1. MATTER

Matter may be defined as anything that occupies space, possesses mass and presence of which can be felt by any one or more of our five senses (i.e. sight, smell, taste, touch and hearing).

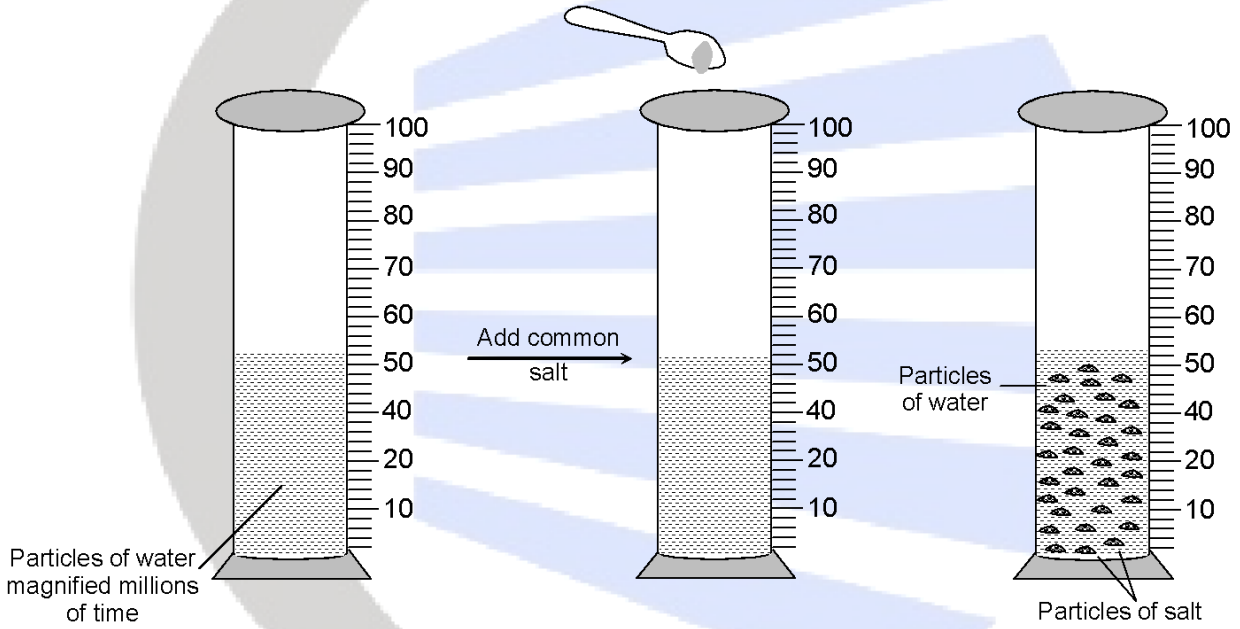
1.1 PHYSICAL NATURE OF MATTER

1.1.1 Particle Nature of Matter – Matter is made up of particles

To show the particle nature of matter, we perform the following experiment :

Experiment : Take about 50ml water in a graduated cylinder and dissolve small amount of common salt (NaCl) or sugar in it with the help of a glass rod.

Observation and explanation: The salt or sugar dissolves in water and there is no noticeable change in the level of water. This is because, there are some spaces in between the particles of water, which are occupied by salt or sugar particles (when salt or sugar dissolves in water) and thus the level of water does not rise.



When salt dissolves in water, the particles of salt get into the spaces between the particles of water and the level of solution does not rise

Figure 1

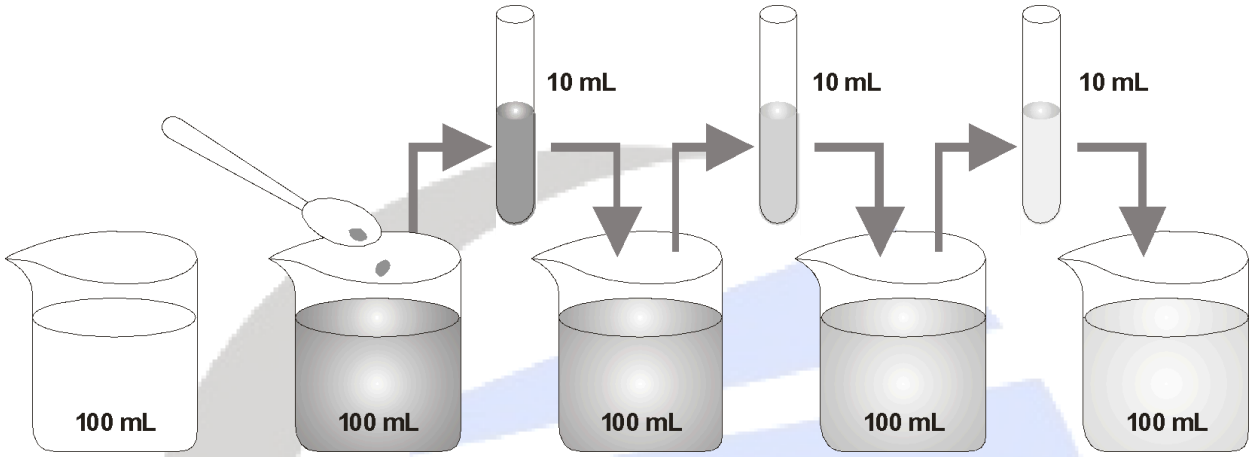
Conclusion : From above experiment, we led to conclude that, there are some spaces between the particles of matter, or in other words matter is made up of particles.

1.1.2 How small are these particles of matter?

To know how small are the particles of matter from which it is made up of, let us perform the experiment :

Experiment : Take about one crystal of potassium permanganate ($KMnO_4$) and dissolve it in 100ml of water. The colour of solution will be dark pink. Take out approximate 10ml of this solution (dark pink) and put it into 90 ml of clear water. Now take 10ml of this solution and put it into another 90ml of clear water. Keep diluting the solution like this 5 – 8 times.

Observation and Explanation : The pink colour will not disappear altogether, though it becomes lighter and lighter with each dilution. This is because, there must be millions of tiny particles present in one crystal of $KMnO_4$ which keep on dividing into smaller and smaller number with each dilution, thereby making colour lighter and lighter.



Estimating how small are the particles of matter. With every dilution, though the colour becomes light, it is still visible.

Figure 2

Conclusion : From above experiment we conclude that "matter is made up of extremely small particles which can not be seen even with a powerful microscope.

or

The particles of matter are very small….. they are small beyond our imagination !!!!!.

1.2 CHARACTERISTICS OF PARTICLES OF MATTER

1.2.1 Particles of matter have spaces between them

When potassium permanganate ($KMnO_4$), dettol, sugar or salt are dissolved in water, then their particles get evenly distributed between the spaces present among the particles of water as discussed in above experiments. Similarly when we make tea, coffee or lemonade (nimbu pani), the particles of one type of matter get into the spaces between the particles of other type of matter.

This shows that there are spaces between particles of matter.

1.2.2 Particles of matter are continuously moving

The continuous motion of particles of matter can be explained more clearly by performing the following experiments :

Experiment 1 : Put one unlit incense stick (Agarbati) in one room & one lit incense stick (Agarbati) in another room.

Observation and Explanation : We will get smell while sitting at a distance from the lit stick, but to smell the unlit stick, we will have to go near it. This is because, when stick is lit, the temperature rises and hence the kinetic energy of the incense particles also increases. As a result,

the particles of incense move rapidly and thus intermix with the particles of air rapidly so, we get smell of incense even when we are sitting at a distance.

On the other hand, when incense stick is not lit, temperature is low, and hence kinetic energy of incense particles is less. As a result particles of incense stick do not intermix with air rapidly, so that we have to go near the incense stick to get its smell (when it is not lit).

Conclusion: From above discussion we led to conclude that, particles of matter are never at rest, but are moving continuously. And their average speed increases with increase in temperature due to increase in kinetic energy of moving particles. As a result, rate of intermixing or rate of diffusion increases.

Experiment 2: Drop a crystal of copper sulphate ($CuSO_4$) or potassium permanganate ($KMnO_4$) into a glass of hot water and another containing cold water. Allow the crystals to settle at the bottom without stirring the solution.

Observation: The crystals of $CuSO_4$ or $KMnO_4$ dissolves more quickly in hot water than in cold water.

Explanation: The particles of $CuSO_4$ or $KMnO_4$ crystals do not move and thus remain fixed in their respective positions due to strong forces of attraction. On the other hand, the particles of cold water are continuously moving and thus possess some kinetic energy. Because of their K.E., the particles of cold water overcome the forces of attraction between particles of $CuSO_4$ or $KMnO_4$ crystals. As a result, the particles of $CuSO_4$ or $KMnO_4$ crystals move in between the spaces of particles of cold water and the crystals of $CuSO_4$ or $KMnO_4$ dissolves in cold water.

As the temperature rises the K.E. of both. i.e. particles of $CuSO_4$ or $KMnO_4$ crystals and water increases. Due to greater K.E., the forces of attraction between particles of $CuSO_4$ or $KMnO_4$ crystals decrease. Further due to greater K.E., the particles of water (hot water) move faster and more easily overcome the weaker forces of attraction between particles of $CuSO_4$ or $KMnO_4$ crystals than cold water.

As a result, the rate of intermixing (or rate of diffusion) increases and $CuSO_4$ or $KMnO_4$ crystals dissolves more quickly in hot water.

Conclusion : From above discussion, we led to conclude that particles of matter are continuously moving and their average speed increases with increase in temperature due to increase in K.E. of moving particles. As a result, rate of diffusion becomes faster and hence solid dissolves more quickly in hot water than in cold water.

Experiment 3 : Take two beakers filled with water and put a drop of blue or red ink slowly along the sides of the first beaker and honey in the same way in the second beaker. Keep them undisturbed for some time.

Observation : The particles of ink quickly get distributed in water. As a result, colour of ink spreads throughout the water. On the other hand, particles of honey take a long time to. get distributed throughout the water.

Explanation : The particles of ink move rapidly due to weak forces of attraction between them. As a result, the particles of ink rapidly get into the spaces between the particles of water and hence quickly get evenly distributed in water. In contrast, the particles of honey move slowly due to strong forces of attraction between them. As a result, it takes a long time for the particles of honey to get into the spaces between the particles of water and to get evenly distributed throughout water.

Conclusion : From above discussion we led to conclude that particles are continuously moving but their average speed at any particular temperature depends upon the forces of attraction : **stronger the forces of attraction, lower is the average speed, and thus lower will be the rate of diffusion.**

1.2.3 Particles of matter attract each other

The particles of matter have a force acting between them, which keeps these particles together. To illustrate this force of attraction, we perform the following experiments.

Experiment 1: Take an iron nail, a piece of chalk and a rubber band. Try to break each one of them by hammering, cutting or stretching.

Observation & Explanation : It is most difficult to break the iron nail, followed by piece of chalk & then rubber band.

This is because, the particles of iron nail are held together by the strongest forces followed by the piece of chalk, while particles of rubber band are held together by weakest forces of attraction.

Conclusion : From above experiment, we conclude that **"Particles of matter attract each other".** The strength of this force, however differs from one kind of matter to other.

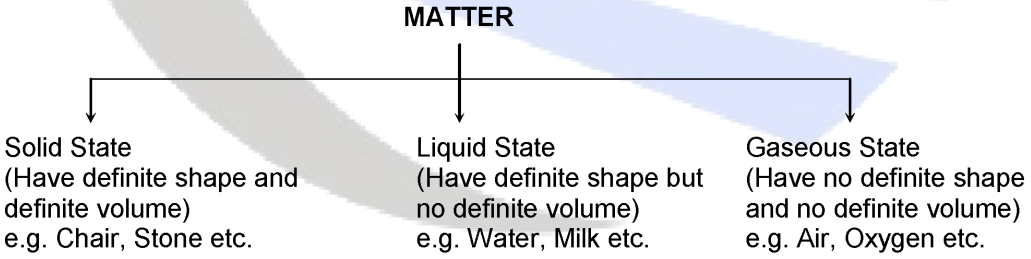
Experiment 2 : Try to break the stream of tap water with your fingers.

Observation & Explanation : The stream can not be cut because particles of water attract each other strongly and hence tend to remain together.

Conclusion : Particles of matter attract each other.

2. STATES OF MATTER

The matter around us exists in three physical states on the basis of physical properties.



(a) Water exists as ice (solid state), as liquid (liquid state) and as steam (gaseous state).

(b) Bones and teeth are solids, the blood that flows in our veins is a liquid and the air that we breathe in is a gas.

2.1. SOLID STATE

Matter in solid state has a definite shape and definite volume.

Examples: Silver, copper, sand, sugar, gold, ice, wood, stone, book, needle, pencil, piece of thread, etc.

2.1.1 Properties of Solids

(a) Solids have a definite shape and distinct boundaries: The solids have a fixed shape and distinct boundaries due to small inter particle distances and strong forces of attraction. e.g. when a pen is put in different containers, it does not change its shape.

However, when sugar and salt, are placed in different containers, they take up the shape of the containers, yet they (sugar & salt) are solids. This is because, the shape of individual sugar or salt crystal remains fixed whether we take it in our hand, or put in a jar or in plate.

(b) Solids possess rigidity: The solids have the tendency to maintain shape, when some outside force is applied (known as rigidity). They may break when dropped or hammered.

However some solids like rubber band, changes its shape when stretched under influence of force, but it regains its original position, when force is withdrawn. However, if excessive force is applied, rubber band breaks.

(c) Solids have a definite volume : Solids have a definite volume as they can not be compressed due to small inter particle distances.

However some solids like sponge can be easily compressed. This is because sponge has minute holes in which air is trapped so that when we press it, air is expelled and the sponge is compressed.

(d) Solids do not possess the property of diffusion :- The solids do not have the property of diffusion into other solids (i.e. the particles of two solids do not intermix). This is because the particles of solid do not move much from their positions due to small inter particle distances and strong forces of attraction.

However particles of some solids like chalk have diffused into other solids like blackboard. i.e. if we write something on blackboard with the chalk and leave it uncleaned for sometime, we will find that it becomes difficult to clean the board. This is because of diffusion of chalk particles in between the particles of blackboard and hence it becomes difficult to rub them off.

2.2 LIQUID STATE

The matter in liquid state have a definite volume and no definite shape.

Examples : Water, blood, benzene, alcohol, milk, petrol, cooking oil, juice, cold drink etc.

2.2.1 Properties of Liquids

(a) Liquid do not have fixed shape but have a fixed volume : The liquids have a fixed volume due to strong inter particle forces of attraction in them which are strong to keep the particles together.

But these forces are not strong enough to keep the particles in fixed position, therefore, liquids do not have a fixed shape, they take up the shape of vessel in which they are placed.

(b) Liquids are not rigid but have a property to flow : Liquids can flow and change shape due to larger inter particle distances and weaker forces of attraction in them, than solids. Thus liquids are not rigid but they possess fluidity (i.e. they have property to flow).

(c) Liquids possess the property of Diffusion : Due to larger inter particle distances in liquids than in solids, the particles of a liquid have more freedom of motion than solids. Thus solids, liquids and gases all can diffuse into liquids as discussed below:

(i) Diffusion of solids into liquids: When a crystal of copper sulphate or potassium permanganate (solid) is added to water (liquid), the particles of $CuSO_4$ or $KMnO_4$ quickly diffuse in between the particles of water to form a solution.

(ii) Diffusion of liquids into liquids: When water is added to alcohol or vice-versa, the two liquids quickly diffuse into each other to form a solution.

(iii) Diffusion of gases into liquids: Some gases especially O_2 and CO_2 diffuse into water i.e. dissolve in water. So that aquatic animals can breathe under water due to presence of dissolved oxygen in water.

Thus solids, liquids & gases – all can diffuse into liquids. However, the rate of diffusion of liquids is much higher than that of solids.

(a) Rate of diffusion of different liquids :- Different liquids have different rates of diffusion. For example a drop of blue or red ink diffuses faster than a drop of honey into water.

(b) Rate of diffusion increase with rise in temperature :- Rate of diffusion increases with rise in temperature, hence sugar dissolves much more quickly in hot water than in cold water.

2.3 GASEOUS STATE

The matter in gaseous state has neither definite volume nor shape.

Examples : Air, oxygen, nitrogen, hydrogen, ammonia, carbon dioxide, compressed natural gas (CNG) etc.

2.3.1 Properties of Gases

(a) Gases neither have a definite shape nor a definite volume : Gases do not have a definite shape, but they acquire the shape of the vessel in which they are placed.

Similarly, gases do not have a definite volume, but attain the volume of container to which they are transferred.

(b) Gases have maximum fluidity and least rigidity : The gases have high fluidity (property to flow) and least rigidity (tendency to maintain shape) due to large inter particle space and weak inter particle forces of attraction in them.

(c) Gases are highly compressible : The gases are highly compressible due to large inter particle spaces in them. Due to high compressibility, large volume of a gas can be compressed into a small cylinder and transported easily. e.g. L.P.G. gas & O_2 supplied to hospitals in cylinders is compressed gas. Similarly these days, compressed natural gas (CNG) is used as a fuel in vehicles.

This can be explained by the following experiment.

Experiment to illustrate comparison between solids, liquid and gases in terms of compressibility.

Or

Experiment to study the compressibility of solids, liquids & gases : Take three syringes (about 100ml) and close their nozzles by rubber corks. Now remove the pistons from all syringes. Fill some water (liquid) in second syringe and chalk pieces (solid) in the third & leaving first syringe untouched. Now insert pistons back into syringes.

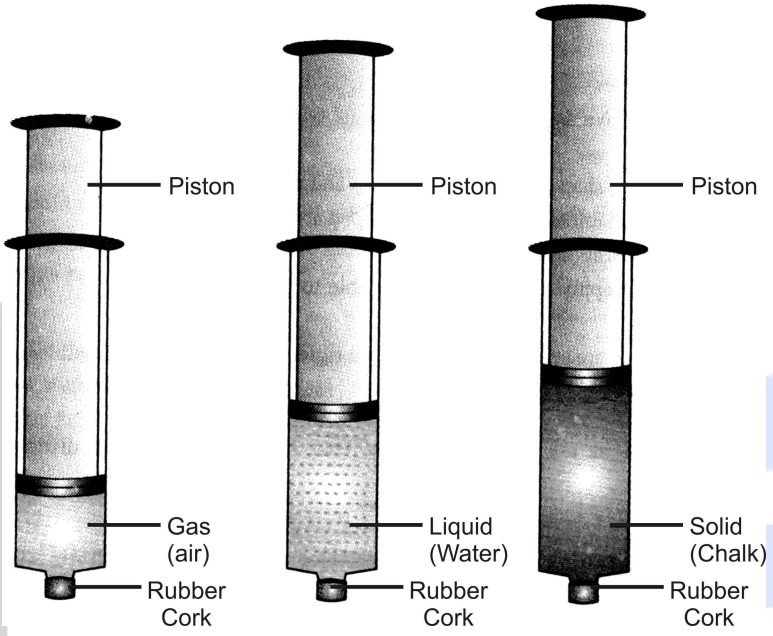


Figure 3

Observation and explanation: The piston of first syringe (left untouched) which contained air (gas) was easily pushed in. The piston of the second syringe which contained water (liquid) was pushed in only a little, while the piston of the third syringe which contained chalk pieces could not be pushed in at all. Thus, air is easily compressible, water is almost incompressible, while chalk pieces are completely incompressible.

Conclusion: The spaces between particles of gases are maximum, intermediate in liquids and minimum in solids. Thus, gases are highly compressible, liquids are almost incompressible, while solids are completely incompressible.

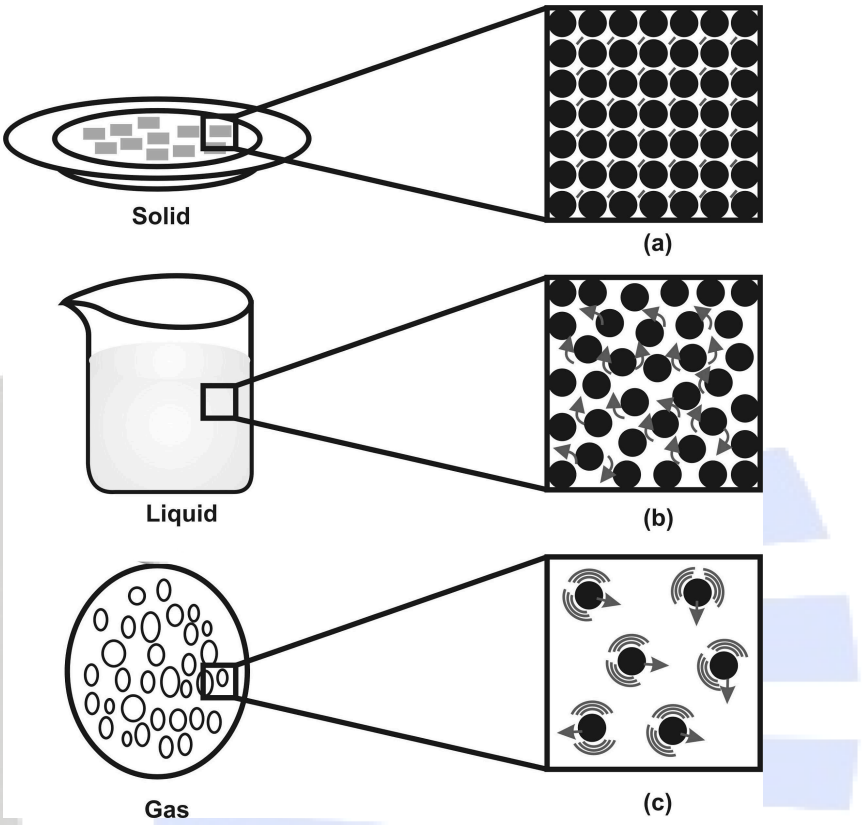
(d) Gases have low density : Gases have low density as compared to solids and liquids due to large inter molecular spaces in them. i.e. mass per unit volume of a gas is small and hence gases have low density.

(e) The Kinetic energy of particles in the gaseous state is quite high :- Due to large inter particle distances and weak forces of attraction, the particles of a gas can move freely & thus have large rotational, translational and vibrational motion and due to large translational motion, their kinetic energy is quite high which can be further increased by increasing the temperature of gas.

(f) Gases exert pressure : Due to larger inter particle distances and weaker inter particle forces of attractions, particles of a gas are moving continuously in different directions with different velocities. Due to this random motion, the particles of gas collide with each other and also with the walls of the containing vessel. Due to these collisions, the particles of the gas exert a force

on the walls of the container. This force per unit area exerted by the particles of the gas on the walls of containing vessel is called the **pressure of the gas**.

The motion and inter particle distances in solids, liquids & gases are as shown in fig.



a, b and c show the magnified schematic pictures of the three states of matter. The motion of the particles can be seen and compared in the three states of matter.

Figure 4

(g) Gases diffuse very rapidly : Due to random motion, the particles of one gas readily move into spaces between the particles of the other gas. (called diffusion)

Thus, gases diffuse very rapidly, rate of diffusion increases with increase in temperature.

The most familiar example of diffusion of gases is found in our homes, e.g. we come to know what is cooked in the kitchen without even entering there, by the smell due to rapid diffusion. (i.e. rapid intermixing of particles of aroma with particles of air). Since rate of diffusion becomes faster at high temperature the smell of hot cooked food travels faster than that of the cold food.

Differences in the characteristics of states of matter (solids, liquids & gases)

S.No.	Property	Solid	Liquid	Gas
1.	Packing	The particles are most closely packed.	The particles are less closely packed than solids.	Particles are at sufficient distances from each other.

2.	Shape	Solids have definite shape.	Liquids do not have definite shape. They assume the shape of container.	Gases do not have a definite shape. They assume the shape of container.
3.	Volume	Solids have definite volume.	Liquids have definite volume.	Gases do not have definite volume. They assume the volume of container.
4.	Density	Solids have high density.	Liquids have less density than solids but more than gases.	Gases have the least density.
5.	Diffusion	Solids have no tendency to diffuse.	Liquids have a tendency to diffuse slowly.	Gases diffuse rapidly.
6.	Rigidity	Rigid.	Fluid.	Fluid.
7.	Compressibility	Negligible.	Very low.	High.
8.	Inter-molecular forces of attraction	Maximum.	Less than solids.	Negligible.
9.	Kinetic energy of molecules	Least.	More than solids.	Very high.

- Among air and exhaust from chimneys, the mass of exhaust from chimneys (which contains some heavier gases like CO_2, SO_2, NO_2 etc and minute solid particles) is much higher than air (which contains only O_2 & N_2 as main constituents). Therefore density of exhaust from chimneys is expected to be higher than that of air. Thus order of densities among different gases like air & exhaust from chimneys is - **air < exhaust from chimneys.**
- Among honey and water, the mass of particles of honey is much higher and inter particle distances are much smaller than those in water. Therefore, the density of honey is higher than that of water. Thus order of densities among different liquids like water and honey is - **water < honey.**
- Among chalk and iron, the mass of the particles of iron is much higher and inter particle distances are much smaller than those in chalk (since particles of iron are very closely packed than of chalk) Therefore, density of iron is much higher than that of chalk. Cotton is also a solid, but its density is lower than that of other solids like chalk & iron due to spaces in which air is trapped. Thus order of densities among different solids like cotton, chalk & iron, is - **cotton < chalk < iron.**

Order of densities among solids, liquids & gases :

Now since gases have larger inter particle distances than liquids, they have lower densities than liquids.

i.e. air < exhaust from chimneys < water < honey. But since liquids have larger inter particle distances than solids, they have lower densities than solids.

i,e water < honey < cotton < chalk < iron thus the **overall order of increasing density is: air < exhaust from chimneys < water < honey < cotton < chalk < iron.**

3. LATENT HEAT

Latent heat: The amount of heat required to change the state of matter from one state to another without rise in temperature is known as latent heat of that substance.

Latent heat is of two types:

(i) Latent heat of fusion: The amount of heat required to change the state of matter from solid state to liquid state without rise in temperature is known as latent heat of fusion.

(ii) Latent heat of vaporisation: The amount of heat required to change the state of matter from liquid state to gaseous state without rise in temperature is known as latent heat of vaporisation.

4. CAN MATTER CHANGE ITS STATE?

Some substances may exist in all the three states of matter in different conditions, for example, water can exist in three states of matter:

(i) in solid state as ice.

(ii) in liquid state as water.

(iii) in gaseous state as water vapours or steam.

This inter conversion of matter can be achieved by the following two ways :

(a) by changing the temperature.

(b) by changing the pressure.

Now question arises, that :

How does the matter convert from one state to another by changing temperature & Pressure ?

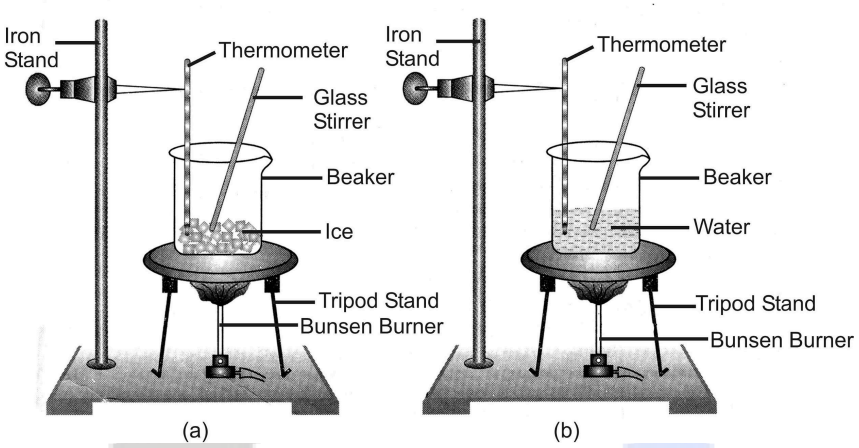
What is the effect of change of temperature and pressure on three states of matter ?

4.1 EFFECT OF CHANGE OF TEMPERATURE

Effect of temperature on the change of state of matter can be explained by the following experiment :

4.1.1 Increasing the temperature by heating

Experiment: Take about 150g of ice in a beaker and suspend a laboratory thermometer so that its bulb is in contact with the ice (figure 5). Now start heating the beaker.



(a) Conversion of ice to water, (b) Conversion of water to water vapour.

Figure 5

Observation: On heating, it will be observed that first the ice (solid) melts to form water (liquid). If the heating is carried out further, the liquid (water) will change to gaseous state (vapour).

Discussion :

(i) Change of state from solid to liquid (fusion): When heat is supplied to a solid (ice), the kinetic energy of solid particles increases due to increase in temperature. As a result, solid particles start vibrating with high speed. On further increasing temperature, the heat energy overcomes the forces of attraction between solid particles. At this temperature, the particles leave their fixed positions, start flowing and thus solid melts to form a liquid.

The temperature at which a solid melts to become a liquid at atmospheric pressure is called its '**melting point'**. This process of change of solid state into liquid state is also called **'Fusion'**.

$$\text{Solid} \xrightarrow{\text{Heat}} \text{Liquid}$$

(ii) Change of state from liquid to gas (vaporisation) : When heat is further supplied to the liquid, kinetic energy of liquid particles increase further, as a result of this, inter-particle distance increase (app. 100 times). Hence, the magnitude of forces of attraction holding the liquid particles becomes so less that, the liquid particles break apart from the liquid state and change to gaseous or vapour state.

The pressure of air in atmosphere is called **atmospheric pressure.**

$$\text{Liquid} \xrightarrow{\text{Heat}} \text{Gas}$$

4.1.2 On decreasing temperature by cooling

(i) **Change of state from liquid to solid (solidification):** When water is cooled (by lowering its temperature) it gets changed into solid 'ice'. The process of changing a liquid into a solid by cooling is called "freezing". When the temperature is lowered particles of the matter lose energy due to which they move slowly. If we continue to lower the temperature then the particles of substance stops moving and vibrates around their fixed position. At this point the liquid freezes and gets converted into solid.

$$\text{Liquid} \xrightarrow{\text{Cool}} \text{Solid}$$

The amount of heat energy that is required to change 1kg of solid into liquid at atmospheric pressure at its boiling point is called, **latent heat of vaporization.**

(ii) **Change of state from gas to liquid (condensation):** When the temperature of gaseous state of matter is lowered, it is converted into liquid state. So, the process of changing a gas (or vapour) to a liquid by cooling, is called **condensation.**

For example, when temperature of water vapour is lowered it gets converted into liquid water.

Explanation: when the temperature is lowered then the particle of gaseous state lose energy and their movement slow down, because of this they move closer together until they start being attracted to each other and form a liquid.

$$\text{Gas} \xrightarrow{\text{Cool}} \text{Liquid}$$

Conclusion: From the above discussion, we led to conclude that one state of matter can be changed into another or vice-versa by changing the temperature.

$$\text{Solid State} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Liquid State} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Gaseous State}$$

Remember: Melting point of ice is same as the freezing point of water. It is O^0C or 273K under one atmospheric pressure. In other words, at O^0C both ice and water exist together. But particles in water have more energy as compared to particles in ice at same temperature i.e. at 0^0C. This is because during the change of state from ice to water, heat energy equal to latent heat of fusion has been absorbed.

The particles of steam have higher energy than the particles of liquid water at same temperature i.e. at 100^0C. This is again because, during change of state from liquid water to steam or vapours, heat energy equal to latent heat of vaporization has been absorbed.

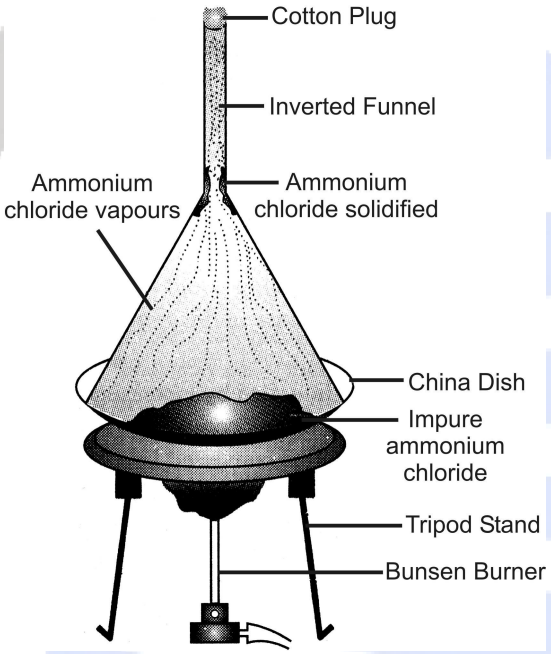
4.2 SUBLIMATION

Sublimation is the process of conversion of a solid directly into a gas or vice-versa without changing into liquid state.

$$\text{Solid} \underset{\text{Cooling}}{\overset{\text{Heating}}{\rightleftharpoons}} \text{Vapour (or gas)}$$

Experiment to demonstrate sublimation : Take some ammonium chloride (NH_4Cl) in a china dish, and cover it with an inverted funnel as shown in figure plug the stem of funnel with cotton. Now heat slowly.

Observation and Discussion : Ammonium chloride, will convert into vapours which will deposit on the inner side of the funnel as sublimate. The vapours in turn, condense on the cooler portions of the funnel to give pure NH_4Cl.



Sublimation of ammonium chloride

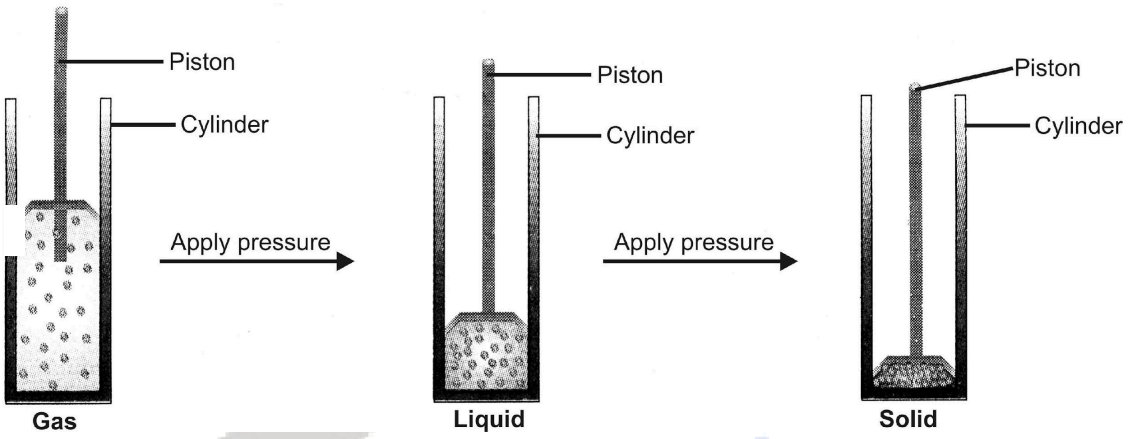
Figure 6

Conclusion: A change of state directly from solid to gas without changing into liquid (or vice-versa) is called **sublimation.**

4.3 EFFECT OF CHANGE OF PRESSURE

The effect of pressure on the states of matter can be discussed by the following experiment:

Experiment : Take a gas in a cylinder and apply pressure by pushing the piston down as shown in figure 7.



By applying pressure, particles of a gas come close together

Figure 7

Observation: A gas can be first liquefied and then converted into solid.

Liquification of gas : A gas can be liquefied by applying pressure or by lowering the temperature. For every gas, there is a minimum temperature above which gas cannot be liquefied by applying pressure. This temperature is called "critical temperature". The minimum pressure which is required to liquefy a gas at critical temperature is called "critical pressure".

Discussion: When the particles of fluid are present under low pressure, they are in the gaseous state as shown in the figure (a). When some high pressure is applied on the gas, the forces of attraction between gas particles become so high that they bind the gas particles together to form the liquid state [figure (b)]. Ultimately under very high pressure, the forces of attraction become so strong that the liquid may change into the solid state [figure (c)].

For example, CO_2 gas can be liquefied easily either by applying pressure or by reducing the temperature. However, CO_2 is cooled (by reducing temperature) under high pressure, it can be directly converted into solid CO_2 called **'dry ice'.**

Conclusion: From above discussion, It is clear that a gas can be liquefied by increasing pressure and decreasing temperature and vice, versa hence, it follows that both pressure and temperature determine the state of a substance, whether, it will be a solid, liquid or gas. The entire change has been represented as below:

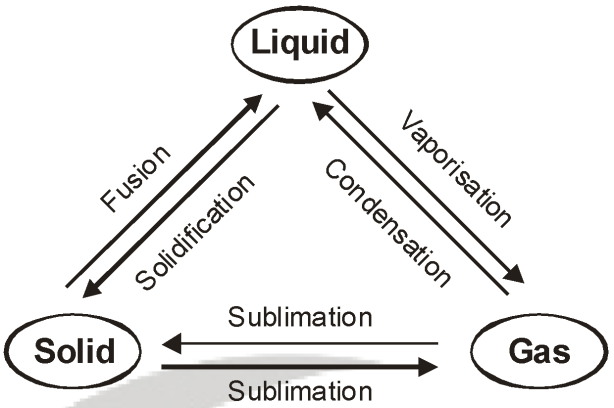


Figure 8

5. EVAPORATION

The phenomenon of change of a liquid into vapours at any temperature below its boiling point is called 'evaporation'. Evaporation is a surface phenomenon i.e. only the particles present on the surface are involved.

5.1 FACTORS AFFECTING EVAPORATION

5.1.1 Surface Area

Greater is the surface area more is the rate of evaporation. This is because only the particles on the surface of the liquid get converted into vapours.

For example, we often spread the wet clothes in air to dry them. By doing so, the surface area available for evaporation of water increases and hence the clothes get dried up soon.

5.1.2 Increase in temperature

The rate of evaporation increases with increase in temperature due to increase in K.E. of liquid particles. This is because, due to increase in K.E., the liquid particles can more easily overcome the forces of attraction of neighbouring particles on the surface of liquid and hence can more easily get converted into vapours.

For example, evaporation of a liquid occurs at a faster rate in summer than in winter.

5.1.3 Decrease in Humidity

By humidity we mean, the amount of water vapour present in air. The air around us can hold only a certain definite amount of water vapours at a particular temperature. Now in case, humidity of air is already high i.e. the amount of water vapours in the air is already high, then air can hold only a little more amount of vapours to reach that optimum level (as air can hold only a certain definite amount of water vapours). Therefore the rate of evaporation decreases.

For example, we sweat a lot in hot and humid weather than in dry weather because, air already has high amount of water vapours in humid and hot weather. Therefore, the sweat liquid that comes out of our skin does not evaporate and remains sticking to our body.

5.1.4 Increase in the speed of wind

The rate of evaporation increases with increase in wind speed. This is because, due to increase in wind energy, the liquid particles move away with the wind and thus decreasing water vapours in the surroundings.

For example, wet clothes dry faster on a windy day due to increase in wind speed and thereby increasing the rate of evaporation. Similarly we usually sit under the fan during summer days (when we sweat a lot) because fan increases the wind speed around us, thereby increasing the rate of evaporation and making us feel more comfortable (since evaporation causes cooling).

5.1.5 Nature of Liquid

The rate of evaporation also depends upon the nature of the liquid. In other words, lesser is the boiling point, more is the tendency of the liquid to evaporate or to change into vapours. It can be explained more clearly by the following example :

Alcohol with a boiling point 351K or 78^0C evaporates much more quickly than water with a boiling point 373K (or 100^0C). This is because the inter particle force of attraction are weaker in alcohol than in water, so that the particles of alcohol can leave the liquid surface to form vapours more easily than the particles of water and thus rate of evaporation of alcohol is faster than that of water.

The effect of factors like surface area, temperature, humidity and wind speed on the rate of evaporation of liquids can be explained more clearly by performing the following experiment :

Experiment:

Step I : Take 5ml of water in a test tube and keep it under a fan.

Step II : Take 5ml of water in an open china dish and keep it under a fan.

Step III : Take 5 ml of water in an open china dish and keep it inside a cupboard.

Step IV : Repeat all above three steps of experiment on a rainy day or humid weather and record the time and days taken for evaporation process in all cases.

Observation :

(i) The water taken in a test tube will evaporate slowly than the water taken in two open china dishes.

(ii) The water taken in open china dish placed under fan will evaporate more quickly then water taken in open china dish placed inside a cup-board.

(iii) The first three processes will take longer time for evaporation process on a rainy day or humid weather

Discussion: The surface area of water exposed to atmosphere is minimum in case of test tube, so, it takes a long time (2/3 days) for 5ml of water to evaporate. Although surface area of 5ml of water taken in two open china dishes is the same, yet water in the china dish

placed under the fan evaporates more quickly than the water in china dish placed inside a cupboard. This is because wind speed increase due to fan and thereby increases rate of evaporation.

On the other hand, three processes will take longer time for evaporation process on a rainy day or humid whether.

This is due to the reason that

(i) on a rainy day, temperature is reduced and thus rate of evaporation is decreased

(ii) in a humid weather, the amount of water vapours in air are already high and thus rate evaporation is decreased.

Conclusion: From above discussion we led to conclude that, the rate of evaporation of liquid increases with

(i) increase in surface area exposed to the atmosphere.

(ii) increase in temperature.

(iii) increase in wind speed.

(iv) decrease in humidity (i.e. amount of water vapours present in air)

5.2 HOW DOES EVAPORATION CAUSES COOLING ?

During evaporation, only the liquid particles having high K.E. leave the surface of the liquid and get converted into vapours. As a result, the average K.E. of the remaining particles of the liquid decreases and hence temperature falls, thus evaporation causes cooling.

It can be explained more clearly by the following example

Place some water in an open vessel. The water keeps on evaporating. For evaporation to occur heat energy is taken from water. The particles of water in turn, absorb energy from the surroundings to regain the energy lost during evaporation. This absorption of energy from the surroundings makes the surroundings cool. Hence evaporation causes cooling.

5.3 SOME EXAMPLES OF COOLING CAUSED BY EVAPORATION FROM DAILY LIFE

(i) Pouring of Acetone on palm : We feel cool when we pour some acetone on our palm. This is because, the energy needed for evaporation is taken from the palm which, in turn, feels cooling.

(ii) Sprinkling water on roof or open ground in summer: We often sprinkle water on the roof of the house or open ground on a hot sunny day. The reason being that the large heat of vaporization of water helps to cool the hot surface.

(iii) Wearing cotton clothes in summer: During summer, we sweat or perspire a lot. The cotton, being a good absorber of water, absorbs the sweat and exposes it to the atmosphere for easy evaporation. Consequently our body feels cool (because evaporation causes cooling). Thus, we wear cotton clothes in summer.

(iv) **Water droplets are seen on the outer surface of a glass tumbler containing ice cold water:** This is due to the reason that, water vapours present in air, on coming in contact with the cold surface of the glass, lose energy and get condensed or get converted into the liquid state which are see as water droplets.

5.4 DIFFERENCE BETWEEN BOILING AND EVAPORATION

Boiling	Evaporation
1. Boiling takes place at a particular temperature when the liquid is heated	1. Evaporation occurs on its own at all temperatures.
2. Boiling is a bulk phenomenon i.e. it takes place from the whole liquid.	2. Evaporation is a surface phenomenon i.e. it takes place only from the surface of the liquid.
3. No cooling is caused during boiling.	3. Cooling is always caused by evaporation.