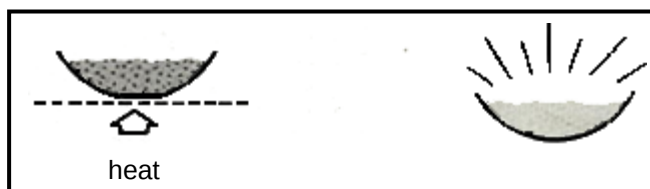
Metals also react differently with acids.

The table below shows results of metals reacting with hydrochloric acid.

| Metal          | Reaction with Hydrochloric acid            | Order of reactivity                                                                                                                                                                                                                                                                                                               | Product                                                       |
|----------------|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Magnesium      | Vigorous                                   | <div style="text-align: center;">             Most reactive<br/> <br/>             Reactivity Increases<br/> <br/>             Least reactive           </div> | Hydrogen and a solution magnesium chloride, $\text{MgCl}_2$   |
| Zinc           | Quite slow                                 |                                                                                                                                                                                                                                                                                                                                   | Hydrogen and a solution of zinc chloride, $\text{ZnCl}_2$     |
| Iron           | Slow                                       |                                                                                                                                                                                                                                                                                                                                   | Hydrogen and a solution of iron(II) chloride, $\text{FeCl}_2$ |
| Lead           | Slow, and only if the acid is concentrated |                                                                                                                                                                                                                                                                                                                                   | Hydrogen and a solution of lead(II) chloride, $\text{PbCl}_2$ |
| Copper<br>Gold | No reaction, even with concentrated acid   |                                                                                                                                                                                                                                                                                                                                   | _____                                                         |

### Competing for oxygen

The reactions with oxygen, water, and hydrochloric acid show that iron is more reactive than copper. Now look at the experiment below.

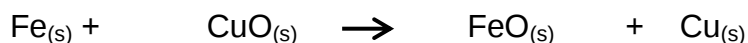


Iron and copper compete for oxygen and iron wins

This is a mixture of powdered iron, and copper (II) oxide. On heating, the reaction starts. The mixture glows, even after the Bunsen is removed. Iron (II) oxide and copper are formed.

Here iron and copper are competing for oxygen. Iron wins:

Iron + copper (II) oxide → iron (II) oxide + Copper



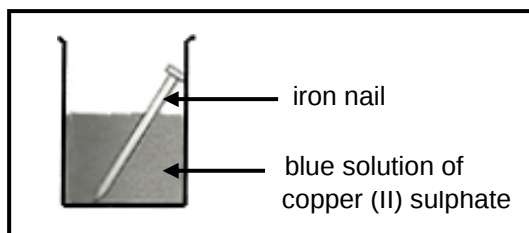
By taking away the oxygen from copper, iron is acting as a reducing agent. Other metals behave in the same way when heated with oxides of less reactive metals.

**When a metal is heated with the oxide of a less reactive metal, it will remove the oxygen from it.**

## Displacement Reactions

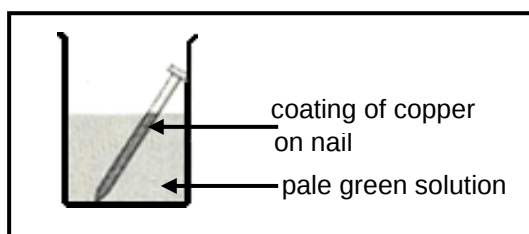
You will now look at another reaction involving iron and copper:

This time, an iron is placed in some blue copper (II) sulphate solution.



Iron nail placed in copper (II) sulphate solution

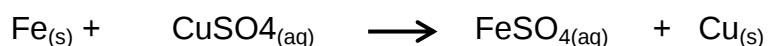
Soon a coat of copper appears on the nail. The solution turns pale green.



Copper coating appears on the nail and the solution turns pale green

Here, iron and copper are competing to be the compound in solution. Ones again iron wins. It drives out or displaces copper from the copper (II) sulphate solution. Green iron (II) sulphate is formed:

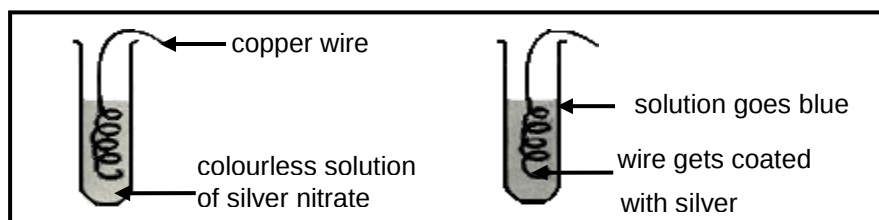
Iron + Copper (II) sulphate → Iron (II) sulphate + Copper



Other metals displace less reactive metals in the same way.

**A metal will always displace a less reactive metal from solutions of its compound.**

You will now look at the way copper reacts with silver nitrate solution:



Copper wire is coated with silver and the solutions turns blue



Crystals of silver on a copper wire. The copper has displaced the silver from the silver nitrate solution

A coil of copper is placed in a solution of silver nitrate. The copper gradually dissolves so the solution goes blue. At the same time, a coating of silver forms on the wire.



When a metal is heated with the oxide of a less reactive metal, it will remove the oxygen from it. A metal will always displace a less reactive metal from solutions of its compound.

### The Reactivity Series

By comparing the reactions of metals with oxygen, water, acid, metal oxides, and solutions of metals salts, you can arrange the metals in order of reactivity. The list is called the reactivity series.

|                      |                       |  |
|----------------------|-----------------------|--|
| <b>Potassium, K</b>  | <b>Most Reactive</b>  |  |
| <b>Sodium, Na</b>    |                       |  |
| <b>Calcium, Ca</b>   |                       |  |
| <b>Magnesium, Mg</b> |                       |  |
| <b>Aluminium, Al</b> |                       |  |
| <b>Zinc, Zn</b>      |                       |  |
| <b>Iron, Fe</b>      |                       |  |
| <b>Lead, Pb</b>      |                       |  |
| <b>Copper, Cu</b>    |                       |  |
| <b>Silver, Ag</b>    |                       |  |
| <b>Gold, Au</b>      | <b>Least Reactive</b> |  |

Reactivity Increases

metals above this line react with acids, displacing hydrogen

### Things to remember about the reactivity series

1. The more reactive the metal, the more it 'likes' to form compounds. So only copper, silver and gold are ever found as elements in the earth's crust. The other metals are always found as compounds.
2. The more reactive the metal, the more stable its compounds. A stable compound is difficult to break down or decompose, because the bonds holding it together are very strong.
3. When a metal reacts, it gives up electrons to form ions. When magnesium reacts with oxygen it forms magnesium ions ( $\text{Mg}^{2+}$ ). When copper reacts with oxygen it forms copper ions ( $\text{Cu}^{2+}$ ). Magnesium is more reactive than copper because it gives up electrons more readily.

**The more reactive the metal, the more readily it gives up electrons.**



**Activity:** Now test yourself by doing this activity.

1. Use the following list of metals to answer questions **a** to **f**:

**iron, calcium, potassium, gold, aluminium, magnesium, sodium, and zinc**

- a. Which metal is found native? \_\_\_\_\_
- b. Which metal will not react with oxygen to form an oxide? \_\_\_\_\_
- c. Which metal will react violently with cold water? \_\_\_\_\_
- d. Use the metal in your answer to **c** and write a word equation for the reaction which takes place.  
\_\_\_\_\_
- e. Which metal has a protective oxide coating on its surface? \_\_\_\_\_
- f. Which of the metals react very slowly with cold water but extremely vigorous with steam? \_\_\_\_\_ and \_\_\_\_\_

**CHECK YOUR WORK. ANSWERS ARE AT THE END OF TOPIC 5.**



### Summary

You have come to the end of lesson 20. In this lesson you have learnt that:

- if similar reactions are carried out using other metals oxygen, water or acids, an order of reactivity can be produced. This is known as the reactivity series
- by looking at the properties of metals scientists have developed the activity or reactivity series which is a list of metals in order of their reactivity. The most reactive metals are at the top and the least reactive are at the bottom
- the activity/reactivity series can be used to predict what will happen in reactions between metals and metal solutions
- the more reactive metal will always displace the less reactive metal
- the more reactive the metal, the more it 'likes' to form compounds
- the more reactive the metal, the more stable its compounds
- when a metal reacts, it gives up electrons to form ions

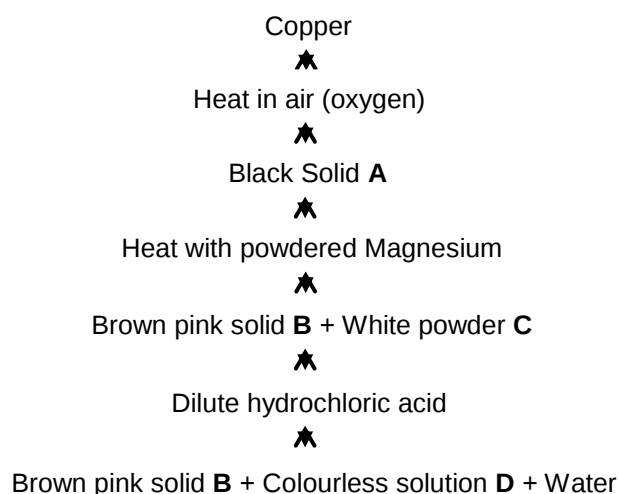
**NOW DO PRACTICE EXERCISE 20 ON THE NEXT PAGE.**



## Practice Exercise 20

1. Refer to the diagram below.

Study the flow chart of the reaction of copper with different substances.



Write the names of the substances A to D.

A. \_\_\_\_\_ B. \_\_\_\_\_

C. \_\_\_\_\_ D. \_\_\_\_\_

2. Use the following list of metals to answer the questions.

**Gold, Potassium, Silver, Sodium, Copper, Calcium, Lead, Magnesium, Iron, Aluminium, Zinc**

- a. Completed the missing names of metals in the reactivity series.

| Potassium | Most Reactive  |  |
|-----------|----------------|--|
| 1. _____  |                |  |
| Calcium   |                |  |
| 2. _____  |                |  |
| Aluminium |                |  |
| Zinc      |                |  |
| 3. _____  |                |  |
| Lead      |                |  |
| 4. _____  |                |  |
| Silver    |                |  |
| 5. _____  | Least Reactive |  |

metals above this line react with acids, displacing hydrogen

**b.** Write symbols of metals listed in the order of the least to the most reactive.

Least  
Reactive → \_\_\_\_\_ → Most  
Reactive

**3.** Complete the sentences by underlining the correct word from the given words in bracket.

1. (Potassium/ Gold) is the most reactive metal in the reactivity series.
2. The (more/ less) reactive the metal the more readily it gives up (electrons/ protons).
3. A metal will always displace a (more/ less) reactive metal from solutions of its compounds.
4. When a metal is heated with the oxide of a (more/ less) reactive metal, it will remove the oxygen from it.
5. The (more/ less) reactive the metal, the (more/ less) stable its compound.

---

|                                                         |
|---------------------------------------------------------|
| <b>CHECK YOUR WORK. ANSWERS ARE AT THE END TOPIC 4.</b> |
|---------------------------------------------------------|

### Answers to Activity 1

- a. Gold
- b. Gold
- c. Potassium
- d. Potassium + Oxygen → Potassium oxide
- e. Magnesium
- f. Magnesium and Zinc

## Answer to Practice Exercises 19-20

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### Practice Exercise 19

1. Chemical process which makes metals change or slowly break down
  2. Air and Water
  3. Tin is used because it is unreactive, therefore does not corrode easily
  4. Sacrificial Protection
  5.
    - a. Air (Oxygen), Water, Salt
    - b. Greasing and Painting
    - c. c-a-b-d-e
- 

### Practice Exercise 20

1.
    - A. Copper (II) oxide
    - B. Magnesium oxide
    - C. Copper
    - D. Copper chloride
- 
2.
    - a.
      1. Sodium
      2. Magnesium
      3. Iron
      4. Copper
      5. Gold
    - b. Au – Ag – Cu – Pb – Fe – Zn – Al – Mg – Ca – Na – K
- 
3.
    1. Potassium
    2. more and electrons
    3. less
    4. less
    5. more
- 

|                                                                                 |
|---------------------------------------------------------------------------------|
| <b>NOW YOU MUST COMPLETE ASSIGNMENT 3. RETURN IT TO PROVINCIAL COORDINATOR.</b> |
|---------------------------------------------------------------------------------|

## REVIEW OF TOPIC 5: CORROSION

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Now, revise all the lessons in this Topic and then do **ASSIGNMENT 3**.  
Here are the main points to help you revise.

### Lesson 19: Cause and Prevention of Corrosion

- After a period of time, objects made of iron or steel will become coated with rust.
- The rusting of iron is a serious problem and wastes enormous amounts of money in PNG.
- Rust is an orange-red powder consisting mainly of hydrated iron (III) oxide.
- Both water and oxygen are essential for iron to rust, and if one of these two substances is not present then rusting will not take place.
- The rusting of iron is encouraged by salt.
- To prevent iron rusting, it is necessary to stop oxygen (from the air) and water coming into contact with it.
- There are several methods used to prevent rust and they are painting, greasing, plastic covering, galvanizing, tin plating, chromium plating and sacrificial protection.

### Lesson 20: Simple Reactivity Series

- If similar reactions are carried out using other metals oxygen, water or acids, an order of reactivity can be produced. This is known as the reactivity series.
- By looking at the properties of metals scientists have developed the activity or reactivity series which is a list of metals in order of their reactivity. The most reactive metals are at the top and the least reactive are at the bottom.
- The activity/reactivity series can be used to predict what will happen in reactions between metals and metal solutions.
- The more reactive metal will always displace the less reactive metal.
- The more reactive the metal, the more it 'likes' to form compounds.
- The more reactive the metal, the more stable its compounds.
- When a metal reacts, it gives up electrons to form ions.

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|                                                                   |
|-------------------------------------------------------------------|
| <b>REVISE WELL AND THEN DO TOPIC TEST 5 IN YOUR ASSIGNMENT 5.</b> |
|-------------------------------------------------------------------|

## GLOSSARY

|                             |                                                                                                                             |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| <b>Apparatus</b>            | is the name given to equipment that has been put together, usually for an experiment.                                       |
| <b>Arbitrary unit</b>       | means that you cannot adjust your equipment and therefore you cannot tell us how your data compares to other data.          |
| <b>Controlled variables</b> | are quantities that a scientist wants to remain constant, and he must observe them as carefully as the dependent variables. |
| <b>Data</b>                 | are pieces of information you collect during investigation.                                                                 |
| <b>Density</b>              | is defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume.            |
| <b>Dependent variable</b>   | is the result of your experiment your results should show something changing.                                               |
| <b>Equipment</b>            | is the name given to all the things used in laboratory such as test tubes, beakers, dry cells and wires.                    |
| <b>First aid</b>            | is the initial provision for an illness or injury.                                                                          |
| <b>Hypothesis</b>           | is your general statement of how you think the scientific idea in question works.                                           |
| <b>Inference</b>            | is an explanation of an event.                                                                                              |
| <b>Instruments</b>          | are pieces of equipment that are used to make measurements.                                                                 |
| <b>Independent variable</b> | is something that you change when you do your experiment.                                                                   |
| <b>Laboratory</b>           | (la-BOR-a tory) is a specially designed room where you can carry out                                                        |
| <b>Length</b>               | is the distance from end to end. It also means the longer distance across.                                                  |
| <b>Mass</b>                 | is the amount of material in an object.                                                                                     |
| <b>Measurement</b>          | is a collection of quantitative data.                                                                                       |
| <b>Miles</b>                | are long distances and are mostly used to measure the distance between places which are far away from each other.           |

|                          |                                                                                                                              |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------|
| <b>Observation</b>       | is the act of seeing an object or an event and noting the physical characteristics or points in the event.                   |
| <b>Parallax error</b>    | is the inaccuracy of measurement which is caused by reading a scale from an incorrect position.                              |
| <b>Precision</b>         | is the smallest unit to which measurement is possible with a particular tool.                                                |
| <b>Prediction</b>        | is a statement about the way things will happen in the future, often but not always based on experience or knowledge.        |
| <b>Scientific report</b> | is an important document for those who need to use it and a recap of what a scientist or a science student has investigated. |
| <b>Time</b>              | is the ongoing string of events taking place in the past, present and future.                                                |
| <b>Unit</b>              | is any measurement that 1 of a physical quantity.                                                                            |
| <b>Volume</b>            | is the amount of space taken up by a substance. It does not always have to be a container.                                   |
| <b>Weight</b>            | is the gravitational force that is acting upon an object.                                                                    |

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