DEPARTMENT OF EDUCATION

GRADE 11

CHEMISTRY

MODULE 1

APPLICATION OF PHYSICAL PROCESSES

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GRADE 11

CHEMISTRY

MODULE 1

APPLICATION OF PHYSICAL PROCESSES

IN THIS MODULE YOU WILL LEARN ABOUT:

11.1.1: GASES

11.1.2: PURE SUBSTANCES AND MIXTURE

11.1.3: SEPARATING MIXTURES

11.1.4: SOLUBILITY

Acknowledgement

We acknowledge the contributions of all secondary teachers who in one way or another have helped to develop this Course.

Our profound gratitude goes to the former Principal of FODE, Mr. Demas Tongogo for leading FODE team towards this great achievement.

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DIANA TEIT AKIS
PRINCIPAL

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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 a part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and 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, Government Policies and Reports. It is developed in line with the National Education Plan (2005 -2014) and addresses an increase in the number of school leavers affected by the lack of access into 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.

UKE KOMBRA, PhD
Secretary for Education

MODULE 1: APPLICATION OF PHYSICAL PROCESSES

Introduction

You have learnt about the basic concept of physical changes in your Lower Secondary Science course, the arrangement of particles in Solids, Liquids, and Gases. For this module you will be studying the particle theory to explain the behaviour of gases and liquids, physical separation techniques, and the concept to separate different mixtures, and their solubility. You will also define the terms solute, solvent, saturated, unsaturated, and supersaturated solution. You will also interpret and calculate the solubilities of substances using solubility curves as well as given data.

Learning outcomes

After going through the module, you are expected to:

- define physical change, arrangement of particle and their shapes in three states of matter. Apply the particle theory to explain the behavior of gases and liquids.
- calculate the relationship between temperature, pressure, and volume using Boyles, Charles, Combined and Ideal gas laws.
- demonstrate an understanding of various physical separation techniques and apply the concept to separate different mixture.
- define the terms solubility, solute, solvent, saturated, unsaturated, and supersaturated solutions. Investigate and collect data on solubility of various salts and gases, plot the solubility curves.
- calculate the solubility's of substances using solubility curves as well as given data.

Time Frame

10 weeks

If you set an average of three hours per day, you should be able to complete the Module by the end of the assigned week. Try to do all the learning activities. And compare your answers with the ones provided at the end of the Module.
If you do not get a particular exercise right in the first attempt, you should not get discouraged, but instead, go back and attempt it again. If you still do not get it right after several attempts then you should seek help from your friend or even your tutor.

DO NOT LEAVE ANY QUESTION UN-ANSWERED.

Terminologies

Before you get into the thick of things, let us make sure you know some of the terminologies that are used throughout this module.

Boiling	Is the change from liquid to a gas or vapour.
Condensation	Is the change from gas to a liquid.
Chromatography	Is the most sensitive techniques that can be used for identifying and separating components or mixture.
Diffusion	Is the rate at which gas travels across a room or particles mix by colliding with each other and bouncing off in all direction.
Evaporation	Is the change of a liquid into gas without boiling.
Fractional distillation	This is to separate two or more liquids that are mixed or separating two immiscible liquids.
Freezing	Is the change from liquid to solid.
Heterogeneous	Is a mixture of more than one phase that can be observed in the system.
Homogeneous	Is a mixture of only one phase that can be observed in the mixture.
Ideal gas	A gas that behaves exactly as described by the gas laws.
Matter	Is anything that occupies space and has mass.
Melting	Is the change from solid to liquid.
Real gas	A gas, especially at high pressure or low temperatures do not behave quite ideally.
Residue	Is the trapped solid particles in the filter.
Saturated solution	Is a solution that cannot dissolve anymore solute at a given temperature.
Simple distillation	This is to collect the pure liquid from a solution.
Solubility	Is the amount of solute that will dissolve in 100 grams of a solvent, at a given temperature.
Sublimation	Is the change from solid directly to gas without going through the liquid state.
Unsaturated solution	Is a solution that contains less solute dissolved at that temperature than a saturated solution.

11.1.1 Gases

Particle Theory of Matter

The **Kinetic theory** model is used to explain how a substance changes from one state to another. For example, if you open a bottle of perfume, the aroma soon reaches the nose of anyone nearby; it means the molecules of the fragrance have been diffused from the bottle. This diffusion is a simple evidence that molecules move. The word kinetic means motion.

The kinetic theory says that the tiny particles in all forms of matter are in constant motion. These particles may be atoms, ions, or molecule of gases, liquids, or solids. For the present, let us concentrate on the kinetic theory as it applies to gases. We know that gas is easily compressed and fills whatever container it is in.

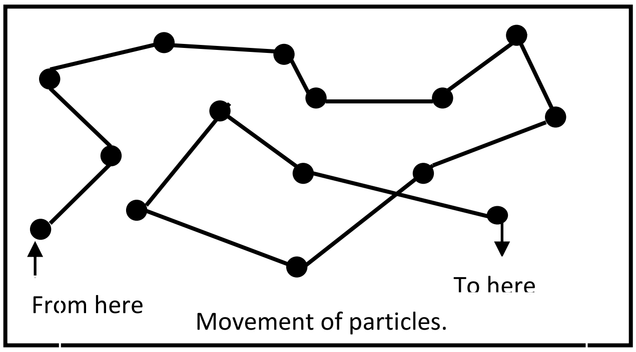
James Clerk Maxwell (1813-79) and Ludwig Boltzmann (1844-1906) studied and found a way to describe how gasses behave by considering them as made up of tiny particles. Their ideas were into the Maxwell-Boltzmann kinetic theory of gasses. Later this theory was expanded to include liquids and solid. Today this theory is simply known as the kinetic theory.

The kinetic theory states that:

- matter is made from tiny particles.
- the particles at a temperature above $^{-}273$K (Kelvin) are moving all the time. They possess the energy of motion, which is called kinetic energy.
- the rate of movement of the particles is linked to their temperature. The particles have low kinetic energy and move slowly at a low temperature, the particles with higher kinetic energy move quickly at a higher temperature.
- particles can be attracted to each other and can be of different weights and sizes.
- heavier particles move slowly than lighter particles.

Particles on the move

In rocks and other solids, the particles are not free to move around. However, in liquids and gases, they moved freely. They collide with each other and bounce off in all directions. So the path of one particle, in a liquid or gas, could look like this:



Movement of particles.

States of Matter

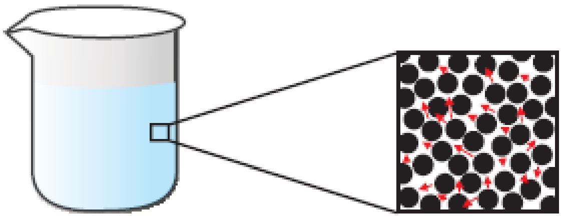
Matter is anything that occupies space and has mass. They can be solid, liquid, and gas. They are also classified as:

- metals, compounds and mixtures.
- metals and non- metals.

How are particles arranged?

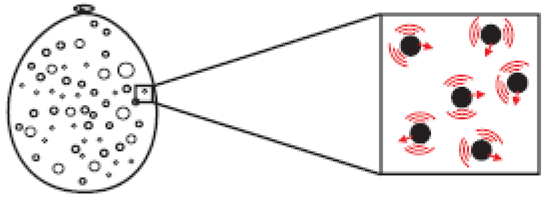
solid

The particles in a solid are arranged in a fixed pattern or lattice. Strong forces hold them together. So they cannot leave their positions. The only movements they make are tiny vibrations to and fro.



liquid

The particles in a liquid can move about they slide past each other. They are still close together, but not in lattice. The forces that hold them together are weaker than in a solid.



gas

The particles in a gas are far apart, and they move about quickly. There are almost no forces holding them together. They collide with each other and bounce off in all directions.

Properties of matter

Particles are always moving. Rocks air and water look very different. They have one big thing in common. They are all made of very tiny pieces. These pieces are called particles. Everything around you is made of particles – and so are you!

Matter exist in three states - solid, liquid and gas

Property	**Solid**	**Liquid**	**Gas**
Mass	Definite	Definite	Definite
Shape	Definite	Indefinite	Indefinite
Volume	Definite	Indefinite	Indefinite
Compressibility	Almost incompressible	Almost incompressible	Compressible
Arrangement of Particles	Compact	Near each other	Far from each other
Motion of the particles	Very little motion	Moderate motion	Fast moving

Physical properties
Physical properties of matter are those properties that can usually be observed with our senses. Some common examples are colour, odour, solubility in water, density, melting point, taste, boiling point and hardness.

Physical changes
In general physical changes alter the physical properties of matter, but the composition remains constant. Some examples are breaking glass, cutting wood, melting ice and magnetizing a piece of metal. In some cases, the process that caused the change can be easily reversed and the substance regains its original form.

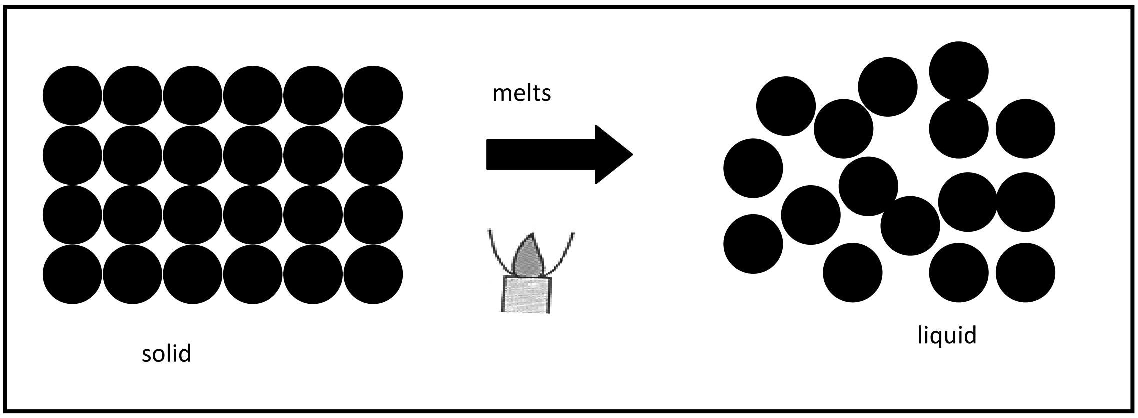
Chemical properties
Chemical properties are those properties that are observed in regard to whether or not a substance reacts with other substances. For example, iron rusts in moist air, nitrogen does not burn, gold does not rust, sodium reacts with water, and water can be decomposed by an electric current.

Chemical changes
Chemical changes are changes in the composition and structure of a substance. They are always accompanied by energy changes.

CHEMICAL CHANGE	PHYSICAL CHANGE
At least one new substance is formed.	No new substance is formed.
Difficult to reverse (hard to un-boil an egg).	Easily reversed (melt an ice and freeze again).
Generally a large input or output of energy (Burning of natural gasses).	Relatively small energy changes involved (evaporate alcohol, dissolve sugar in water).

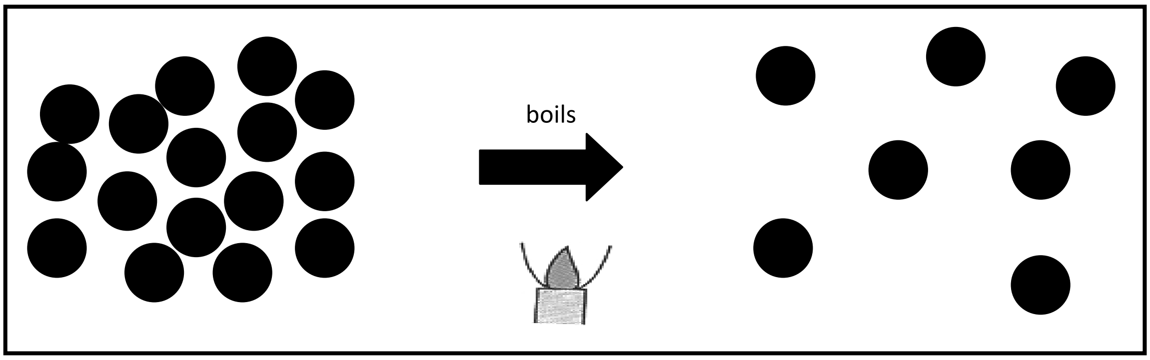
Change of states of matter

1. **Melting is the change from solid to liquid**
When solid is heated, its particles get more energy and vibrate more. This makes the solid expand. At the melting point, the particles vibrate so much that they break away from their positions. The solid turns liquid.



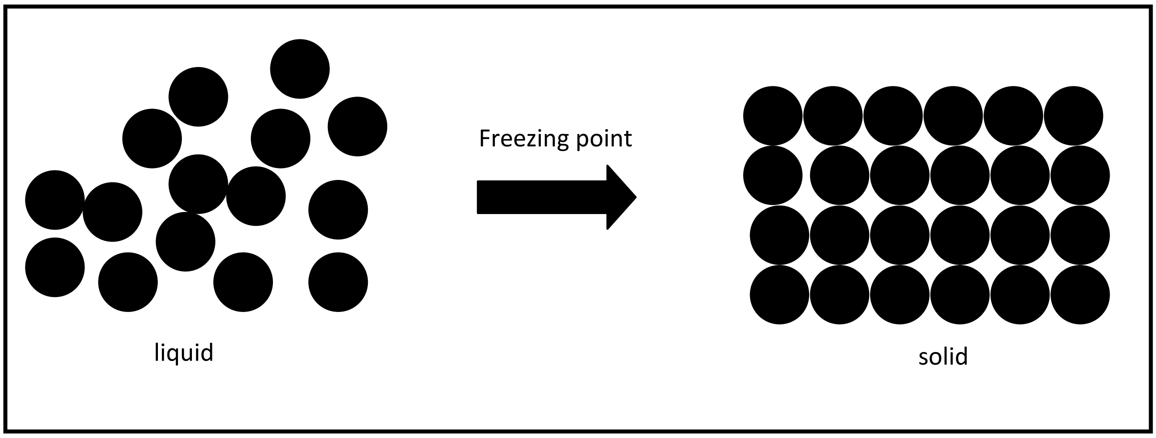
2. Boiling is the change from liquid to a gas or vapour

When liquid is heated, its particles get more energy and move faster. They bump into each other more often, and bounce further apart. This makes liquid expand. At the boiling point, the particles get enough energy to overcome the forces between them. They break away to form gas.



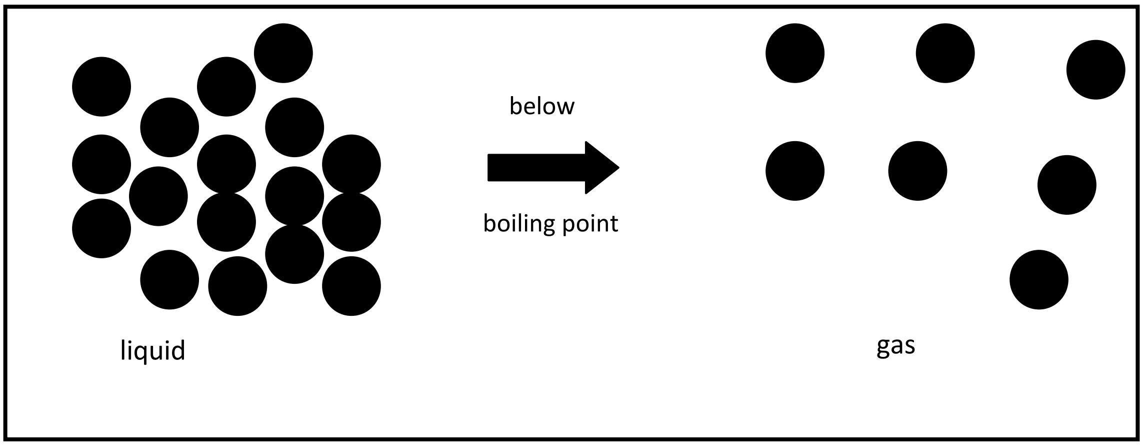
3. Freezing is the change from liquid to solid

If a liquid is cooled its particles lose kinetic energy. This makes them move more slowly. If the liquid is cooled down enough each particles stops moving and vibrates about a fixed point. When this happens the liquid frozen and turns into a solid.

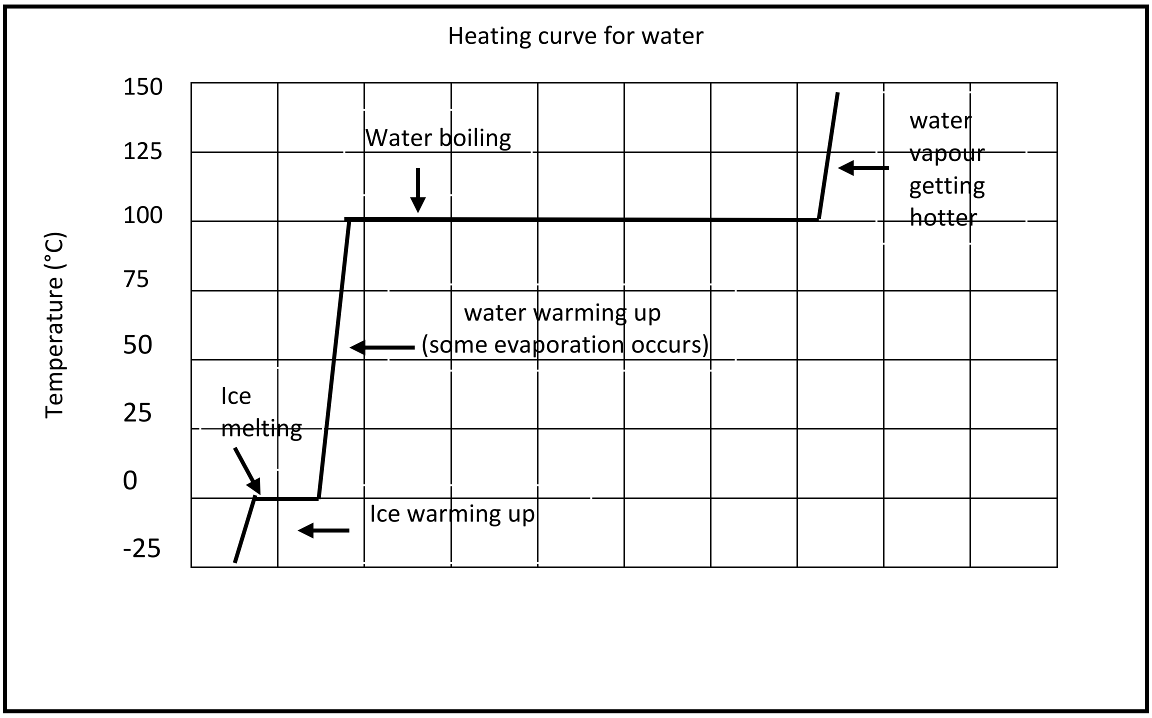


4. Evaporation is the change of a liquid into gas without boiling

The particle in a liquid has different amounts of energy. Some have less kinetic energy than others and move more slowly than them. Others have more kinetic energy and move quickly. At the surface of the liquid the particles with the largest amount of kinetic energy move so fast that they can pull away from the force of attraction that exists between them and other liquid particles and escape into the air as vapour. If a liquid is warmed the energy of all particles is increased and more particles acquire enough energy to escape from the surface. This increases the rate of evaporation. This is the opposite of condensation.



The graph below shows the heating curve.

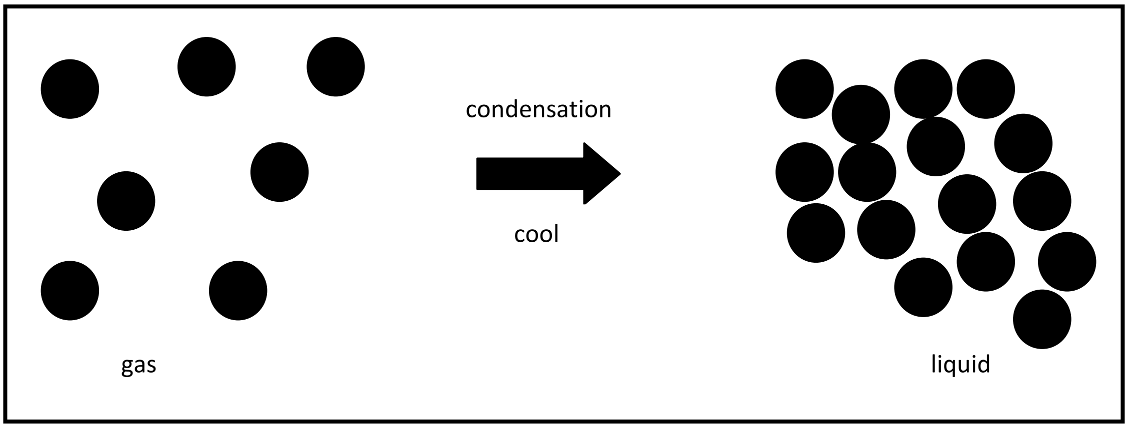


Melting curve for water.

The graph above shows the ice is melting. Once melting starts, the temperature stays at 0°C until all ice has melted. When the water starts to boil, the temperature stays at 100°C until all the water has turned to steam. So melting and boiling points are clear and sharp.

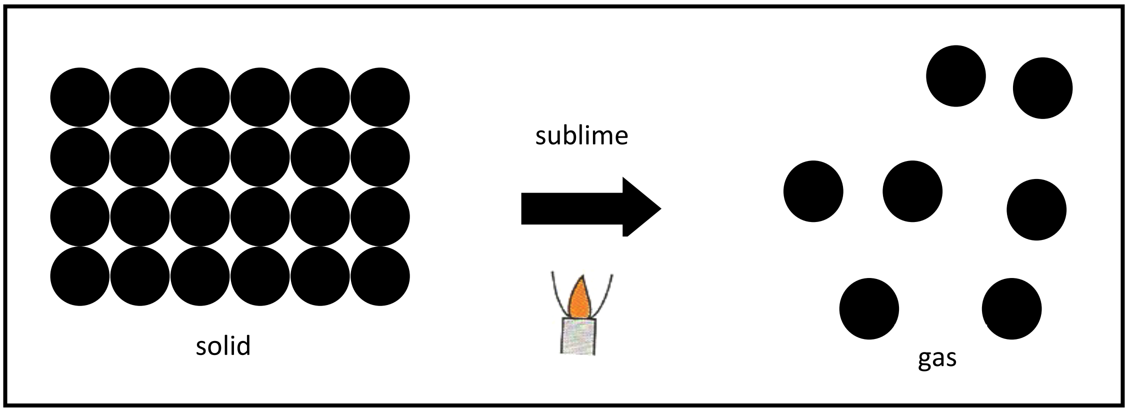
5. **Condensation is the change from gas to a liquid**

When a gas is cooled sufficiently, it changes into liquid. This is the reverse of boiling. Heat energy is given out during condensation. As the temperature drops, the gas particles lose energy and move more slowly. Eventually, the movement of the particles becomes slow enough for the gas to change into a liquid.



6. **Sublimation is the change from solid directly to gas without going through the liquid state.**

It occurs because particles at the surface of the solid have enough energy to break away from the solid and escape as a gas. Iodine and ammonium chloride are two other examples of solids that sublime.



Now, check what you have just learnt by trying out the learning activity below!

Learning Activity 1 **20 minutes**

Answer the following questions:

1. Define the following terms:

   i. Kinetic theory

   ____

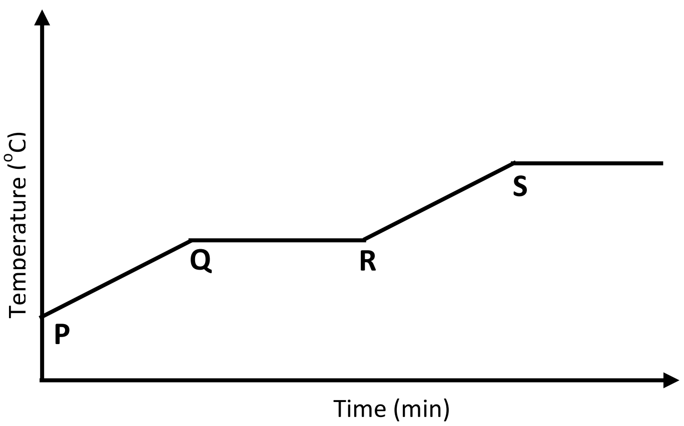
   ii. Physical change

   ____

   iii. Chemical change

   ____

2. The graph below shows the temperature of a liquid when heated from room temperature.

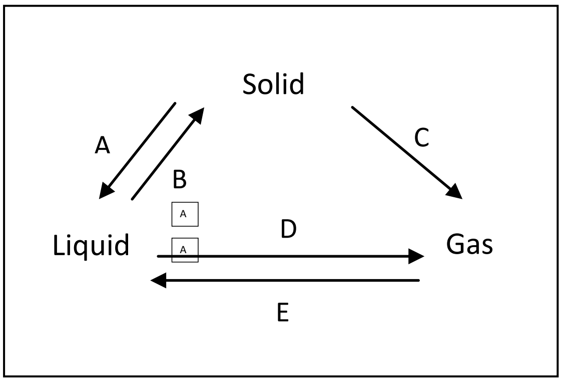


Which part of the graph shows that liquid is boiling?

a) PQ b) QR

c) RS d) ST

3. The diagram below represents the physical changes between the three states of matter.



A. ___________

B. ___________

C. ___________

D. ___________

E. ___________

Thank you for completing your learning activity 1. Check your work. Answers are at the end of this module.

Diffusion

Diffusion is the rate at which gas travels across a room or particles mix by colliding with each other and bouncing off in all directions.

Gases do not all diffuse at the same rate, every time. It depends on these two factors:

1. The mass of the particles
   The lower the mass of its particles, the faster a gas will diffuse.
2. The temperature
   The higher the temperature, the faster a gas will diffuse.

The molar mass of an element is the mass of one mole of atoms of the elements.

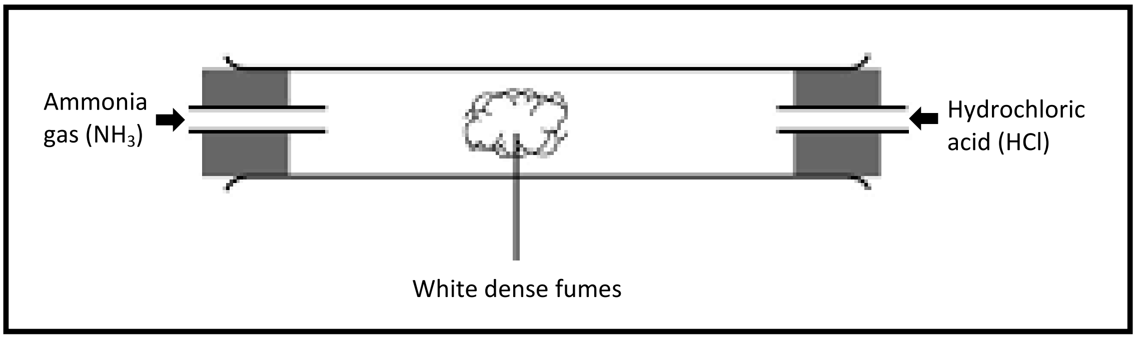
Look at the table below you will notice the relationship between the value of atomic mass (A_r) and the molar mass of a substance. The molar mass is equal to the relative atomic mass of the element in grams.

Element	Atomic mass (A_r)	Molar mass
aluminium	27	27g
carbon	12	12g
neon	20	20g
oxygen	16	16g

Molar mass of some elements.

Examples:
The particle of hydrogen chloride gas is twice as heavy as those in ammonia gas. So which gas do you think will diffuse faster? Let us see:

- Cotton wool soaked in ammonia solution is put into one end long tube. It gives off ammonia gas.
- At the same time, cotton wool soaked in hydrochloric acid is put into other end of the tube. It gives off hydrogen chloride gas.



The gases diffuse along the tube. White smoke forms where they meet.

The relative rates at which two gasses diffuse is explained by **Graham's law**, shown here:

$$\frac{R_A}{R_B} = \sqrt{\frac{M_B}{M_A}}$$

Where:

R_A = rate of effusion/diffusion of gas A
R_B = rate of effusion/diffusion of gas B
M_A = molar mass of gas
M_B = molar mass of gas B

Now, check what you have just learnt by trying out the learning activity below!

Learning Activity 2 **20 minutes**

Answer the following questions:

1. Define diffusion.
____

2. List the factors that affect diffusion.
____
____

3. Which gas effuses faster, hydrogen or chlorine? How fast? Explain your answer.
____
____

Thank you for completing your learning activity 2. Check your work. Answers are at the end of this module.

Gas laws

Application of Graham's Law of Diffusion/Effusion of Gases:

The rate of diffusion of a gas is inversely proportional to the square root of its molecular mass.

Example:

At 25^0C, the average speed of oxygen molecule is $482\frac{m}{s}$.

Find the average speed of a hydrogen molecule at the same temperature. Which gas will diffuse faster using the relationship of relative rates of diffusion of gases to their molar masses?

We know that H_2 has $2\frac{g}{mole}$ and O_2 has $32\frac{g}{mole}$. Since H_2 has a lighter molar mass, does it mean that H_2 will diffuse faster?

$$\frac{R_{H_2}}{R_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}}$$

$$\frac{R_{H_2}}{R_{O_2}} = \sqrt{\frac{32\,g/mole}{2.016\,g/mole}} = 3.984$$

$$\frac{R_{H_2}}{R_{O_2}} = 4\,(H_2 \text{ diffuses 4 times as fast as } O_2)$$

Solving for the rate of diffusion of H_2 if rate of diffusion of O_2 is 482m/s;

$$R_{H_2} = 3.984 \times 482 m/s = 1.92 \times 10^3 m/s$$

Boyle's Law

Robert Boyle, a seventeenth-century English scientist, found that the volume of a gas decreases when the pressure on it increases, and vice versa, when the temperature is held constant.

> **Boyle's Law states that:**
> **If the temperature remains constant, the volume of a gas varies inversely as the pressure changes.**

Then $\mathbf{P_1V_1 = P_2V_2}$ at a constant temperature.

Where:
P_1 = initial pressure
P_2 = new pressure
V_1 = initial volume
V_2 = new volume

Example:
Given the volume of a gas at 200mL at 1.05atmospheric(atm) pressure, calculate the volume of the same gas at 1.01atm. The temperature is held constant.

Solution:
P_1V_1 = P_2V_2 at a constant temperature
P_1 = 1.05atm
V_1 = 200mL
P_2 = 1.01atm
V_2 = ?

To look for the V_2, change the subject of the formula.

$$\frac{P_1}{P_2} x \frac{V_l}{V_2}$$

$$V^2 = \frac{P_1V_1}{P_2}$$

$$V^2 = \frac{1.5atm \times 200ml}{1.01atm}$$

Therefore: V_2 = 208 ml

Charles' Law

Jacques Charles's, a French chemist of the early nineteenth century discovered that volume of a gas changes with temperature if the pressure is remained constant.

$$\frac{V_1}{T_2} = \frac{V_2}{T_2}$$

Where:

V_1 = initial volume
V_2 = new volume
T_1 = initial temperature
T_2 = new temperature

Zero corresponds to $^-273^0$ in Celsius scale. The scale is called the Kelvin or the absolute zero. A degree Kelvin has the same magnitude as degree Celsius. However, there are no negative readings on the Kelvin scale. A comparison of Celsius and the Kelvin scale is shown below.

To change
Kelvin to degree Celsius or degree Celsius to Kelvin:
K= °C + 273 or °C = K - 273

	Kelvin scale	Degree Celsius scale
Absolute zero	0^0C	$^-273^0C$
Freezing point of water	273K	0^0C
Boiling point	373K	100^0C

Example:
The volume of a gas at 20°C is 500mL. Find its volume at standard temperature if the pressure of the gas is held constant.

Given:
V_1 = 500 ml
V_2 = ?
T_1 = 20°C + 273 = 293K
T_2 = 0°C + 273 K = 273K

Looking for the volume:

$$\frac{V_1}{T_1} x \frac{V_2}{T_2}$$

$$V_2 = \frac{T_2}{T_1} x V_1$$

$$V_2 = \frac{273K \times 500ml}{293K}$$

V_2 = 465. 8 mL

Charles' Law states that:
If the pressure remains constant, the volume of a gas varies directly as the absolute temperature in Kelvin.

Combined Gas Law
The volume of a gas is greatly affected by changes in pressure and temperature; hence, temperature and pressure at the time of measurement must always be specified. In this lesson, you will learn more about the Combined Gas Law, which connects the variables pressure, temperature and volume of gas. Also, you will learn about Gay-Lussac's Law, which describes how changing the temperature of a gas that is kept at constant volume affects the pressure of the gas.

Because pressure and temperature will change from day to day and from location to location, it is common to use more than one of the gas laws to determine the resulting volume of the gas. If we combine the relationships expressing Boyle's Law, V α 1 / P, and Charles' Law, V α T / P, we obtain the relationship: V α T / P.

The formula for the Combined Gas Law can be expressed as: $P_1V_1T_2 = P_2V_2T_1$, where the subscript of 1 refers to the original conditions while 2 refers to the new conditions.

Boyle's law and Charles' law can be combined to obtain the following equation:

$$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

Example:
A cylinder of compressed oxygen gas has a volume of 30L and 100atm pressure at 27°C. The cylinder is cooled until pressure is 5atm. What is the new temperature of the gas in the cylinder?

Solution:
First we convert degree Celsius to Kelvin: 27°C + 273 = 300K.

We know that:

T_1 = 300K
P_1 = 100atm
P_2 = 5atm
$\left.\begin{matrix}V_1\\V_2\end{matrix}\right\}$ = 30L
T_2 = ?

We can now re-arrange the combined gas law to obtain T_2.

$$T_2 = \frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

Therefore:

$$T_2 = \frac{P_2 \text{ x } V_2 \text{ x } T_1}{P_2 \text{ x } V_1}$$

We can now substitute the known quantities into the expression for the combined gas law.

$$T_2 = \frac{5\text{atm} \text{ x } 300\text{K}}{100\text{atm}}$$

T_2 = 15K

We can now convert K back to degrees Celsius.

K = °C + 273
°C = K - 273
= 15 - 273
= -258°C

The Ideal Gas Law

Certain hair spray products are packaged in aerosol cans. Serious accidents could occur if you throw the empty cans into the fire because the pressurized gas could explode. These cans usually have a printed warning such as “Do not puncture or incinerate” but users seldom read what is on the label.

A gas that behaves exactly as described by the gas laws is called an **ideal gas**. Many gases, especially at high pressure or low temperatures do not behave quite ideally; hence, they are called **real gases**. This lesson applies the gas laws covered in Boyle’s and Charles’ law to derive the Ideal Gas Law and analyze how it governs ideal gas behavior.

If we combine the relationships expressing Boyle’s Law,

$$V \alpha 1 / P,$$

Charles’ Law,

$$V \alpha T$$

and the proportionality

$$V \alpha n$$

where (n stands for the number of moles of gas), we obtain the relationship:

$$V \alpha nT / P$$

By introducing a constant, this relationship can be expressed as the equation

$$V = RnT/P,$$

and further simplified to:

$$PV = nRT$$

we will obtain the ideal constant gas law or **R** by:

$$\frac{P_1 X V_1}{T_1 X n_1} = \frac{1 atm x 22.4 L}{273 K x 1 mol}$$

$$= \frac{0.0821 L x atm}{K x mol}$$

Example:

A rigid steel cylinder with a volume of 20L is filled with nitrogen gas to a final pressure of 200atm at 27°C. How many moles of nitrogen gas does the cylinder contain?

Solution:

First we convert degrees Celsius to degrees Kelvin scale:

27°C + 273 = 300K

Given:

P = 200atm

V = 20L

T= 300K

Since we want to find the moles of nitrogen (N_2) gas, we may rearrange the ideal gas law to obtain the number of moles. (n*)*

$$n = \frac{PxV}{RxT}$$

We can now substitute the known values into the equation.

$$n = \frac{200\cancel{atm}x20\cancel{L}}{0.0821\cancel{L}xa\cancel{tm}x300K}$$

$$\mathbf{n = 162mol}$$

Now, check what you have just learnt by trying out the learning activity below!

Learning Activity 3 **40 minutes**

Using the law of gases, calculate the following problem:

1. A balloon is filled with 30L of helium gas at 1atm. What is the volume when balloon rises to an altitude where the pressure is only 0.25atm?

2. A balloon, inflated in an air-conditioned room at 27°C, has a volume of 4.0L. It is heated to a temperature of 57°C. What is the new volume of the balloon if the pressure remains constant?

3. A cylinder of compressed oxygen gas has a volume of 30L and 100atm pressure at 27°C. The cylinder is cooled until the pressure is 5.0atm. What is the new temperature of the gas in the cylinder?

4. A container of gas has a volume of 10L and is at a pressure of 2.0atm at 30°C. What size of the container would be needed for the same amount of gas at a pressure of 4.0atm at 20°C?

Thank you for completing your learning activity 3. Check your work. Answers are at the end of this module.

11.1.2 Pure Substances and Mixtures

Substances are divided into three: Elements, Compounds and Mixture

Elements cannot be broken down into simpler substances which are made up of same kind of atoms or molecules and can be divided into metals or non-metals.

Example of metals and non-metals

Metals	Formula	Non metals	Formula
Aluminiun	Al	Carbon	C
Copper	Cu	Nitrogen	N
Magnesium	Mg	Chlorine	Cl
Zinc	Zn	Oxygen	O

Example of compounds:

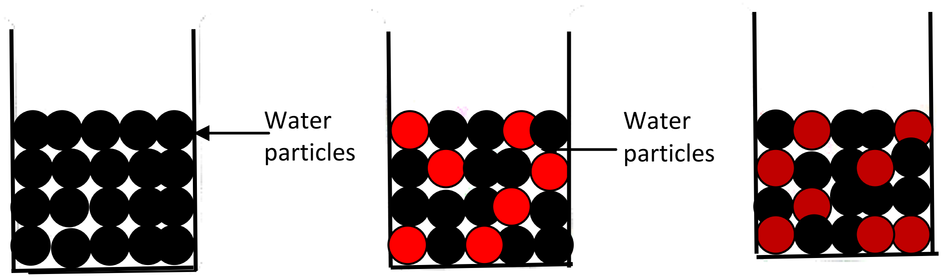
Compound name	Formula
Aluminium chloride	$AlCl_3$
Copper oxide	CuO
Magnesium fluoride	MgF_2
Zinc Iodide	ZnI_2

Compounds are made up of two or more elements chemically joined together.

Pure and Impure Substances

What is a pure substance?
A pure substance has no particles of any other substance mixed with it. In real life, very few substances are 100% pure. For example tap water contains small amount of many different particles.

Look at the example below.



This is water. It has only water particles in it, and nothing else. So it is 100% pure

This is water. Has particles of other substance mixed with it. So it is not pure.

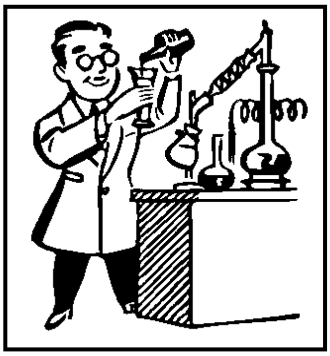
This is water has particles of harmful substance in it. So it is not pure and could make you ill.

Water particles

How can you tell if a substance is pure?
Chemists use complex methods to check purity. There is one simple method you can use to check the purity of a substance, using their melting and boiling points.

- A pure substance has definite, sharp, melting and boiling points.
- When substance contains an impurity. Its melting point falls and its boiling points rise.

Mixture



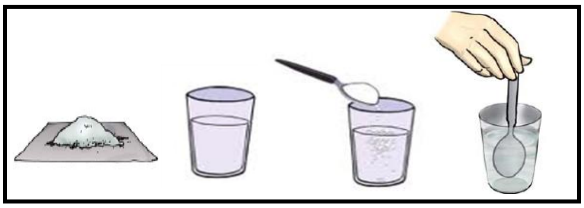
Mixture contains more than one substance. The substances are just mixed together, and not chemically combined.

For example:

- Air is a mixture of nitrogen, oxygen, and small amounts of amounts of other gases.
- Shampoo is a mixture of several chemicals and water.

Two types of Mixture

1. **Homogeneous** is mixture only one phase that can be observed in the mixture.

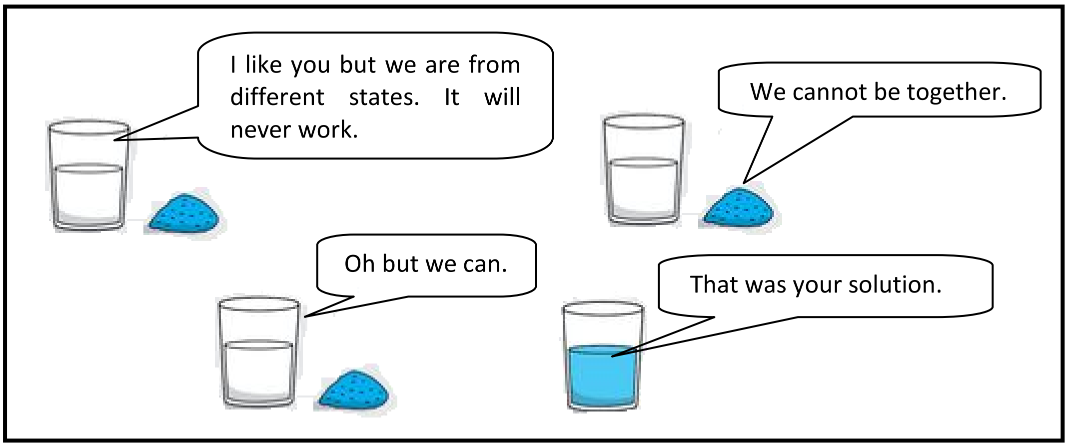


Mixture of sugar and water.

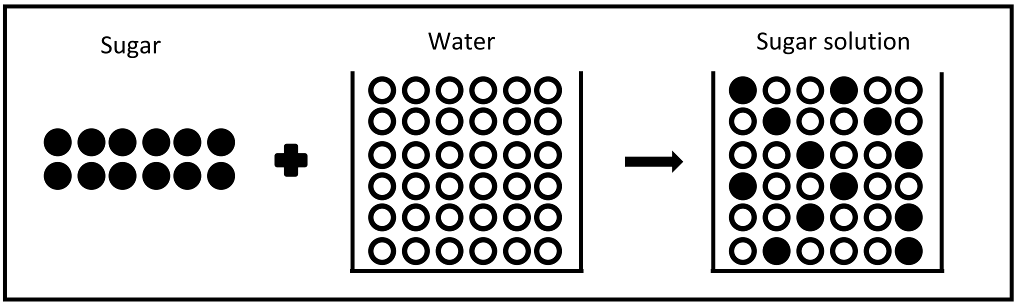
2. **Heterogeneou**s is a mixture of more than one phase that can be observed in the system.

Muddy water

Solutions



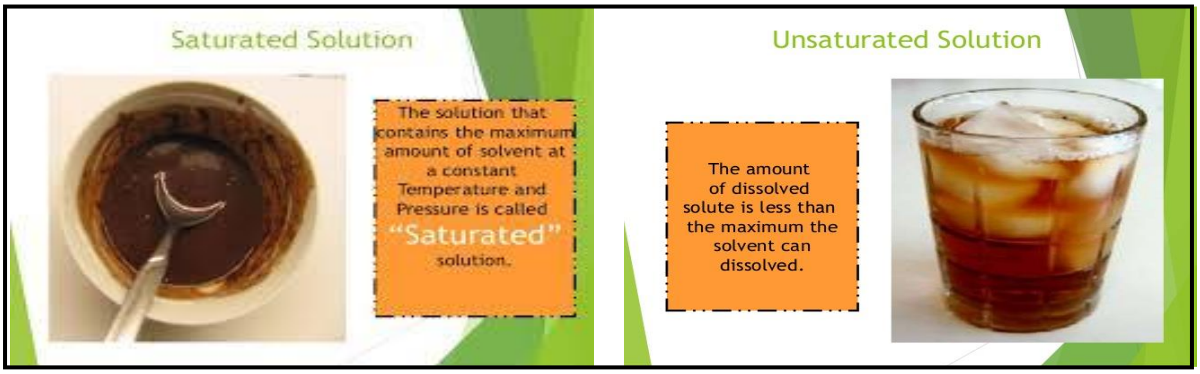
When you mix sugar with water, the sugar seems to disappear. It is because its particles spread all through the water particles, like this as shown in the diagram below.



The sugar has dissolved in the water, giving a mixture called **solution.**

- Sugar is the solute and water is the solvent.
- Solute plus solvent equals solution.
- You cannot get sugar out again by filtering.
- Sugar is more soluble in hot water than cold water.
- A soluble solid usually gets more soluble as the temperature rises.
- A solution is called **saturated** when it can dissolve no more solute at that given temperature.
- **Solute** is the substance that dissolves in the solution.
- **Solvent** is the substance that has greater amount and dissolve the solute.

Saturated solution	is a solution that cannot dissolve anymore solute at a given temperature.
Unsaturated solution	is a solution that contains less solute dissolved at that temperature than a saturated solution.



Now, check what you have just learnt by trying out the learning activity below!

Learning Activity 4 **20 minutes**

Answer the following questions:

1. Define the following terms:
   i. Solute
   ____
   ii. Solvent
   ____
   iii. Homogeneous
   ____
   iv. Heterogeneous
   ____

2. Classify the following substances below as elements, compound or mixtures.

   i. air ___________
   ii. neon ___________
   iii. gold ___________
   iv. water ___________
   v. honey ___________
   vi. magnesium chloride ___________

Thank you for completing your learning activity 4. Check your work. Answers are at the end of this module.

11.1.3 Separating Mixture

As you have learnt in the previous topic, most of the things around us are not pure. They are mixed with other substances. What method is used to separate different substances? It depends on whether the solid dissolved, and how its solubility changes with temperature.

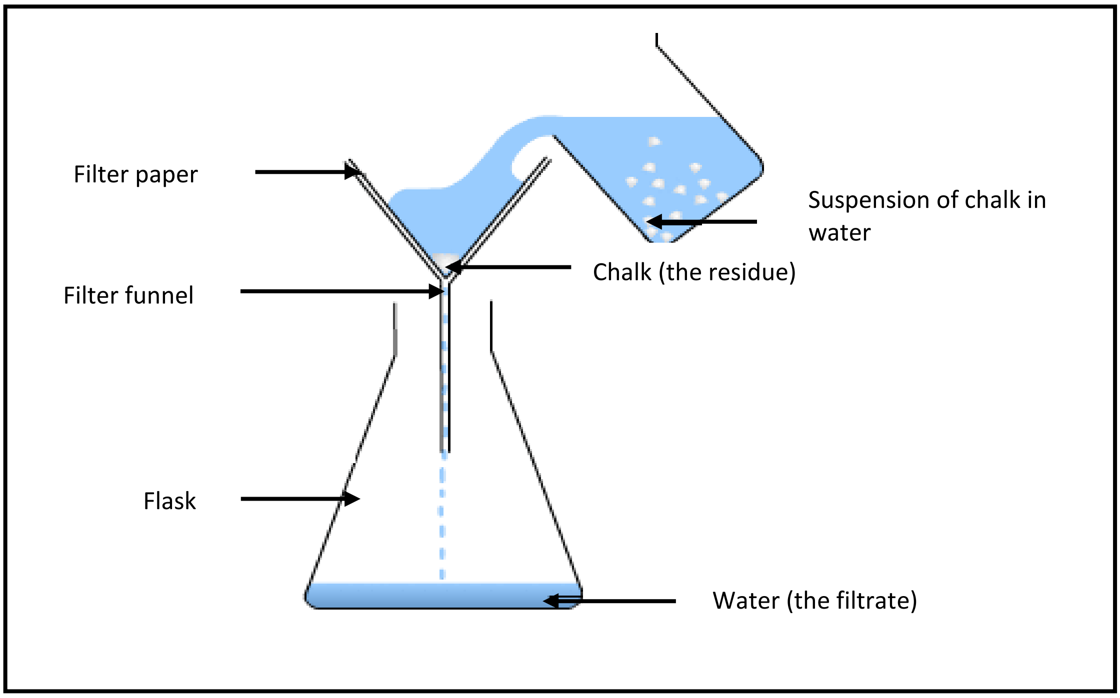
The difference between a mixture and a compound is represented below.

MIXTURE	COMPOUND
The amount of each substance can vary.	The amount of each element is always fixed.
Has the properties of each substance in the Mixture.	Have completely different properties from the elements in the compound.
The substances is separated from each other.	It is easy to separate the elements from the compound.

Separation of a Solid – Liquid Mixture

Let us look at some different ways to separate mixture.

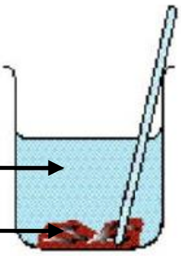
1. **By filtering**
   For example, chalk is insoluble in water. So it is easy to separate by filtering. The chalk is trapped in the filter paper, while the water passes through. The trapped solid particles in the filter is called the **residue**. The water is the filtrate.



2. By crystallization

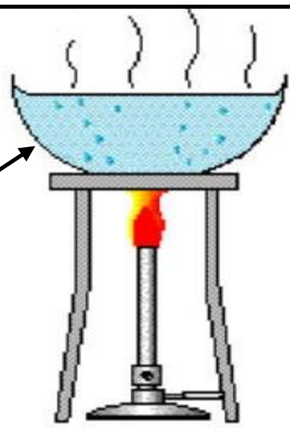
You can obtain many solids from their solutions by letting crystals form. The process is called **crystallization.** It works because soluble solids tend to be less soluble at lower temperatures.
For example:

Step 1



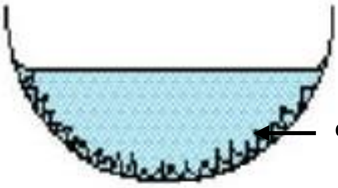
The impure solid is dissolved in a solvent.

Step 2



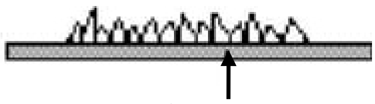
The solution is heated to evaporated most of the solvent.

Step 3



The hot solution is allowed to cool. The solid appears as pure crystals.

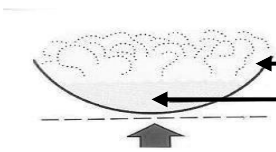
Step 4



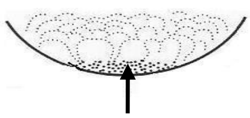
The cold solution is poured off to obtain the crystals. The crystals may be dried pressing them between sheets of filter paper.

3. By evaporating all the solvent

For some substances, the solubility changes very little as the temperature falls. So crystallization does not work for these. For example, salt.



To obtain salt from an aqueous solution, you need to keep heating the solution, to evaporate the water.



The water evaporates leaving the salt behind when there is only a little water left. The salt will start to appear. Heat carefully until it is dry.

Evaporation of salt

4. Sublimation

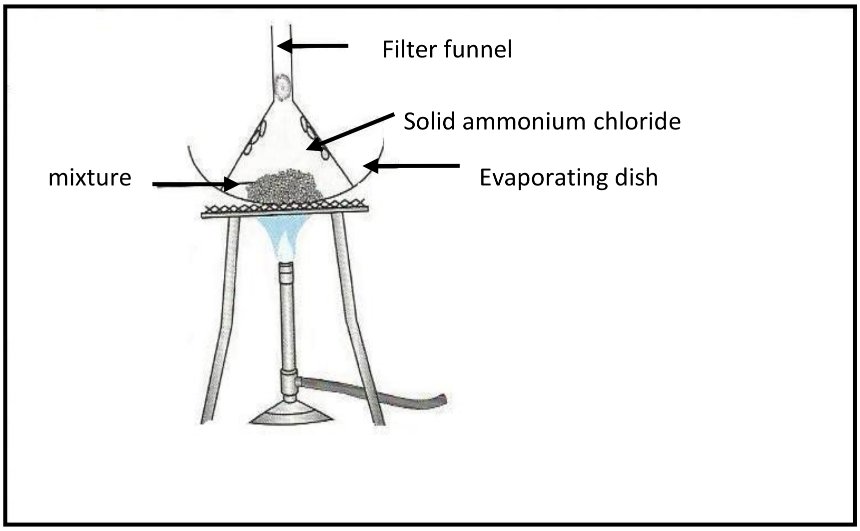
It is the process of solid changing directly into gas without going through the liquid state. Ammonium salts, iodine and naphthalene are examples of solids that sublime. Sublimation can be used to separate mixtures containing substances that will sublime and those that will not sublime.

To separate a mixture by sublimation:

(i) Place the solid mixture of sodium chloride and ammonium in an evaporating dish. Cover it with a filter funnel as shown in the diagram below.

2. Heat the mixture gently. The ammonium chloride will sublime and condense on the cooler parts of the funnel as solid crystal. The sodium chloride crystals will remain inside the evaporating dish.

Example diagram below:



Separating a mixture by sublimation.

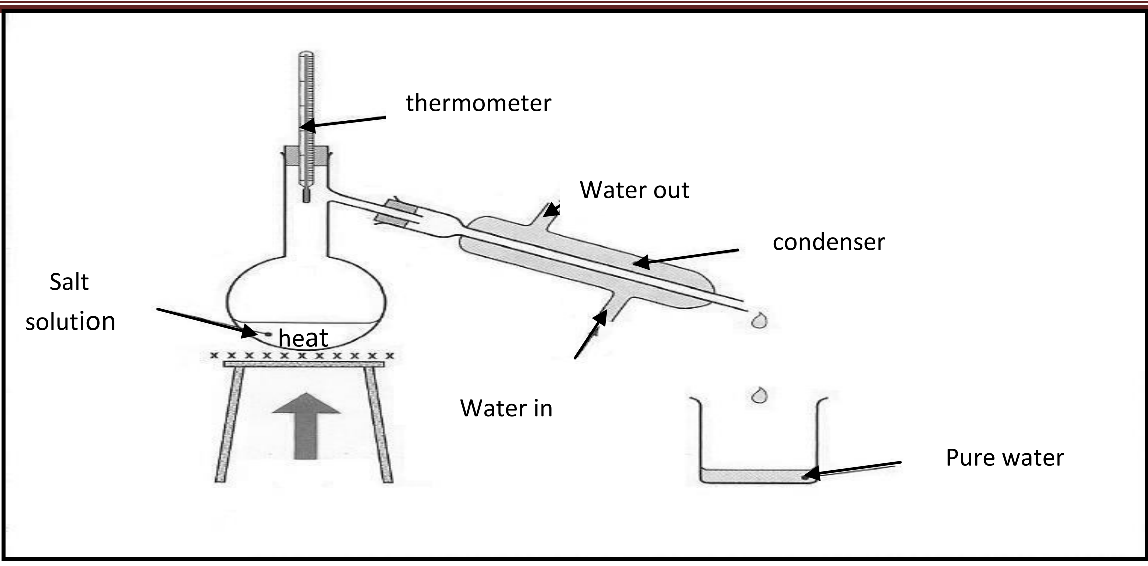
5. Distillation

In the last process of separation, you got salt from the mixture of salt and water. What happened to the water? If we want to collect it, we can distil the mixture. The water is evaporated. The steam given off is condensed and collected as pure water.

There are two types of distillation:

(i) Simple distillation - this is to collect the pure liquid from a solution.

(ii) Fractional distillation - this is to separate two or more liquids that are mixed or separating two immiscible liquids.



Simple distillation of salt solute.

Ways on how to separate two or more liquids with different boiling points.

1. Ethanol vapour and water vapour rise up the column as the solution is heated.

2. Water vapour condenses in the fractionating column and drops back into the flask.

3. Ethanol, which has a lower boiling point than water, reaches the upper part of the column and is distilled over.

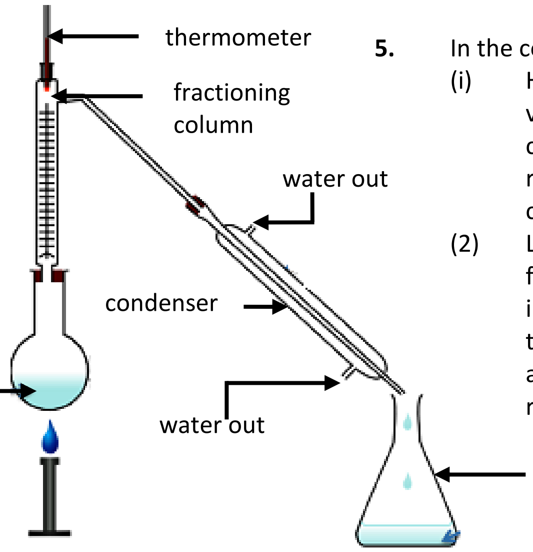
4. At this stage, the thermometer shows a constant temperature of 78°C, which is the boiling point of ethanol.

5. In the condenser:

(i) Hot ethanol vapour condenses as running water cools it.

(2) Liquid ethanol flows down the inner tube of the condenser and into the receiver.

6. Ethanol is collected as the distillate in the receiver.



7. When all the ethanol has distilled over, the temperature rises rapidly to 100°C, which is the boiling point of water. At this temperature, water distils over and can be collected separately.

5. Chromatography

One of the most sensitive techniques that can be used for identifying and separating components or mixture is **chromatography.** We can use chromatography to:

- Separate small amounts of dissolved solids.
- Identify unknown substances.
- Purify a substance, by separating it from its impurities.

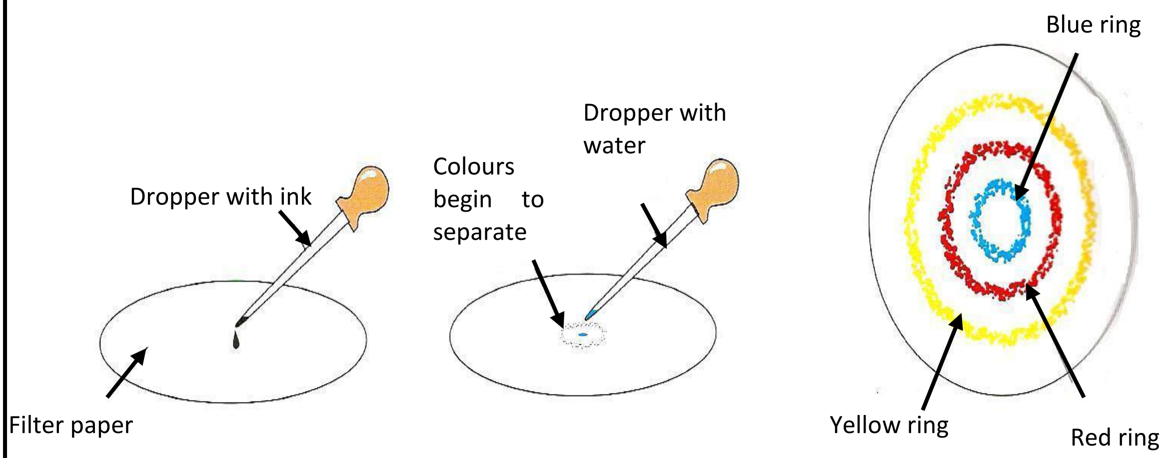
The simplest version of these techniques is **paper chromatography.**

How paper chromatography works

Paper chromatography depends on how the substances in a mixture interact with chromatography **paper** and the **solvent.**

Example:

You could separate how many different dyes there are in black ink.



1. Place a drop of black in the centre of some filter paper. Let it dry. Then add three or four drops in the same spot in the way.

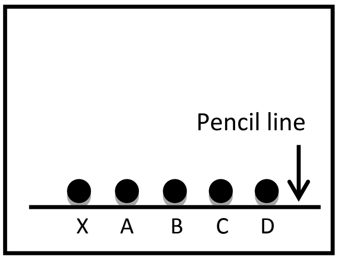
2. Now drip water onto the same spot one drop at a time. The ink slowly spreads out and separates into rings.

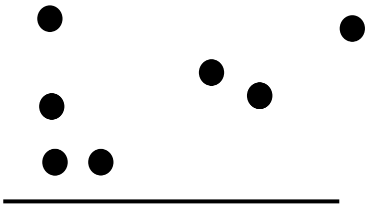
3. Suppose there are three rings: yellow, red and blue. This show that the ink contains three dyes coloured yellow, red and blue.

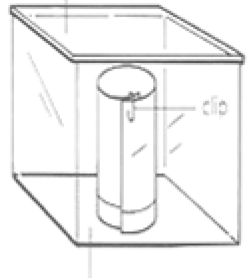
The dyes in the ink have different solubilities in water. They travel across the paper at different rates.

- The most soluble one travels fastest. That is the reason they separate into rings.
- The filter paper with the coloured rings is called a **chromatogram.**
- Chroma means colour.

- Paper chromatography is also used to **identify** substances. For example, mixture X is thought to contain substances **A, B, C,** and **D,** which are all soluble in propanone. You could check the mixture like this:







1. Prepare concentrated solutions of **X, A, B, C** and **D** in propanone. Place a spot of each along a line on chromatography paper. Label them.

2. Stand the paper in a little propanone in a covered glass tank. The solvent rises up to the paper.

3. When **X** has separated into three spots, two of them are at the same height as **A** and **B,** so **X** must contain substances **A** and **B.** Does it also contain **C** and **D**?

Now, check what you have just learnt by trying out the learning activity below!

Learning Activity 5

40 minutes

Answer the following questions:

1. Define the following:
   i. Mixture

   ____

   ii. Pure substance

   ____

   iii. Simple distillation

   ____

   iv. Paper chromatography

   ____

2. Explain how fractional distillation works.

   ____

   ____

3. How would you obtain pure water from sea water?

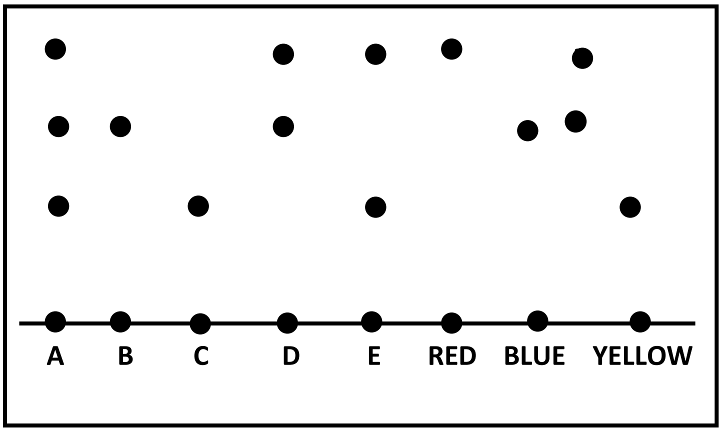
____

4. Choose from the list the most suitable method for each of the following separations:

chromatography	dissolving
distillation	evaporation
filtration	fractional distillation

i. To separate the mixture of liquids in crude oil. ___________
ii. To obtain some solid salt from a solution of salt in water. ___________
iii. To separate a mixture of different coloured ink. ___________
iv. To obtain a sample of pure water from the tap water. ___________

5. In a chromatography experiment, eight coloured substances were spotted onto a piece of filter paper. Three were the basic colours red, blue, and yellow. The others were unknown substances, labelled **A-E.** This shows the resulting chromatogram:



a) Which of the substances **A - E** contains one basic colour? ___________
b) Which contains all three basic colours? ___________
c) The solvent was propanone. Which of the three basic colours is the most soluble in propanone? ___________

Thank you for completing your learning activity 5. Check your work. Answers are at the end of this module.

11.1.4 Solubility

Solubility is the amount of solute that will dissolve in 100 grams of a solvent, at a given temperature.

Solubility of Solids and Gases
The solubility of a substance is the quantity of a substance that will dissolve in a certain volume of a solvent in a given temperature.
For example:

- solubility of solids usually increases with temperature.
- solubility of decreases with the increasing temperature.

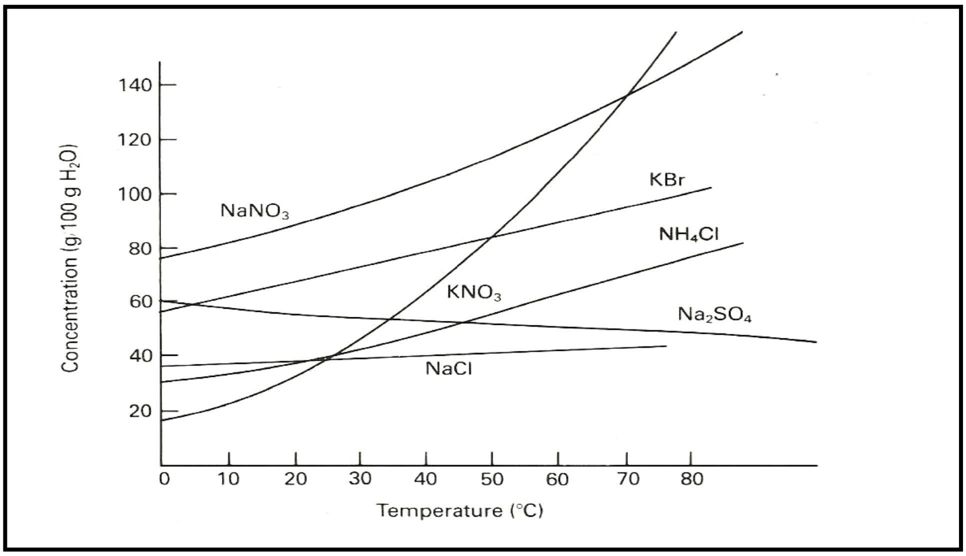
Factors affecting solubility of solids in liquids

- The solubility of a solid in a liquid depends on the nature of the solid and the liquid.
- It also depends on the temperature. Most solids dissolve more quickly at higher temperature**.**

The solubility of most substances increases as the temperature of the solvent increased.

For example:
At 25°C the solubility of sodium chloride (NaCl) in water is 36.2g per 100 g of water. When the temperature is raised to 100°C, the solubility is increased to 39.2g of NaCl per 100g of water. As shown in the diagram below. For some substances, however, the reverse occurs. The solubility of sodium sulphate (Na_2SO_4) in water drops from 50 g per 100 g at 40°C to 41g per 100g at 100°C.

The table below shows the list of common substances at various temperatures.



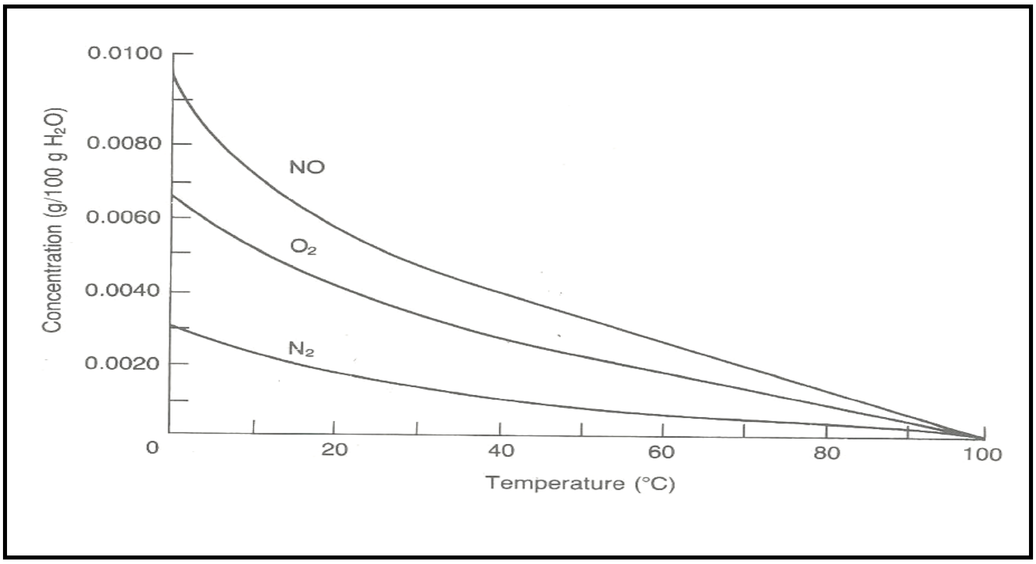
Solubility of some common substances.

Solubility of Gases

Solids solute usually gets more soluble in water as the temperature rises. The opposite is true for gases.

Look at the graph below:

Gases have different solubilities at different temperatures. Generally, as the temperature increases, the solubilities decrease. Notice that Oxygen, Nitrogen, and Nitric oxide is insoluble at 100°C.

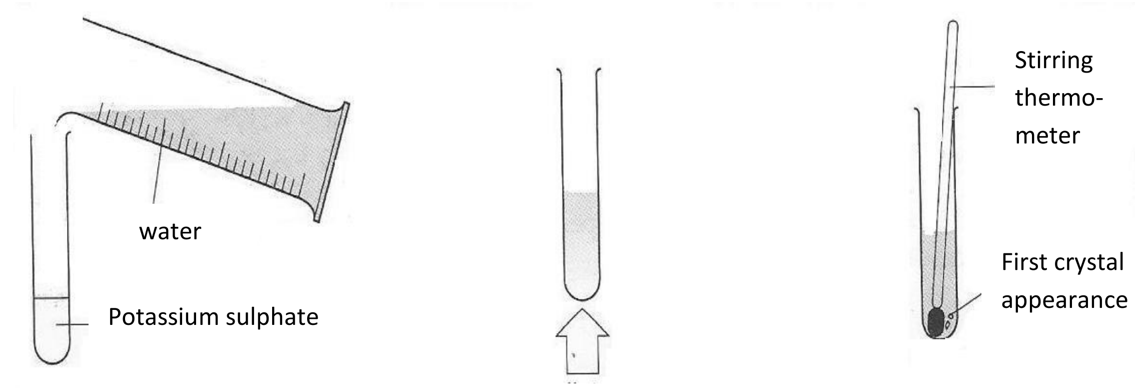


Solubility of some common gases.

Calculating Solubility

Measuring the solubility of solid in water.

Take potassium sulphate as our example. This is what to do:



Put a weighed amount (say 2g) of potassium sulphate in a test tube. Add a little water from a measuring cylinder.	Heat the test tube gently until the water is not boiling. Add more water if necessary until the solid is just dissolved.	Let the solution cool, stirring it with a thermometer. Note temperature at which the first crystal appear.

Since you know the mass of solute and the volume of water you used, you can work out the solubility as shown in the calculation below:

2 grams of potassium sulphate were dissolved in 12.5cm^3 of water. On cooling, the first crystal appeared at 60°C. What is the solubility of potassium sulphate in water at 60°C?

Solution:

In 12.5g of water 2g of potassium sulphate dissolve so

In 1g of water $\frac{2}{12.5}$ g dissolve, and

In 100g of water $\frac{2 \text{x} 100\text{g}}{12.5}$ disso = 16 grams

The solubility of potassium sulphate in water at 60°C is 16 grams.

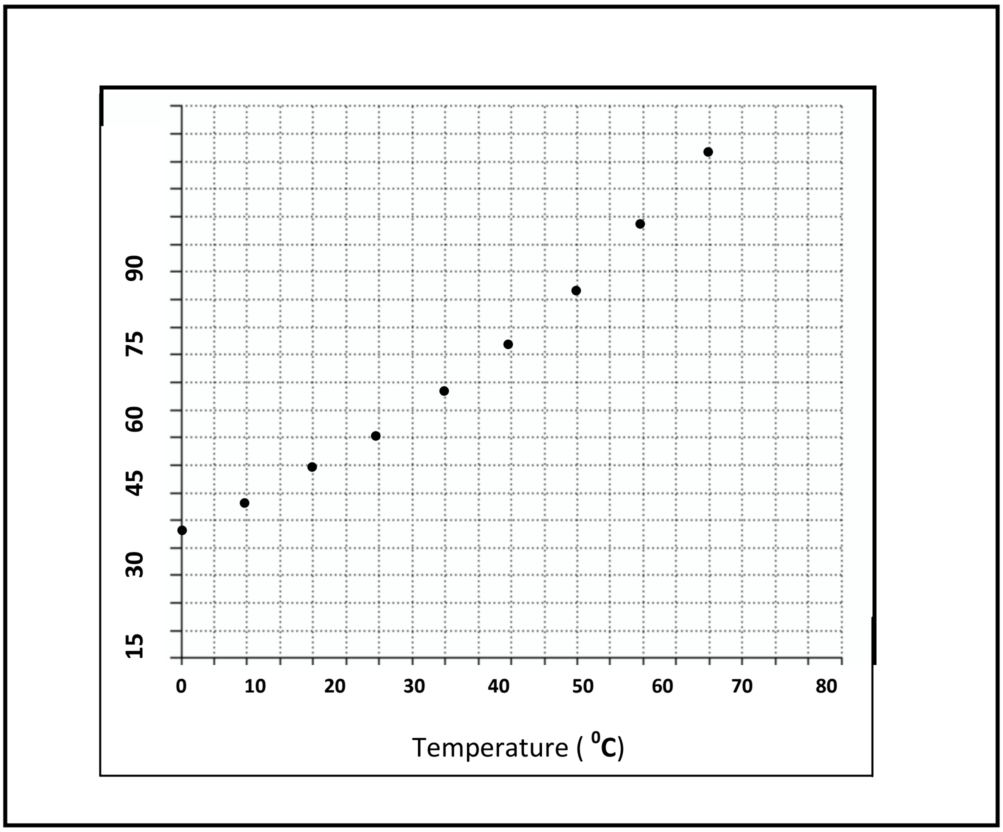
Now look at the last step again. If you add a little more water, heat the solution again to make sure all the crystal have dissolved. Let it cool, you will find the solubility at a lower temperature. You can repeat this for a range of temperatures.

Solubility Curves

Solubility of copper (II) sulphate in water

Temperature °C	0	10	20	30	40	50	60	70	80
Solubility (g)	14	17	21	24	29	34	40	47	55

The results in the table above were obtained through experiment. You can use them to plot a graph called a **solubility curve.**



We call the lines on the graph **solubility curves**. They show us how much salt dissolves at different temperatures.

Now, check what you have just learnt by trying out the learning activity below!

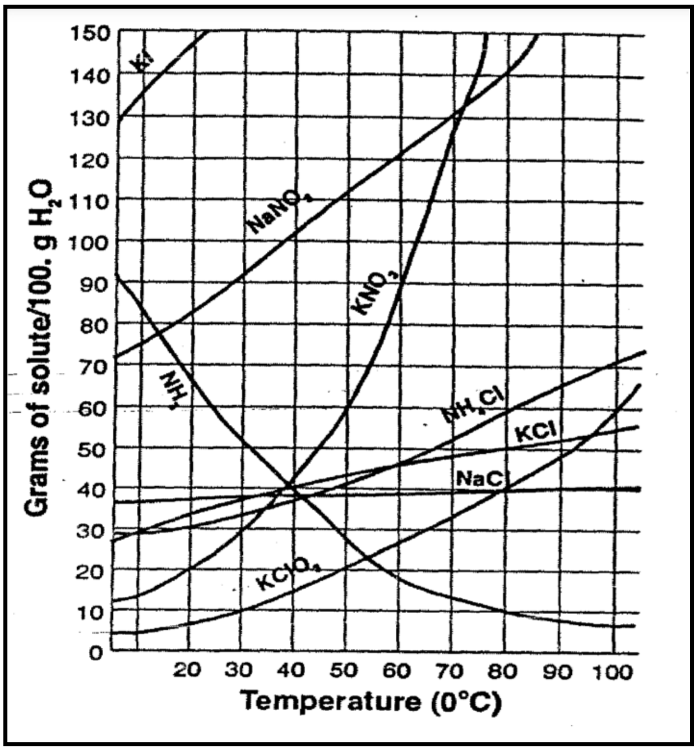
Learning Activity 6

40 minutes

Answer the following questions:

1. 4 grams of potassium sulphate were dissolved in 25cm^3 of water. On cooling, the first crystal appeared at 60°C. What is the solubility of potassium sulphate in water at 60°C?

2. Answer the following questions below based on solubility curve below.



a) Which salt is least soluble in water at 20°C?

b) How many grams of potassium chloride can be dissolved in 200 g of water at 80°C?

c) At 40°C, how much potassium nitrate can be dissolved in 3300g of water?

Thank you for completing your learning activity 6. Check your work. Answers are at the end of this module.

REVISE WELL USING THE MAIN POINTS ON THE NEXT PAGE.

SUMMARY

You will now revise this module before doing Assessment 1. Here are the main points to help you revise. Refer to the module topic if you need more information.

Kinetic theory a theory explaining the states of matter based on the concept that the particles in all forms of matter are in constant motion.

The kinetic theory states that:

- matter is made from tiny particles.
- the particles at a temperature above $^{-}273$K (Kelvin) are moving all the time. They possess the energy of motion, which is called kinetic energy.
- the rate of movement of the particles is linked to their temperature. The particles have low kinetic energy and move slowly at a low temperature, the particles with higher kinetic energy move quickly at a higher temperature.
- particles can be attracted to each other and can be of different weights and sizes.
- heavier particles move slowly than lighter particles

Matter is anything that occupies space and has mass. Solid, liquid, and gas are the three states of matter. It is classified as element, compound and mixture.

The particles in a solid are arranged in a fixed pattern or lattice. Strong forces hold them together. So they cannot leave their positions. The only movements they make are tiny vibrations to and fro.

The particles in a liquid can move about they slide past each other. They are still close together, but not in lattice. The forces that hold them together are weaker than in a solid.

The particles in a gas are far apart, and they move about quickly. There are almost no forces holding them together. They collide with each other and bounce off in all directions.

The rate of diffusion increases as the temperature of the particles rises:

$$\frac{R_A}{R_B} = \sqrt{\frac{M_B}{M_A}}$$

Where: R_A = rate of effusion/diffusion of gas A
R_B = rate of effusion/diffusion of gas B
M_A = molar mass of gas
M_B = molar mass of gas B

Boyle's law states that, if the temperature remains constant, the volume of a gas varies inversely as the pressure changes.

Then $P_1V_1 = P_2V_2$ at a constant temperature.

Charles' law states that, If the pressure remains constant, the volume of a gas varies directly as the absolute temperature in Kelvin. Scale where zero corresponds to $^{-}273°$ is in Celsius scale.

To change Kelvin to Celsius or Celsius to Kelvin:
K= °C + 273 or °C = K – 273

Since the temperature is express in Kelvin, William Thomson or Lord Kelvin devised a temperature.

V_1 = initial volume
V_2 = final volume
T_1 = initial temperature
T_2 = final temperature

Therefore, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Combine Gas Law is the volume of a gas is greatly affected by changes in pressure and temperature; hence, temperature and pressure at the time of measurement must always be specified.

Boyle's law and Charles' law can be combined to obtain the following equation:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Pure Substances and Mixtures
A mixture contains more than one substance. The substance are just mixed together and not chemically combined.

For example:
- Air is a mixture of nitrogen, oxygen, and small amounts of other gases
- Shampoo is a mixture of several chemicals and water.

Two types of Mixture
- **Homogeneous –** mixture only one phase can be observed in the mixture.
  For example: sugar or salt dissolve in water. Only one phase obtained.
- **Heterogeneous - mixture** of more than one phase can be observed in the system.
  For example: starch in water and muddy water. More than one phase will observed.

- A pure substance is made up of only one substance.
- A pure substance can exist as crystal and has fixed melting point and boiling point.
- A mixture is made up of two or more substances not chemically combined together.
- A mixture does not have a fixed melting and boiling point.

Separation of a Solid – Liquid mixture

1. **By filtering**
   For example, chalk is insoluble in water. So it is easy to separate by filtering. The chalk is trapped in the filter paper, while the water passes through. The trapped solid is called the residue. The water is the filtrate.

2. **Crystallization / evaporation**
   You can obtain many solids from their solutions by letting crystals form. The process is called crystallization. It works because soluble solids tend to be less soluble at lower temperatures.

3. **By evaporating all the solvent**
   For some substances, the solubility changes very little as the temperature falls. So crystallization does not work for them.

4. **Sublimation**
   Is the process of solid changing directly into gas without going through the liquid state. Ammonium salts, iodine and naphthalene are examples of solids that sublime. Sublimation can be used to separate mixtures containing substances that will sublime and those that will not sublime.

5. **Distillation**
   In the last process of separation you got salt from the mixture of salt and water. What happened to the water? If we want to collect it, we can distil the mixture. The water is evaporated. The steam given off is condensed and collected as pure water.

There are two types of distillation:

- **Simple distillation** is to collect the liquid from the solution.
- **Fractional distillation** is to separate two or more liquids that are mixed or separating two immiscible liquids.

6. **Chromatography**
   One of the most sensitive techniques that can be used for identifying and separating components or mixture is **chromatography.**

We can use chromatography to:

- separate small amounts of dissolved solids.
- identify unknown substances.
- purify a substance, by separating it from its impurities.

The simplest version of these techniques is **paper chromatography.**

Solubility is the amount of solute that will dissolve in 100 grams of a solvent, at a given temperature.
Solutions is a mixture obtained when a solute dissolve in a solvent**.**

A solution has two components, a solute and a solvent.

- **Solute** is a substance that dissolves in the solvent to make a solution.
- **Solvent** is the liquid in which a solute is dissolved to make a solution.

Saturated solutions no more of the solute will dissolve in it, at that temperature.

Solubility of Solids and Gases
The solubility of a substance is the quantity of a substance that will dissolve in a certain volume of a solvent in a given temperature.

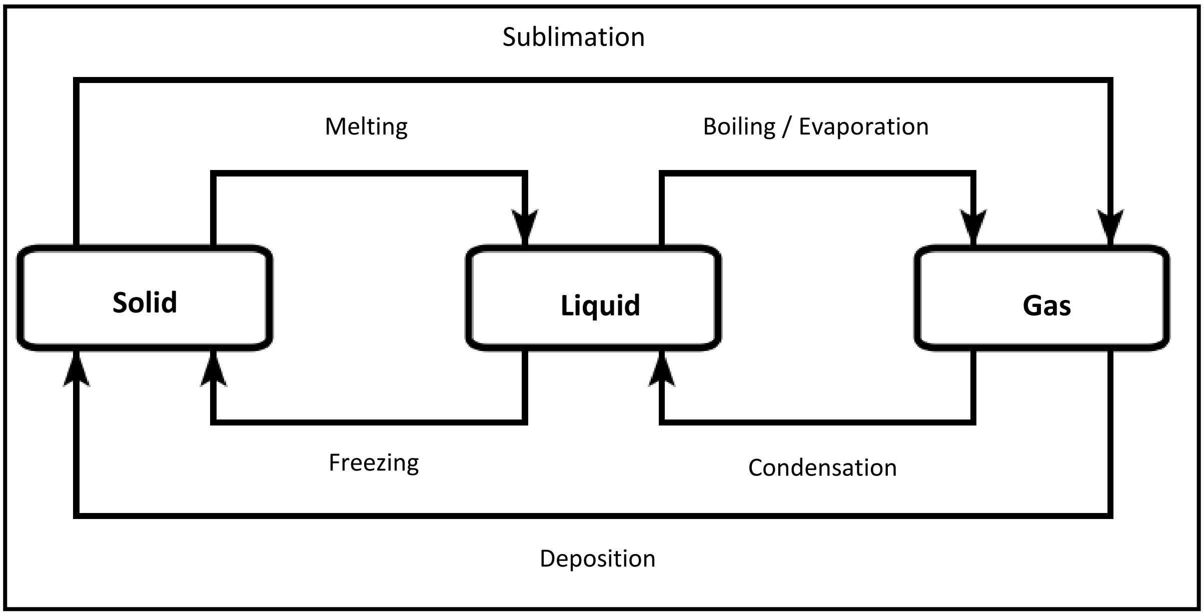
For examples:

- Solids usually increases with temperature.
- Gases usually decreases with the increasing temperature.

Factors affecting solubility of solids in liquids

- The solubility of a solid in a liquid depends on the nature of the solid and the liquid.
- It also depends on the temperature. Most solids dissolve more quickly at higher temperature**.**
- Mixtures can be separated by the following methods:
  - **Filtration** is to separate an insoluble solid from suspension.
  - **Evaporation** is to obtain a solute from a solution by heating to dryness.
  - **Crystallisation** is to obtain pure crystal from a solution by evaporation and cooling.
  - **Sublimation** is to separate substances which sublime.

  - **Distillation** is to obtain the liquid (solvent) from a solution.
  - **Fractional distillation** is to separate two or more immiscible liquids with different boiling points.
  - **Use of separating funnel** is to separate two immiscible liquids.
  - **Chromatography** is to separate small amount of substances such as dyes.
  - **Separation techniques** are useful in our everyday lives. They are used in water filtration, production of salts and fractional distillation of petroleum.
  - **Chromatography** is used to detect pesticides and banned drugs.



NOW YOU MUST COMPLETE ASSESSMENT 1 AND RETURN IT TO THE PROVINCIAL CENTRE CO-ORDINATOR.

ANSWERS TO LEARNING ACTIVITIES 1- 6

Learning Activity 1

1. i. Explain how a substance changes from one state to another.
ii. Alter the physical properties of matter, but the compositions remain constant.
iii. Properties that are observed in regard to whether or not a substance reacts with other substances.

2. B

3. A. melting
B. freezing
C. sublimation
D. evaporation
E. condensation

Learning Activity 2

1. Is the rate at which gas travels across a room or particles mix by colliding with each other and bouncing off in all directions.

2. i. The lower the mass of its particles, the faster a gas will diffuse.

ii. The higher the temperature, the faster a gas will diffuse.

3. Hydrogen will diffuse faster because it has a lighter particle than chlorine. So it can travel faster.

Learning Activity 3

1. $$\frac{P_1}{P_2} = \frac{V_1}{V_2}$$

$$V_2 = \frac{V_1 P_2}{P_1}$$

$$V_2 = \frac{1atm \times 30L}{0.25atm}$$

$\mathbf{V_2 = 120L}$

2.

$$\frac{V_1}{T_1} x \frac{V_2}{T_2}$$

$$V_2 = \frac{T_2 V_I}{T_1}$$

$$V_2 = \frac{330k \times 4.0L}{300K}$$

$V_2 =$ 4.4 L

3.

$$T_2 = \frac{P_2 x V_2 x T_I}{P_1 x V_2}$$

$$T_2 = \frac{5.0atm x 300K}{100atm} = 15K$$

Then convert 15K back to degrees Celsius.
K =°C +273 = °C=K-273 = 15-273
T2 = -258°C

4.

$$V_2 = \frac{2.0x10}{303} = \frac{4.0xV_2}{293}$$

$$V_2 = \frac{2.0x10x293}{4.0x303}$$

V_2 = 4.8L

Learning Activity 4

1. **i.** **A substance that dissolves in the solution.**
ii. **A substance that will dissolve the solute.**
iii. **A mixture of only one phase that can be observed in the mixture.**
iv. **Is the mixture of more than one phase that can be observed.**

2. **i.** **mixture**
ii. **element**
iii. **element**
iv. **compound**
v. **mixture**
vi. **compound**

Learning Activity 5

1. **i.** Made up of two or more substances not chemically combined together.
ii. Contains only one substance.
iii. To collect the liquid from the solution.
iv. Techniques that can be used for identifying and separating components or mixture.

2. Fractional distillation works to separate two or more immiscible liquids with different boiling points.

3. Pure water will be obtained from sea water by the process of simple distillation.

4. **i.** fractional distillation
ii. Filtration
iii. chromatography
iv. simple distillation

5. **a.** B
b. A
c. Red

Learning Activity 6

1. 25 cm^3 of water weigh 25 g.
In 25 g of water 4 g of potassium sulphate dissolve so
In 1 g of water $\frac{4g}{25}$ dissolve, and

In 100 g of water $\frac{4x100g}{25}$ dissolves. $= \frac{4x100}{25} = 16$

2. **a.** $KClO_3$

b. $\frac{50}{100}x200 = 100g$

c. 123g

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FODE PROVINCIAL CENTRES CONTACTS

PC NO.	FODE PROVINCIAL CENTRE	ADDRESS	PHONE/FAX	CUG PHONE (COORDINATOR)	CUG PHONE (SENIOR CLERK)
1	ALOTAU	P. O. Box 822, Alotau	6411343/6419195	72228130	72229051
2	BUKA	P. O. Box 154, Buka	9739838	72228108	72229073
3	CENTRAL	C/- FODE HQ	3419228	72228110	72229050
4	DARU	P. O. Box 68, Daru	6459033	72228146	72229047
5	GOROKA	P. O. Box 990, Goroka	5322085/5322321	72228116	72229054
6	HELA	P. O. Box 63, Tari	73197115	72228141	72229083
7	JIWAKA	c/- FODE Hagen		72228143	72229085
8	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	72229069
9	KEREMA	P. O. Box 86, Kerema	6481303	72228124	72229049
10	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	72229065
11	KUNDIAWA	P. O. Box 95, Kundiawa	5351612	72228144	72229056
12	LAE	P. O. Box 4969, Lae	4725508/4721162	72228132	72229064
13	MADANG	P. O. Box 2071, Madang	4222418	72228126	72229063
14	MANUS	P. O. Box 41, Lorengau	9709251	72228128	72229080
15	MENDI	P. O. Box 237, Mendi	5491264/72895095	72228142	72229053
16	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194/5423332	72228148	72229057
17	NCD	C/- FODE HQ	3230299 ext 26	72228134	72229081
18	POPONDETTA	P. O. Box 71, Popondetta	6297160/6297678	72228138	72229052
19	RABAUL	P. O. Box 83, Kokopo	9400314	72228118	72229067
20	VANIMO	P. O. Box 38, Vanimo	4571175/4571438	72228140	72229060
21	WABAG	P. O. Box 259, Wabag	5471114	72228120	72229082
22	WEWAK	P. O. Box 583, Wewak	4562231/4561114	72228122	72229062

FODE SUBJECTS AND COURSE PROGRAMMES

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English
	2. Mathematics
	3. Personal Development
	4. Social Science
	5. Science
	6. Making a Living
Grades 9 and 10	1. English
	2. Mathematics
	3. Personal Development
	4. Science
	5. Social Science
	6. Business Studies
	7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature
	2. Mathematics – General / Advance
	3. Science – Biology/Chemistry/Physics
	4. Social Science – History/Geography/Economics
	5. Personal Development
	6. Business Studies
	7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) subjects.
- For Grades 9 and 10, you must complete five (5) subjects and one (1) optional to be certified. Business Studies and Design & Technology – Computing are optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) subjects to be certified.

Your Provincial Coordinator or Supervisor will give you more information regarding each subject and course.

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

GRADES 11 & 12 COURSE PROGRAMMES			
No	**Science**	**Humanities**	**Business**
1	Applied English	Language & Literature	Language & Literature/Applied English
2	General / Advance Mathematics	General / Advance Mathematics	General / Advance Mathematics
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry and Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	

REMEMBER:

You must successfully complete 8 courses: 5 compulsory and 3 optional.