Matter and its Properties

Key Words

Volume	condense	molecule	property
mass	evaporate	particle	extensive(general)
density	melt area	kinetic model	intensive(characteristic)
boiling point	freeze	state of matter	
melting point	sublime(verb)	change of state	

Properties of Matter

Matter is the 'stuff' that things are made of - it **occupies space** and we can **measure its properties**.

General or **extensive** properties of matter depend on the amount of matter that is being measured, and do not allow us to identify or distinguish one substance from another; for example mass or volume.

Characteristic or **intensive** properties of matter do not depend on the amount of matter and help us identify or distinguish one substance from another (- for example boiling/freezing point or density).

We use intensive properties to help distinguish matter.

- **More on General or extensive properties**

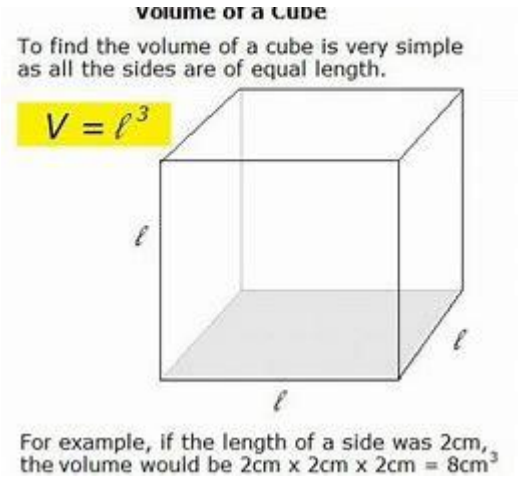
Mass is the quantity of matter in an object. **The SI unit of mass is the kilogram (kg),** although the gram is often used for smaller quantities and the tonne for larger quantities.

There is not direct link between the mass and the size of a body or object. A body can have very little mass but be very big, such a balloon or it can have a lot of mass but be very small, such as a metal ball. This is because a body's matter can be more or less compact and therefore occupy more or less volume.

The link between a body's mass and its size (the volume it occupies), is determined by its density, which is explained further down.

Remember that mass and weight are not the same thing! Mass is the amount of matter an object has, while weight is the gravitational force exerted on it. (basically, the force with which the Earth pulls on it due to gravity).

Volume is the space an object occupies. **The SI unit of volume is the cubic metre (m^3)**. However, you may be more familiar measuring the volume of liquids or of irregular objects in L or its multiples. It is therefore important that you learn and understand the volume equivalence between the two units.



This should already be familiar to you as you have already learnt it in your math class**.**

- **Use a ruler and draw a cube in your notebook which side is 1 cm. Then calculate its volume, including the unit of measurement.**
- If you were to fill up your 1 cm side cube with water or any other liquid, you would be able to fit exactly 1 mL inside it.

Therefore, we can say that **1 mL = 1 cm^3**

- Similarly, if you had a cube which side was 1 dm, (volume 1 dm^3), you would be able to fit 1 L of liquid. And in a 1 m side cube, (volume 1 m^3), the total volume you can fit is 1 kL.

<u>So, from now on, you need to remember the following volume equivalence</u>:

1 kL = 1 m^3 **1 L = 1 dm^3** **1 mL = 1 cm^3**

- **More on Characteristics or intensive properties**

Density is the relation between the mass and the volume of an object or substance. The density of an object or substance is the quotient of its mass per unit of volume. The Si unit of density is kg/m^3. (It measures how concentrated the mass is).

The Formula for density is the following: $$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Substances will order themselves according to their densities; denser substances sinking under less dense ones.

Density of water. Water is a very special molecule. You will learn more about water and some of its properties throughout the years. One important characteristic is its density. The density of pure water at 4ºC is 1 g/cm^3

But what does that mean? If you take 1 mL of pure water and place it on an electronic scale, you will find that its mass is 1 gram.

We can therefore say that 100 mL of pure water is the same as 100 g of pure water. **This 1 to 1 volume – mass equivalence is only valid for pure water, as its density at 4ºC is 1 g/cm^3.**

Melting point is the temperature at which a solid, at standard pressure, completely changes into a liquid. And **boiling point** is the temperature at which a liquid boils and turns into a gas (or vapour), under standard pressure. The SI unit of temperature is the Kelvin (K), although the Celsius (ºC) temperature scale is often used.

(Remember that a liquid can change into gas at temperatures well below its boiling point by the process known as evaporation).

Activities:

1. Why or how do intensive properties helps us determine the type of substance we have?
2. Give two intensive properties that are not in the notes.
3. A plastic object has a mass of 18 g and a volume of 20 cm^3.
    A) Calculate its density.
    B) Will it sink or float in water? Explain your answer.
4. What volume, in mL, does a block of iron have if its mass is 158 g? The density of iron is 7900 kg/m^3.
5. We have prepared a salt solution in the lab with a density of 1.03 g/cm^3. If we measured 300g of salt, what would be the volume of our solution?
6. What volume would 300 g of mercury occupy if it has a density of 13600 kg/m^3.
7. What volume, in mL, does 0.04 kg of pure water occupy?
8. Determine the density of a rock which has a mass of 2,5 tonnes and a volume of 1000 dm^3. Give your answer in SI units.
9. How many grams of pure water would 23 daL be?
10. Determine the volume of an iron nail with a mass of 20 g, if the density of iron is 7.9 g/cm^3.
11. Determine the density of olive oil knowing that a bottle of 3 L has a mass of 2.7 kg.
12. Determine the mass of 3 L of oil, if the density of the oil is 0.9 g/cm^3.
13. Which is denser, water or oil? How can you prove it?
14. In banks, gold is stored in the form of ingots (blocks of gold). I have an ingot with a mass of 60 hg. Calculate its volume if we know that the density of gold is 19300 kg/m^3.
15. A water container, filled to the top, contains 240000 L of pure water. Calculate its depth if its length is 10m and its width is 6 m. Give your answer in SI units.

Kinetic Theory - Particles on the Move
States of Matter – Changing State

The kinetic particle theory explains the properties of the different states of matter. Everything is made of tiny particles (we will study them in the next unit). These particles are not free to move around in a solid, but they move freely in liquids and gases. As they randomly move they collide with each other and bounce off in all directions. Therefore, the particles in solids, liquids and gases have different amounts of energy. They are arranged differently and move in different ways.

These particles can establish forces of attraction between them. Depending on how strong these forces are the state of matter is determined.

There are four states of matter: solid, liquid, gas and plasma. We will study the first three.
Solids have a fixed shape and a fixed volume. They cannot be compressed and do not flow.
Liquids have a definite volume, but not a definite shape, as they take the shape of the container they are in. They flow easily and are not compressible.
Gases have no definite volume or shape. They assume the volume and shape of the container they are in. They flow easily and can be compressed.

But, how can we explain the different characteristics of solids, liquids and gases? It is the arrangement of the particles and how strong the forces of attraction between them are that makes a difference. Let's take a closer look!

Particles in Solids, Liquids, and Gases

- **Solid:** The particles are packed tightly in a fixed position. The forces of attraction which holds them together are very strong, allowing them only to vibrate. Therefore, solids have a fixed shape and volume.

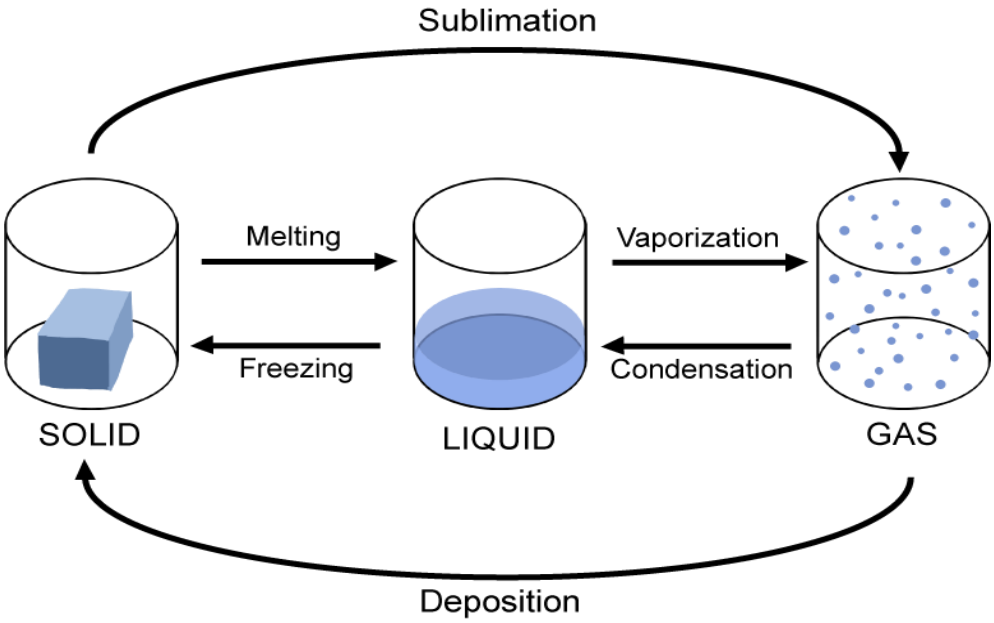
- **Liquid:** The particles in a liquid are close together, but are not in a fixed pattern. The forces holding them together are weaker than in a solid, giving them some freedom of movement. These particles can move about and slide past each other but not escape. Therefore, liquids have a constant volume (particles don't separate from each other), but not a fixed shape. Liquids take the shape of the receptacle in which they are contained, and they can be poured (they flow).

- **Gas:** There are almost no forces holding the particles of a gas together. The particles in a gas are far apart and they move about very quickly, occupying all the space available. Gases do not have a fixed shape or volume. Gases are easily compressed into a smaller volume. We say gases are compressible.

Changing states – Phase changes

How do substances go from one state to another? It is all about energy!

We use **heat (= thermal energy)** to melt a solid. Heat makes the particles move faster. Once the particles have enough energy, they can start to overcome those forces which hold them together. As we keep providing energy in the form of heat the particles will move faster and eventually the liquid will boil and change into a gas (vapour).



("2016")

In a solid body (e.g. ice), there is in general very little movement of the particles. As we heat the solid its particles get more energy and vibrate more. As the particles now have more energy, they can start to overcome those attractive forces between them breaking away from their position. The particles start to change places and the solid melts into a liquid (e.g. liquid water). If we continue heating the particles, they get more energy, moving even faster. Eventually the particles get enough energy to overcome the forces between them. Spaces will start to open up between the particles until they break way to form a gas (e.g. water vapour).

Now, if we do the opposite, that is, if we **cool down**, or remove energy from the system the reverse changes will take place. The gas will condense into a liquid and the liquid will freeze forming a solid.

The changes from a gas to a liquid, a liquid to a solid etc. are called **phase changes**.

During a phase change the temperature remains constant (lab demonstration)
So even though you keep on adding heat, the temperature stays steady while the substance melts, and again while it boils.

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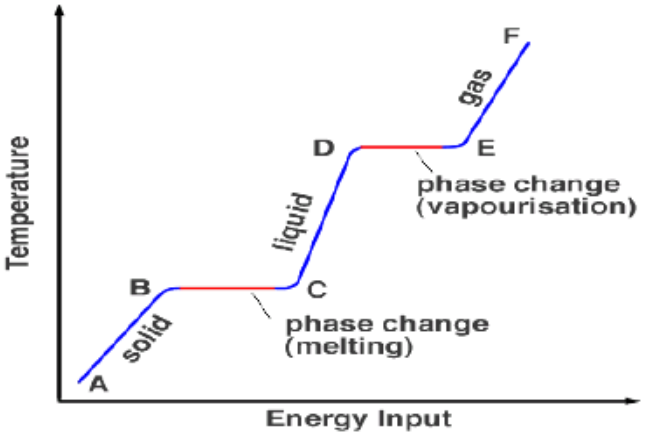


Phase change diagram.

There are two types of phase changes: progressive and regressive.

Progressive phase changes are those that take place when **energy is provided** to the system. Fusion, vaporization and positive (or progressive) sublimation.

Regressive phase changes are those that take place when **energy is removed** from the system. Solidification, condensation, and negative (or regressive) sublimation (deposition).

- **Fusion (melting):** the change in state from a solid to a liquid.
- **Solidification (freezing):** the change in state from a liquid to a solid.
- **Sublimation:** the direct change of state from a solid to a gas.
- **Negative sublimation:** the direct change of state from a gas to a solid.
- **Vaporization:** the change in state from a liquid to a gas.

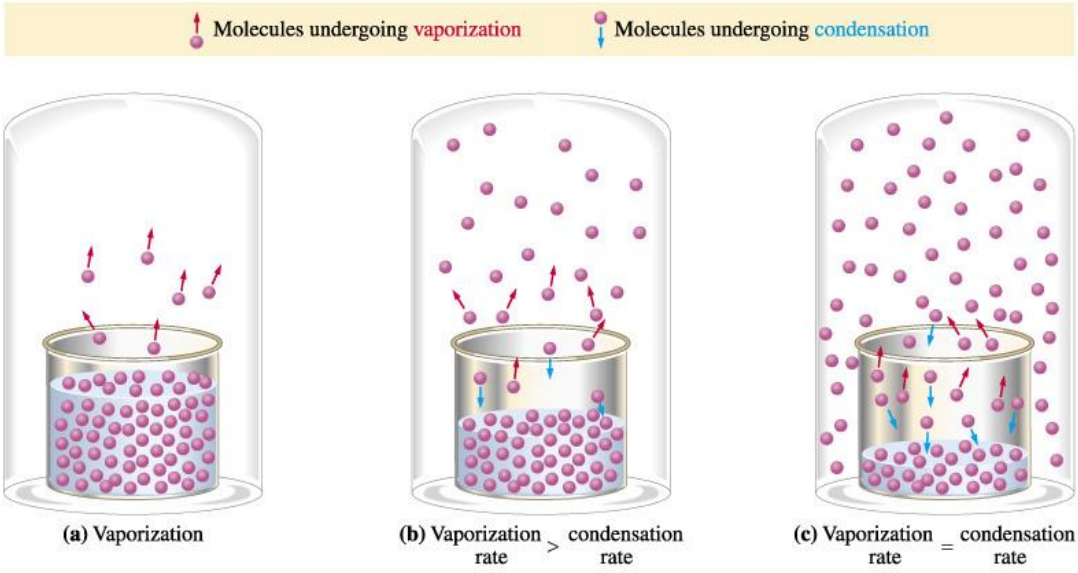
Evaporation: is the process of a liquid changing into a vapour at temperatures below its boiling point. It only occurs on the surface of a liquid when a particle has by chance sufficient energy to escape.
Boiling: is the rapid change in state from a liquid to a gas usually caused by heating. When heating, the particles in a liquid gain energy. Eventually they have sufficient energy to overcome the binding forces in the liquid, and spread away as particles of gas.

- **Condensation:** the change in state from a gas to a liquid at room temperature.

Pressure affects the temperatures at which the phases change.
For instance, the boiling point of water lowers down when pressure decreases. Similarly, **the boiling point rises when pressure increases**. In a pressure cooker, we increase the pressure to obtain a situation where the elevated boiling point (≈ 120 °C) allows us to prepare our food at a higher temperature and thereby reduce the cooking time.

Vapour Pressure

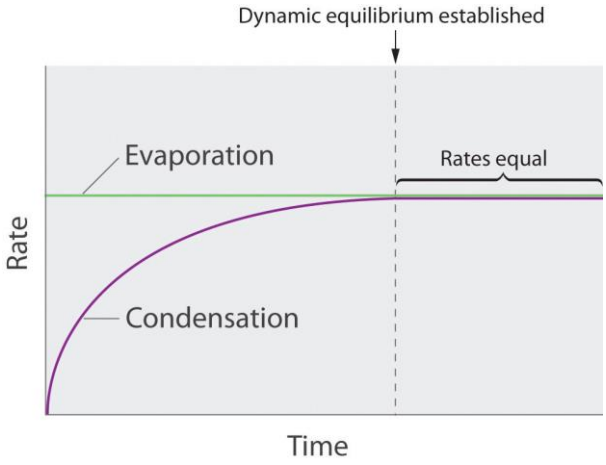
The vapour pressure of a liquid is the pressure exerted by the vapour when equilibrium is reached between its vapour phase and its liquid phase.



("CH105: Lesson 2 - Intermolecular Bonds", 2016)

So, at any given temperature, for a particular substance there is a pressure at which the vapour of that substance is in equilibrium with its liquid form (the same number of particles leaving the liquid by evaporation return to the liquid by condensation). This is termed the vapour pressure of that substance at that temperature.

Why does this happen? Well, as not all particles have the same kinetic energy, in all liquids at a given temperature, some particles will move faster than others. The faster ones and near the surface have enough energy to escape and turn into a gas – **evaporation** – As the number of these gas particles increases, so will the vapour pressure. Eventually a point will be reached where the inverse process will take place; gas particles will lose energy and will turn back into the liquid state – **condensation** - , reaching an equilibrium, when evaporation rate = condensation rate. At this point the pressure exerted by the vapour is called the vapour pressure.



("Vapor Pressure", 2016)

As temperature increases more molecules are able to escape the liquid, and as a consequence vapour pressure increases and vice versa. When the pressure reaches atmospheric pressure the entire liquid will start to boil. We can therefore say that the boiling point of a liquid is that at which its vapour pressure equals atmospheric pressure.

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Activities

1. Write down two properties of a solid, two of a liquid, and two of a gas.
2. Which word means the opposite of: a) boiling?, b) melting?
3. Are the following statements true or false? Fix the false statements. Make sure to use proper English and write full sentences
   a. Changes of matter occur as energy is added or taken away from a system.
   b. Mass is a derived physical quantity.
   c. In a solid particles are close together, but not in a fixed position.
   d. General or extensive properties of matter do not allow us to identify a substance.
4. Draw a scheme of the phase changes of matter, including everything we have learned in class.
5. Use the kinetic particle theory to ***outline*** the properties of a liquid.
6. ***Convert*** the following units using conversion factors. Give your final answer in scientific notation. **Show your work**!

   a) 25 m/s to km/h. b) 13000 kg/m^3 to g/cm^3

7. ***Outline*** the differences between evaporation and boiling.