Matter

Matter-In Depth

Matter can be defined as anything that has both mass and volume and occupies a certain space in the universe. The air we breathe, the food we eat, the water we drink, the clothes we wear, the different plants and animals, stones, sand, etc., are all examples of matter.

Matter and non-matter: Matter can be distinguished from non-matter in terms of mass, volume, and space it occupies. A chair, a computer, a car, and a bridge are all examples of matter. Each of them has mass and volume, and also occupies space. Non-matter, on the other hand, cannot be measured in terms of mass and volume. It does not occupy any space either. Examples of non-matter include thirst, anger, love, and smell.

Can air be classified as matter?

Though air is invisible and intangible, it does have mass and volume. But it occupies space. Hence, air can be classified as matter.

Examples of matter and non-matter

Matter	Non-matter
Air, building, animal, plant, water, fruit, vegetable, chair, table, computer, car, book, pen, pencil, bag	Cold, hot, big, small, anger, love, song, lecture

Know More

We measure the mass of matter, and not its weight. This is because the mass of matter is constant, but its weight can vary from place to place. To calculate the weight of any object, we multiply its mass with the acceleration due to gravity (g) which varies from place to place. Consequently, the weight of the object varies as well.

The SI unit of mass is **kilogram**.

The CGS unit of mass is **gram**.

The FPS unit of mass is **pound**.

The SI unit of volume is **cubic metre** (m^3).

The common unit of measuring volume is **litre**.

$1 L = 1000 mL = 1 dm^3$

Characteristics of Matter

Let us investigate the characteristics of matter.

By now we know that the nature of matter is particulate and not continuous. The particles of matter have certain characteristics. The characteristics of particles of matter are as follows:

- Matter is made up of extremely small particles called **atoms**. Atom is the smallest possible unit of matter that exhibits all the properties of that matter.
- When atoms combine with one another, minute particles are formed, which are called **molecules.**
- The particles of matter have spaces between them.
- The particles of matter are in continuous motion.
- The particles of matter attract one another.

The Phlogiston Theory

- It was used to explain the combustion reactions during the seventeenth and eighteenth centuries.
- According to it, "any material undergoing combustion mainly contains a mysterious matter called phlogiston and also some clax."
- When a substance is burnt, the phlogiston goes into the surrounding and the clax is left as ash.
- During the burning of a candle in a closed container, the air present inside the container becomes saturated with phlogiston. No further phlogiston can be accommodated in the air and as a result, the candle gets extinguished.

Whiz Kid

While preparing sugar syrup, we dissolve sugar in water. However, after adding a certain amount of sugar, we observe that sugar does not dissolve anymore and gets settled at the bottom of the container. Why is it so?

The water is able to dissolve only up to a certain amount of sugar particles. Once its maximum capacity for dissolving the sugar particles is reached, it does not dissolve any more of them. In other words, there is no space left between the water particles to accommodate any more sugar particles. So, any additional sugar added simply settles at the bottom of the container.

Know More

Gas pressure

Particles of gas always move with high speed. Pressure is created when gaseous particles hit the walls of the container in which they are enclosed.

For example, you must have observed that the continuous blowing of a balloon causes it to burst. This is because the gas particles put pressure on the inner walls of the balloon. Excess blowing in of air increases the number of gas particles inside the balloon. As a result, the pressure of the gas increases and, ultimately, the balloon bursts.

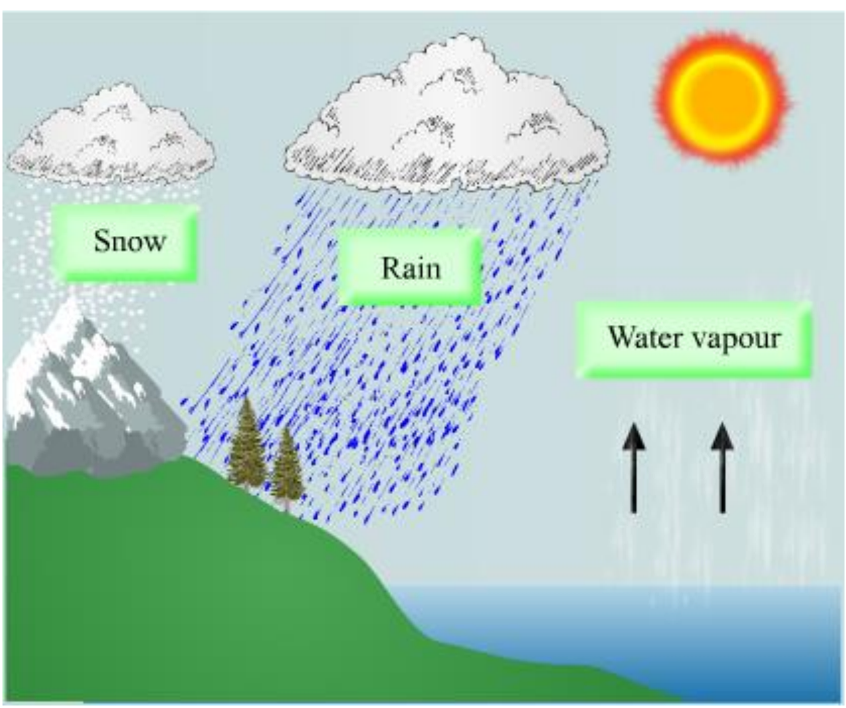
The Solid State

States of Matter-An Overview

We know that everything is made up of matter, yet things exist in different forms. What makes things look different from one another?

Matter is a broad umbrella covering different sub-categories which we know as the **states of matter**.

The view of the hills during winters is ideal for observing the three main states of matter—solid, liquid and gas. Here, you can see heavy clouds which are nothing but collections of vapourised water particles. You can also see liquid water falling from these same clouds as rain. And of course, there is the dusting of snow which is in fact solidified water.



The different states of matter are:

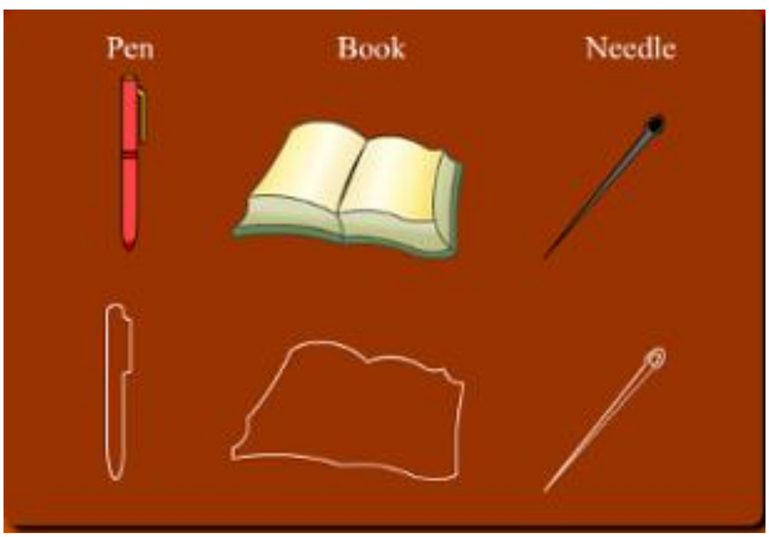
- Solid
- Liquid
- Gaseous
- Plasma
- Bose-Einstein condensate

The Solid State

Matter is said to be solid if it has a fixed **shape** and a fixed **volume**. For example, a pen. It has a fixed shape and a fixed volume; hence, it is solid. Matter that does not have a fixed shape is not solid, as is the case with water.

The particles of solids have a minimum or no kinetic energy and therefore the particles do not have any movement. The intermolecular spaces between the particles of solid are very small due to stronger attraction among the particles. Solids, therefore, cannot be compressed.

Activity Time



Procedure: Collect a pen, a book, and a needle. Trace the shapes of these materials in a notebook and compare the tracings. Also, try compressing each material.

Result: When you compare the tracings, you will observe that each material has a distinct shape and boundary. When you try compressing the materials, you will observe that each material has negligible [[mn: glossary]] compressibility [[/mn: glossary]].

Conclusions: The following conclusions can be made about a solid.

- It has a fixed shape, fixed volume, and a fixed boundary.
- There are very little **intermolecular** spaces in a solid. Hence, it has a tendency to maintain its shape. This means that it has negligible compressibility.
- It is **rigid**. It may break under force, but it is difficult to change its shape.
- It rarely **diffuses** in another solid. Example- Diffusion of chalk powder on a blackboard. This is the reason why it is difficult to clean (rub) a used blackboard that has not been cleaned for several days.

Whiz Kid

Solids have the following forms.

- **Crystalline**: Calcite (rhombic), fluorite (octahedral) and quartz (hexagonal) are crystalline solids.
- **Polycrystalline**: Metals are polycrystalline solids.
- **Amorphous**: Glass is an amorphous solid.
- **Polymeric**: Natural rubber is a polymeric solid.

It is possible to stretch certain substances without breaking them. These substances are made up of long chains of atoms bonded together (usually carbon atoms bonded by covalent bonds). These substances are called polymeric substances. This is why the shape of rubber changes when stretched even though it is solid.

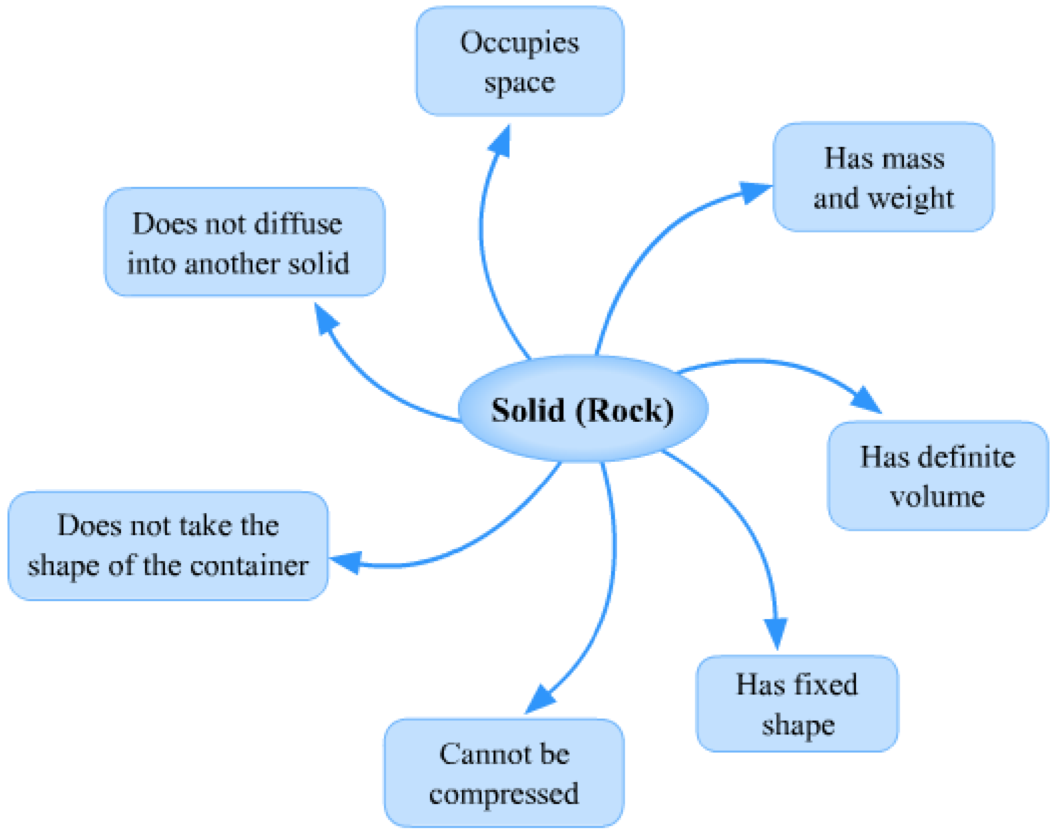
Did You Know?

Although sponge is solid, it can be bent and squeezed. Sponge has minute holes on its surface. Air is trapped in these holes.

This air is expelled as we press or squeeze sponge. This makes it possible to bend and squeeze sponge.

The Solid State

The following diagram illustrates the properties of a solid.



The Liquid State

Unlike a solid, a liquid has no fixed shape. However, it does have a fixed volume. It takes the shape of the container in which it is kept. For example, water does not have a fixed shape, but its volume is fixed. When a certain volume of water is poured into a container, it takes the shape of the container, but its volume remains the same.

On the other hand, a pen (which is a solid) has a fixed shape and volume. A liquid is not rigid, i.e., it flows freely. The intermolecular spaces in a liquid are greater than in case of a solid. Hence, a liquid has more compressibility than a solid. The particles of liquids have more kinetic energy than solid particles and therefore has greater speed than solid particles.

Characteristics of a liquid on the basis of the particle nature of matter

- A liquid does not have a fixed shape. It takes the shape of the container in which it is kept.
- A liquid has a fixed volume.
- It is not rigid, i.e., it flows freely.
- It has more compressibility than a solid. So, it can easily diffuse in other liquids.
- In most cases, the density of a substance in the liquid state is lesser than its density in the solid state.

Usually liquids have lower density than solids, yet ice floats in water. Can you say why?

Ice is lighter than water since a particular mass of ice occupies more space than the same mass of water. In ice, water molecules are closely packed because of the tight bonding between them. This makes ice lighter than water.

Know More

Solids, liquids and gases can diffuse in liquids. The dissolution of salt or sugar in water and the dissolution of ink in water are examples of the same. Gases such as oxygen and carbon dioxide diffuse and dissolve in water bodies.

It is because of these gases that aquatic plants and animals are able to survive underwater.

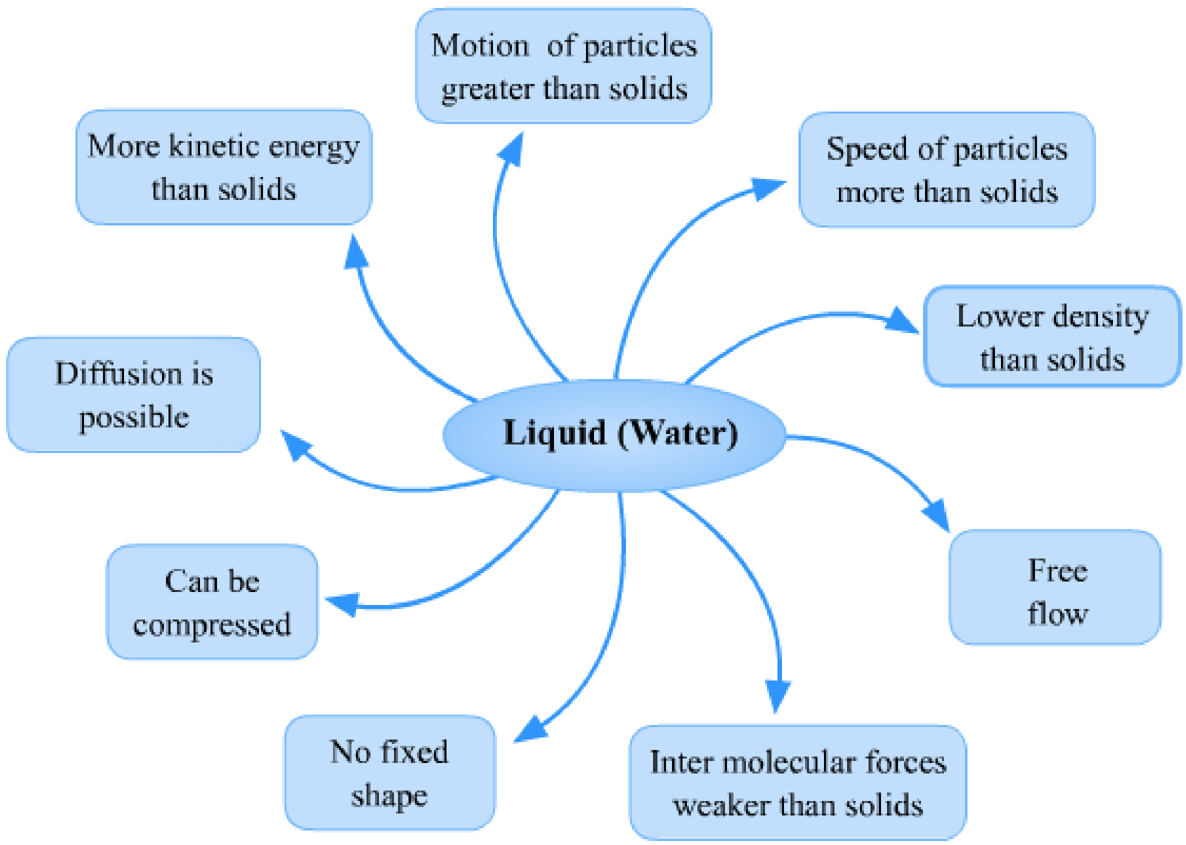
This high rate of diffusion in liquids is because of the fact that a liquid has larger intermolecular spaces.

Did You Know?

Bronze, an **alloy**, expands when its state changes from liquid to solid. This property of bronze is utilized in moulding statues.

The Liquid State

The following diagram illustrates the properties of a liquid.



The Gaseous State

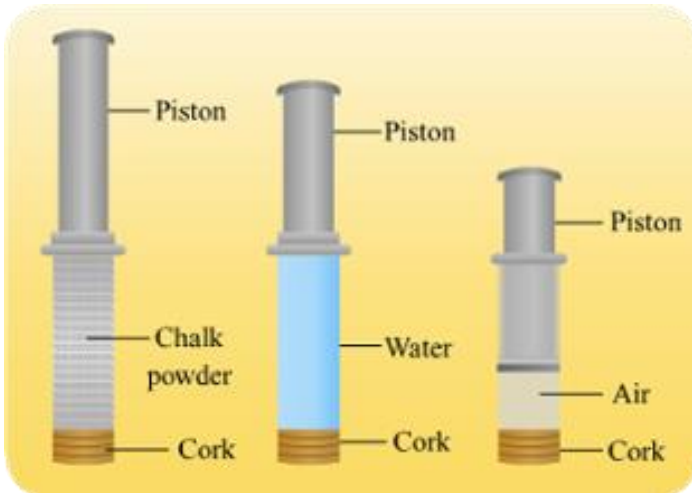
A gas neither has a fixed shape nor a fixed volume. Hence, it does not have a fixed boundary. It can flow in all directions and can be easily compressed. In a given space, the number of particles in a gas is lesser than in the case of a solid or a liquid.

The constituent particles of a gas show a random motion because of the presence of large spaces between them. Consequently, the kinetic energy of the particles in a gas is more than in the case of a solid or a liquid.

Due to the large distances between the particles, the forces of attraction between them are very low or negligible.

Activity Time

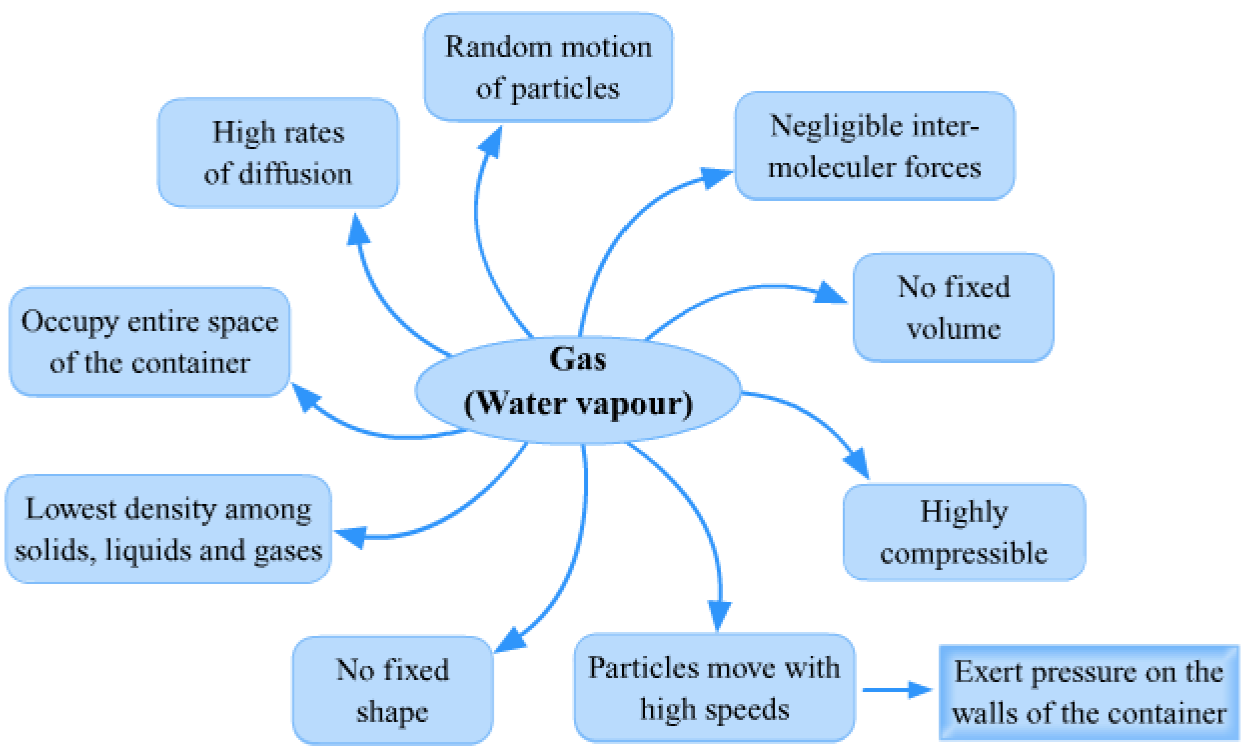
Procedure: Take three 100 mL syringes and remove their pistons. Close the nozzles of the syringes with rubber corks. Fill one syringe with chalk powder and another with water. Now, reinsert the pistons and push them.



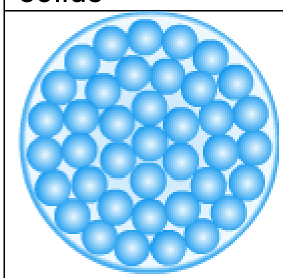
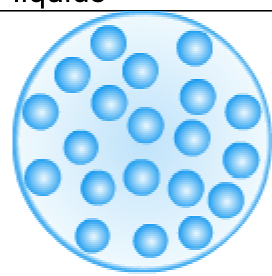
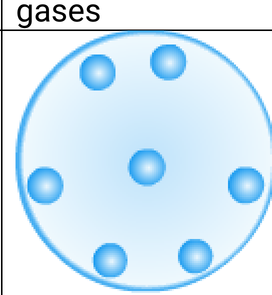
Result: The force required to push the pistons of syringes containing chalk powder and water will be greater than that required to push the piston of the syringe containing air.

The Gaseous State

The following diagram illustrates the properties of a gas.



Differentiating the Three States of Matter

Solid	Liquid	Gas
Definite shape Occupies space Definite volume Cannot be compressed Rigid Does not diffuse in other solids	No definite shape Occupies space Definite volume Slightly compressible Not rigid Can diffuse in other liquids	No definite shape Occupies space No definite volume Highly compressible Not rigid Can diffuse in other gases
 Solid	 Liquid	 Gas

Solved Examples

Easy

Example 1: **Answer the questions with a 'Yes' or a 'No' for each of the three states of matter.**

Questions	**Solid**	**Liquid**	**Gas**
Does it occupy space?			
Does it have a definite volume?			
Can it be compressed?			
Does it take the shape of the container enclosing it?			
Can it diffuse in a like state of matter?			

Solution:

Questions	**Solid**	**Liquid**	**Gas**
Does it occupy space?	Yes	Yes	Yes
Does it have a definite volume?	Yes	Yes	No
Can it be compressed?	No	Yes	Yes
Does it take the shape of the container enclosing it?	No	Yes	Yes
Can it diffuse in a like state of matter?	No	Yes	Yes

Solved Examples

Easy

Example 2:

Identify the state I'm in.

Object	**State**
Glass Welding arc Liquid helium Mercury Fog	Bose-Einstein condensate Solid Gas Plasma Liquid

Solution:

i → b; ii → d; iii → a; iv → e; v → c

Medium

Example 3:

Guess who I am.

i) The container I'm placed in does not matter. My shape does not change. I'm ______.

ii) I'm flexible and particles can move with some speed. I'm ______.

iii) I possess highest kinetic energy and my particles move with high speed. I'm ______.

iv) I'm charged and have high temperature. I'm ______.

Solution:

(i) solid

(ii) liquid

(iii) gas

(iv) plasma

Change of State-An Overview

Let's see this video illustrating about changes in states of matter.

In daily life, we see different kinds of changes in the states of matter. The formation of ice cubes from water in the refrigerator is an example of the change in the state of matter from liquid to solid. When water is boiled, vapours are formed. This is an example of the change in the state of matter from liquid to gas.
The following terminologies are used to describe the changes in the states of matter.

- Change from the solid state to the liquid state is called **melting**.
- Change from the liquid state to the solid state is called **freezing**.
- Change from the liquid state to the gaseous state is called **vapourisation**.
- Change from the gaseous state to the liquid state is called **condensation**.

There are two other changes between the three states of matter—sublimation and deposition.

Sublimation: It is the process in which a substance changes directly from the solid state to the gaseous state without entering into the liquid state. The changing of snow into water vapour is an example of sublimation. Some common examples of substances that sublime are dry ice, camphor and naphthalene.

Deposition: It is the process opposite to sublimation. In this, a substance changes directly from the gaseous state to the solid state. Frost is an example of deposition.

When we open the refrigerator, we see freezing fog. This is nothing but condensed water.

Air contains vapours. When we open the refrigerator, the temperature comes down. This condenses the vapours into tiny drops of water and produces freezing fog.

Temperature Affecting the Change of State

Temperature tells us about the **hotness** or **coldness** of an object. A hot body will have a high-temperature while a cold body will have a low temperature.

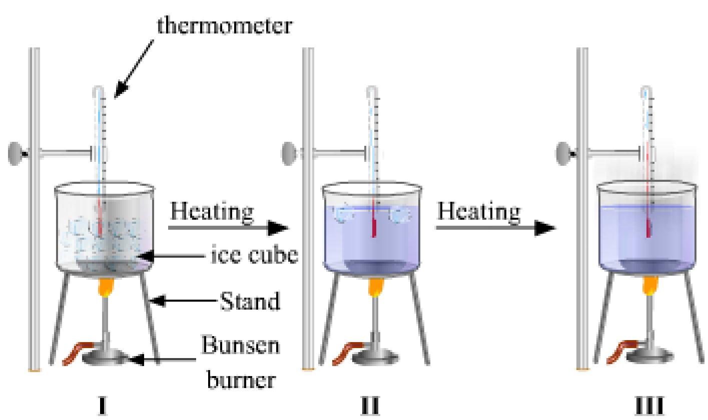
How to know the degree of hotness or coldness of a body?

The temperature of an object is measured using a thermometer. The standard unit of temperature is **Celsius**. There are various types of thermometers like **mercury thermometer**, **digital thermometer** but nowadays digital thermometer is used frequently.

Do you Know?
The body temperature of a healthy person is 370 370 C while 250250 C is the room temperature.

Let us perform an activity to understand the effect of temperature on the different states of matter.

Procedure: Take about 150 g of ice in a beaker and use a laboratory thermometer to note the temperature of ice. Start heating the beaker on a low flame and record the temperature when the ice starts melting. Observe the temperature when all the ice gets converted into water. Stir the water with a glass rod till it starts boiling.



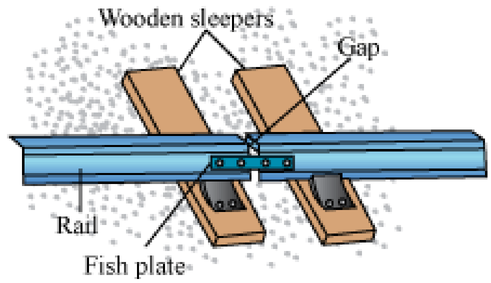
Result: In the beginning, the temperature of ice is below 0°C. When ice begins melting, the temperature is recorded to be 0°C. Temperature remains constant at 0°C till all the ice melts. The continued heating of water causes its temperature to rise.

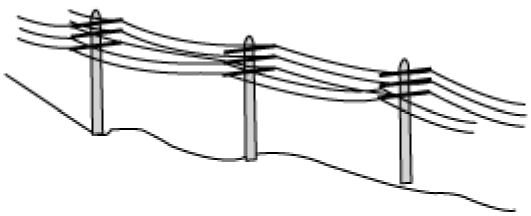
Conclusion: It can be concluded from this activity that an increase in temperature changes a substance from its solid state to its liquid state, and further heating (i.e., the further increase in temperature) changes the liquid so formed into vapour.

Thermal Expansion

Expansion of Solids

Rohit was travelling from Nasik to Mumbai. While waiting on the platform for the train to arrive, he noticed the rail track carefully. He observed that the rail tracks were joined by a metal plate and there was a small gap between the rail tracks. Can you explain the reason behind leaving a small gap between two rails at the joining?





Have you ever noticed the electric transmission wires connected to electric poles? Their lengths are always kept longer than the distance between the poles, so that they sag down. Do you know why?

The rail tracks and the electric wires are made up of metals. On heating, almost all metals expand. The expansions may be along the length, area or volume.

Now, can you answer why a gap is left between two rail tracks at the joining? During summers, the metals rail tracks expand because of heating. If the rail tracks are fitted end-to-end leaving no gap, then on expansion, the rail track would bend. To avoid this, rail tracks are joined by a fish plate, leaving some gap between the rail tracks.

The lengths of electric transmission wires are also kept longer to avoid any tension in the wires when they contract during winters.

Expansion of Gases and Liquids

Have you seen people gliding in the air in a basket tied to a balloon? This is called hot-air ballooning. How does the balloon move?

Situated just below the balloon and above the basket is a flame that heats up the air inside the balloon up to about 100ºC. This hot air expands as a result of heating.

When the air expands, its density reduces. The air inside the balloon thus becomes lighter and less dense than the air outside the balloon. This makes a hot-air balloon rise.

Thus, we know that air expands on heating.

Not only air, but **all gases expand on heating**.

Let us perform an activity to understand this principle

We know that hot air expands. How does hot air make a balloon move up?

Let us perform an activity to understand this phenomenon

Using a pump, inflate a balloon with cold air and another one with hot air. Hang them on a horizontal, wooden stick. Observe the motion of both the balloons.

You will find that the balloon filled with hot air rises more in comparison with the balloon filled with cold air. **Can you explain why this happens?**

Since air expands on heating and occupies more space, the hot-air balloon becomes lighter than the cold-air balloon.

Why does the smoke from a fire move upwards? This is because fire heats the air and causes the air to move upwards. The upward-moving air carries the smoke along with it.	

Like gases, liquids also expand on heating. Let us perform an experiment to see the expansion of liquids on heating.

Take three similar glass bottles. Fill the bottles with three different liquids, say kerosene oil, coloured water and milk. Now, insert a straw in each bottle with the help of a cork.

Mark the liquid levels in the straws. Place the bottles in a big beaker and pour hot water in the beaker. What do you observe after 10 minutes?

You will see that the liquid levels in the straws increase, and the increases are different for all the three liquids. This happens because the liquids expand on heating, and they expand at different rates on the same amount heating.

Physical and Chemical Changes

You must have observed that when ice melts, it changes to water. Similarly, when we burn paper, it changes to ash. Thus, in both cases, a change is taking place. There are many changes taking place all around us. **Can we classify these changes?** All the changes can be broadly classified into two types:

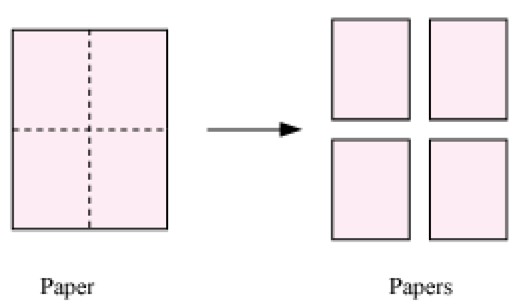
1. Physical changes

2. Chemical changes

Let us differentiate between physical changes and chemical changes.

We know that the shape, size, colour, and state of a substance are its physical properties. Physical changes usually involve changes in these properties of a substance. A change in any one of these physical properties is called a **physical change**.

For example, if you cut a piece of paper into 4 equal squares, then the shape of the paper changes, but there is no change in the properties of the paper. Also, no new substance gets formed in the process. Hence, the cutting of paper is a physical change.



In this case, we cannot join back the pieces to form the original paper. Hence, the cutting of paper is irreversible in nature. Let us now discuss a physical change, which is reversible in nature that is evaporation. **Evaporation is the process in which a liquid gets converted into its vapours**. This process depends on various factors such as,

- **Nature of liquids:** There are some liquids which evaporate quickly, such as petrol and kerosene, while there are other liquids which take some time to evaporate, such as water.
- **Surface area:** Evaporation of a liquid depends on the surface of the liquid. If surface area of the liquid increases, then evaporation increases.
- **Humidity:** It is the amount of water vapour present in the environment. If humidity or water vapour in air is high, evaporation will be slow and if air is free of water vapour then evaporation takes place rapidly.
- **Temperature:** As the temperature rises, the evaporation takes place more quickly.

Let's understand the evaporation process with the help of an illustration:

If we add a spoon of common salt in some water and stir the mixture for sometime, then the salt disappears. Now, if we place the salt solution in a china dish over a hot plate, then it will be observed that the water evaporates after sometime, leaving behind a white solid (as shown in the figure).

Evaporating salt solution

The white solid that is left after all the water is boiled is nothing but salt. This proves that when salt dissolves in water, no new substance is formed. However, this process is reversible. Thus, dissolution of salt in water is a physical change.

Hence, it can be concluded that in a physical change,

- a change in the physical properties of a substance such as state, shape, size, and colour takes place
- no new substances are formed

For example,

Ice → Water → Steam (They are all still water!)

- The original substance can generally be recovered again

Now, you know what physical changes are. **Do you know the characteristics of chemical changes?**

A chemical change is the one in which the formation of one or more new substances takes place. The new substance formed has different chemical properties from that of the substance that formed it.

Now, watch the following animation to see an example of chemical change.

Let us add more to our knowledge by performing the next activity.

When lime is added to water, the temperature of water increases and water almost starts boiling. A substance called slaked lime is produced during this change. Hence, it is a chemical change. The following chemical equation can be used to represent the chemical change.

$CaO + H_2O \rightarrow Ca(OH)_2 + \text{Energy}$

Lime   Water   Slaked lime

Thus, it can be concluded that in a chemical change,

- one or more new substance(s) are formed
- the chemical properties of the new substance(s) are different from those of the starting material
- the original material cannot be recovered easily

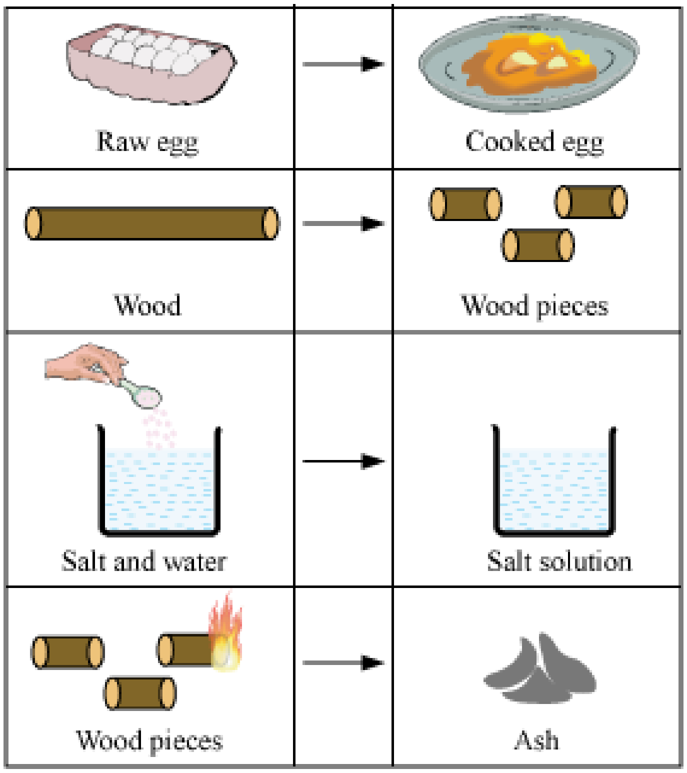
For example, magnesium oxide and calcium hydroxide (formed in the above activities) cannot be converted back into their original substances.

Hence, we can summarize the differences between physical and chemical changes as given in the table below.

Physical Change	**Chemical Change**
1. The chemical composition of a substance does not change.	1. The chemical composition of a substance changes.
2. Most changes are reversible.	2. Most changes are irreversible.

3. No new substances are formed. For example, Ice → Water → Steam	3. New substances are formed. For example, Paper → Ashes

Can you specify the type of changes given in the table?



Some other examples of physical changes

- Melting of butter
- Boiling of water
- Condensation of water vapours
- Making of fruit salad with raw fruits
- Expansion or contraction of metals on heating or cooling
- Freezing of water
- Beating of metals into sheets
- Mixing of sugar and sand
- Crystallisation of salts from their solutions

Some other examples of chemical changes

- Digestion of food

- Cooking of food
- Rusting of iron
- Decaying of wood
- Burning of paper
- Souring of milk
- Ripening of mangoes
- Burning of candle

  Burning a candle: We now understand the difference between physical change and chemical change. But there are a few changes in which simultaneous physical and chemical changes occur. Let us study about those changes.

  When we burn a candle, heat and light is produced, which melts the candle. This process is a physical change. But at the same time, two new products, which are carbon dioxide and water vapours, are formed, making it a chemical change.

  Thus, burning a candle is a combination of physical and chemical change.

- **Sublimation of ammonium chloride**

  Sublimation of an element is a change from the solid directly to gas phase with no intermediate liquid stage. For example, when ammonium chloride is heated, it goes directly into the vapour state. When these vapours are cooled, ammonium chloride is obtained back.

  Since we obtain the original substance back at the end, it is a physical change. **But do you know why does it sublime?**

  Ammonium chloride sublimes because of dissociation of ammonium chloride into ammonia and hydrogen chloride in the vapour state. On cooling, ammonia and hydrogen chloride recombine to form ammonium chloride again.

  Thus, the physical change taking place is the result of chemical dissociation and combination.

- **Cooking rice**

  Do you know what happens when we cook rice?

  While cooking rice, water molecules pierce the walls of the cells of the starch present in rice. Thus, some of the starch is decomposed. Therefore, this change is physical to a major extent since the composition of rice remains the same.

Allotropic Changes

Evaporating salt solution

Allotropy is exhibited by certain chemical elements, which can exist in two or more different forms, known as allotropes of that element. For example, carbon has graphite and diamond as its allotropes. Oxygen has ozone as its allotrope.

In each allotrope, the element's atoms are bonded together in a different manner. Also, they may differ in number of atoms forming the unit.

In oxygen gas, there are two atoms in a molecule. On the other hand, in ozone, three atoms are present in a molecule. Also, oxygen and ozone are different in some of their chemical properties.

Hence, we conclude that allotropic changes are chemical changes.