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MATTER IN OUR SURROUNDINGS

Matter

Matter is anything that has mass and occupies space. Examples of matter are iron, wood, oil, kerosene, petrol, rock, minerals, water, air, coal, etc. Matters are classified on the basis of physical and chemical properties. On the basis of physical properties, matter is classified as solid, liquid and gas. On the basis of chemical properties, matter is classified as elements, compounds and mixtures. Matter is made up of particles.

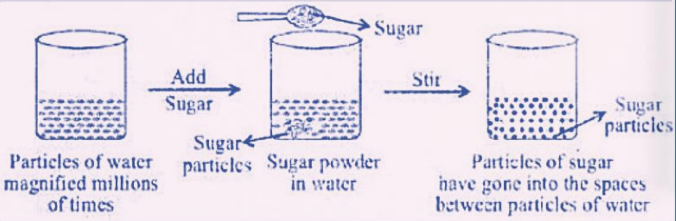
Characteristics of Particles of Matter

The various characteristics of particles of matter are:

- They are extremely small in size.
- They have spaces between them.
- They are constantly moving.
- They attract each other. The force of attraction between particles of same substance is known as cohesion. Particles of different matter exert different amount of force of attraction.

To demonstrate that particles of matter have spaces between them

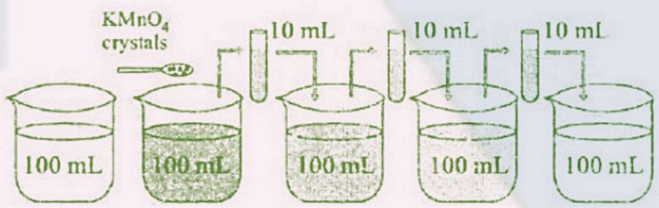
- Take a beaker and fill it half with water.
- Mark the level of water.
- Dissolve some salt or sugar in it.
- **Observation:** Water level remains the same as earlier.
- **Conclusion:** When sugar or salt is dissolved in water, the particles of sugar or salt get into the spaces between particles of water.



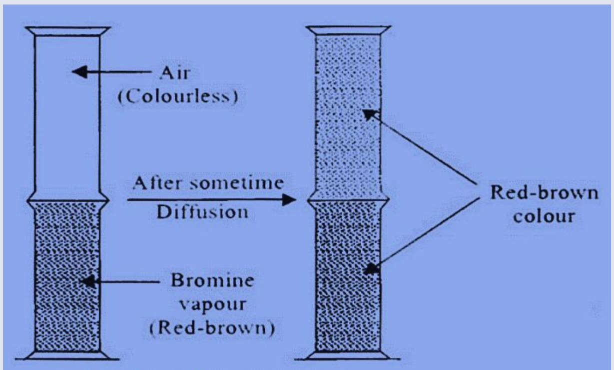
To demonstrate that the particles of matter are very small

- Take 2-3 crystals of potassium permanganate and dissolve in 100 mL of water.
- Take 10 mL of this purple solution and mix with 90 mL of fresh water in second beaker.
- Take 10 mL of this second solution and mix with 90 mL of fresh water in third beaker.
- Take 10 mL of this third solution and mix with 90 mL of fresh water in fourth beaker.
- Dilute the solution five to six times.

- Observation: The water in the last beaker is still coloured and is light pink now.
- Conclusion: Just 2-3 crystals of potassium permanganate impart colour to a large volume of water. It shows that the particles of matter are very very small.



- **Diffusion**
  - The intermixing of particles of two substances on their own is called diffusion.
  - The rate of diffusion increases on heating, since with increase in temperature kinetic energy of the particles increases and they move faster.
  - Diffusion occurs in gases, liquids and solids. The diffusion is fastest in gases because the particles in gases move very rapidly. The diffusion is slowest in solids because the particle in solids do not move much. The diffusion in liquids is, however, much faster than that ill solids and slower than that in gases.



Diffusion of bromine vapour (or bromine gas) into air

To demonstrate that particles of matter are continuously moving

Experiment-I

- Light an agarbatti in one corner of a room.
- **Observation:** The fragrance spreads in the whole room quickly.
- Conclusion: The vapours of agrabatti are mixed with air and move rapidly in the room. Thus particles of matter are in continuous motion (Diffusion).

Experiment-II

- Put a few crystals of copper sulphate in a beaker containing water.
- Do not stir.
- **Observation:** The water of the whole beaker turns blue after sometime.
- **Conclusion:** The spreading of blue colour of copper sulphate is due to the movement of copper sulphate and water particles (Diffusion).

To demonstrate the strength of attractive forces between particles of different kinds of matter

- Take an iron nail, a piece of chalk and a cube of ice.
- Try to break each of them by beating with a hammer.
- Observation: It is very easy to break the piece of chalk into smaller particles. It requires more force to break a cube of ice whereas the iron nail does not break at all.
- Conclusion: The force of attraction between particles of chalk is weaker than ice while the force of attraction between particles of iron is very strong.

ILLUSTRATION

1. When we smell the odour of a rose our olfactory nerves are sensing molecules of the scent. Explain how smelling a rose demonstrates that molecules are always moving.

Sol. The molecules that give roses their aroma evaporate from the surface of the flower. Once in the gas phase, they collide countless times with other gas molecules, moving slowly away from the rose, when they reach a nose, they are sensed by the olfactory sensors.

2. Even one or two crystals of potassium permanganate can impart colour to a very large volume of water. Which characteristic of matter is illustrated by this observation?

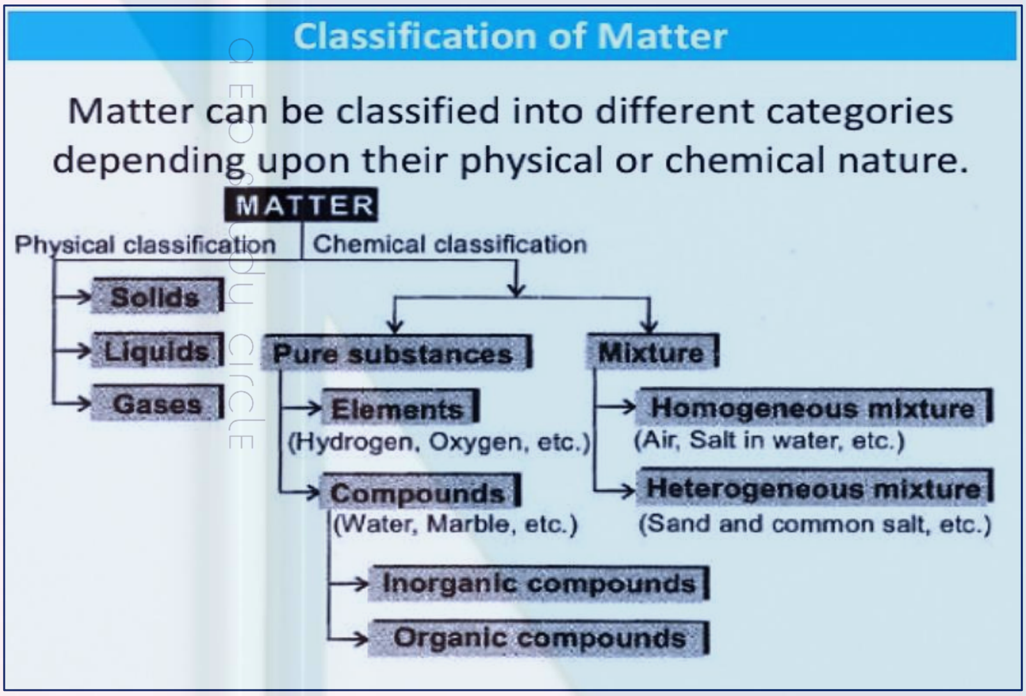
Sol. From this observation we conclude that each potassium permanganate crystal is made up of millions of small particles which keep on separating and imparting colour to more and

EFFECT OF TEMPERATURE ON PARTICLE MOTION

Particle motion always increases with rise in temperature. Upon heating, the kinetic energy of the particles increases. This leads to increase in their motion.

Points to Remember

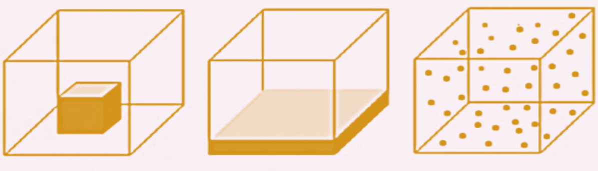
- Anything or everything which occupies space and has mass is known as matter,
- According to ancient Greeks and Indian philosophers, matter is made from five constituents or tatvas namely air, earth, water fire and sky.
- Matter has two ways of classification. These are physical and chemical classification.
- Matter Is made up of particles which are characterised by shape, size and mass.
- Interparticle spaces are present in all types of matter. Their size and number can vary from one matter to the other.
- Matter is always seen as an aggregate of small or tiny particles which cannot be seen individually by naked eye
- Particles present in a matter are in a state of motion. It is least in the solid state and maximum in the gaseous state.
- Interparticle attraction depends the physical state of the matter.
- Particle motion generally increases with the rise in temperature.



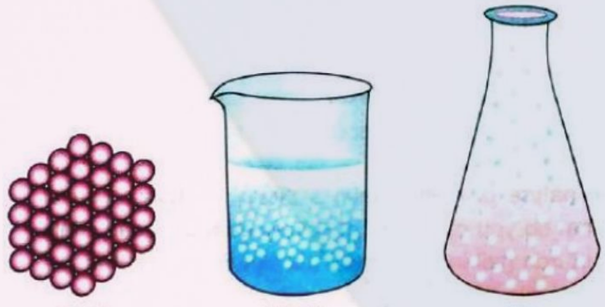
Classification of Matter on the Basis of Their Physical Properties

On the basis of physical properties, all the matters are classified into three groups namely solid, liquid and gas. In other words, it can be said that matter exists in three physical states namely solid, liquid and gas.

States of Matter



matter in our surrounding



Interparticle spaces in the three states of matter.

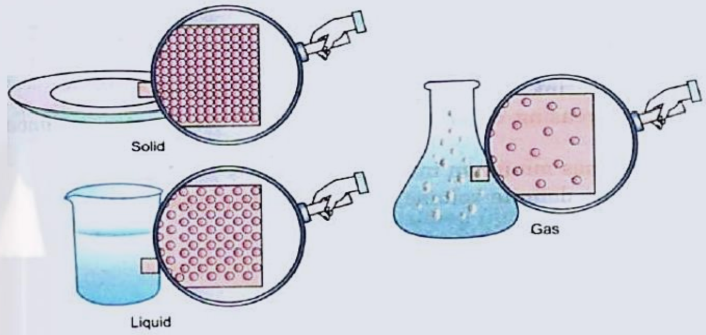


Illustration of three states of matter in terms of interparticle spaces.

THE SOLID STATE

Solids are known for their hardness and rigid nature. The important characteristics of the solid state are listed.

1. Solids have fixed shapes

Solids generally have fixed shapes. They do not change their shapes even when put in different containers. For example, blue crystals of copper sulphate have needle like shape which they retain whether kept in a beaker or in a china dish or placed on the palm of our hand.

2. Some solids can change their shape under force but regain the same when the applied force is removed.

A rubber band can be stretched on applying force. However, when the stress or the force is removed, the rubber band regains its original shape.

3. Solids keep their volume which means that they have fixed volume.

Volume is the space occupied by a substance. The solids have fixed .volume. Actually in the solid state, the constituents are very closely packed in space and interparticle force are strong. As a result, the solids keep their volume. The density of a solid may be defined as :

Mass occupied by a solid per unit volume and is obtained by dividing the mass of a particular solid by the volume occupied by that mass of the solid.

The unit of density : kg/L or kg/dm^3.

Here kg is unit of mass while litre (L) or dm^3 is the unit of volume (1 L = 1 dm^3).

4. Solids can be hardly compressed on applying pressure.

It is very difficult to compress a solid on applying pressure. For example, we cannot press a piece of stone by applying pressure with our hands. Actually, the constituent particles are so closely packed in a solid that they either do not come closer or do so only slightly when a high pressure is applied. However, there are some exceptions. For example, a sponge made from some foam or rubber material can be easily compressed.

> Please note that density is maximum in the solid state of a substance. The relative close packing in different solids can be compared in terms of their densities. More the density greater will be the close packing of the constituent particles in a solid.

In fact, there are very small or pin size holes throughout the body of the sponge in which air is present. When pressure is applied, the air is expelled from these holes or pores and the sponge gets compressed.

5. Solids have negligible kinetic energy of the particles.

The kinetic energy is linked with movement of the particles from one place to the other. Since the constituents in the solid state are very closely packed, they have negligible kinetic energy. That is why solids do not flow.

6. Solids do not have the property of diffusion.

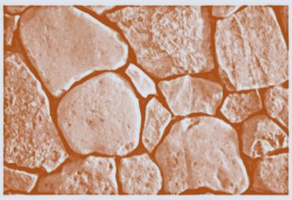
When particles of one substance occupy the vacant spaces present in the particles of the other substance, this is called diffusion. Due to the absence of kinetic energy in the particles of a solid, there is hardly any diffusion. For example, let us keep pieces of metals like copper and silver side by side. They may touch each other but they will not mix. However, in certain cases, diffusion is noticed when the two solids are kept in contact for a long time. For example, if we try to rub something written on the black board by a chalk after a gap of about a week or so, it becomes rather difficult to rub the same. Probably some particles of chalk in the form of dust have diffused in the pores of the black board which is normally made from some wooden material.

Examples Rocks. stone, wood, sand, crystalline solids, metals like iron, copper, nickel and ice etc. are some typical examples of the substances which are in the solid state.

Solid

The various properties of solids are:

- They have fixed shape and fixed volume.
- They have closely packed particles. There is a strong force of attraction between the particles that holds them together in fixed position.
- They cannot be compressed.
- They have high density.
- They do not flow.



Stone (Solid)

THE LIQUID STATE

We have seen that rigidity is maximum in the solid state and fluidity or particle motion is negligible. In the liquid state of a substance, both these characters are different. The liquids are less rigid than the solids and the molecular motion is also comparatively more. Both these characteristics in the liquid state are because of the presence of weaker interparticle forces. The important characteristics of the liquid state of a substance are listed.

1. Liquids do not have fixed shapes.

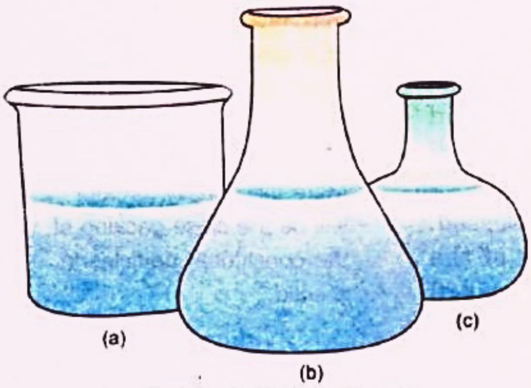
Liquids do not have fixed shapes and take up the shape of any container in which these are put.

ACTIVITY

Take a known volume of a liquid (say water) first in a glass beaker (a). Then transfer water into a conical flask (b) and finally into a flat bottomed flask (c). If we look at the three figures, we observe that the water has acquired the shape of a(l the three containers.

2. Liquids have fluidity and not rigidity.

Unlike solids, the liquids have fluidity and not rigidity i.e., they have tendency to flow. This is due to lesser interparticular or intermolecular forces that are present in the liquid state as compared to the solid state. However, the liquids differ in their relative fluidity. For example, water flows at a faster rate than honey because in honey, the particles are more closely packed.



A liquid (water) can take up the shape of any container.

3. Liquids occupy definite volume or keep their volume.

Though the liquids do not have definite shape, but they do have definite volume. This means that like a solid, a liquid cannot be compressed on applying pressure. Actually, the intermolecular forces in the liquids are so strong that the pressure which is applied is not in the position to overcome these. Therefore, the particles in a liquid do not change their positions and come closer.

4. Liquids have lesser density as compared to solids.

As compared to solids, liquids are generally light. This is on account of greater number of interparticle spaces in the liquid state as compared to the solid state of the same substance. But there are certain exceptions also. Ice (solid state) floats over water (liquid state). Both are chemically the same and are made from H_2O molecules. Actually, the structure of ice is more porous* as compared to that of water. Therefore, for a given mass, the volume of ice is more than that of water and its density is comparitively less. As a result, ice floats over water.

5. The kinetic energy of the particles iii the liquid state is more than in the solid state.
The particles in the liquid state are less closely packed as compared to the solid state. As a result, the interparticle forces are weaker. Therefore, the kinetic energy of the particles in the liquid state of a substance is more than in solid state. It further increases with the rise in temperature.

6. Particles in the liquid state can easily diffuse.
Due to lesser interparticle forces of attraction, the particles in a liquid state can diffuse more readily than the solid, state of a substance. This also helps I the intermixing of certain liquids. For example, water and alcohol are both liquids and can easily mix to form a liquid mixture or solution.

The liquids differ in their relative diffusion rates. For example take water in two glass beakers. From the side of one of the beakers add a drop of blue ink and a drop of honey from the side in the other beaker. The blue colour will immediately spread throughout eater indicating fast diffusion. However honey will diffuse slowly. Actually the attractive forces among the particles in blue ink (a dye in nature) are less as compared to honey which is also heavier. Therefore diffusion in case of blue ink is faster than in honey.

Example : Water, milk, kerosene, petrol, alcohol, benzene, etc. are the examples of the substances which exist in the liquid state.

Liquid
The various properties of liquids are:

- They have fixed volume but not fixed shape.
- They cannot be compressed much.
- They have closely packed particles, but not as closely packed as in solids.
- They have moderate to high density. Liquids are usually less dense than solids.
- The force of attraction between the particles is strong enough to hold the particles together, but not strong enough to hold them in fixed position.
- They generally flow easily.


Water (Liquid)

THE GASEOUS STATE
Out of the three states of matter, the interparticle spaces are the maximum in the gaseous state. The interparticle forces which hold the different particle in the gaseous sate together are the minimum. As a result, rigidity is the minimum while fluidity is the maximum. The important properties of this state of matter are listed.

1. Gases do not have fixed shape.
Gases do not have any shape of their own. They acquire the shape of the container in which they are filled or kept.

ACTIVITY
You quite often come across a balloon seller with a variety of balloons hanging from a stick. They have different shapes but all of them have air inside. This shows that the same air has acquired different shapes depending upon the nature and size of the balloons.

L.P.G. Cylinder

2. Gases have maximum fluidity and least rigidity.
Since the interparticle spaces are the maximum in the gaseous state, the attractive forces are the least. As a result, the fluidity is very large while rigidity is negligible.

3. Gases do not keep their volume and are highly compressible.
Since the interparticle distances in the gaseous state are very large, they can be changed (increased or decreased) by altering the pressure. This means that change in pressure can bring a change in volume or we can say that gases do not keep their volume.

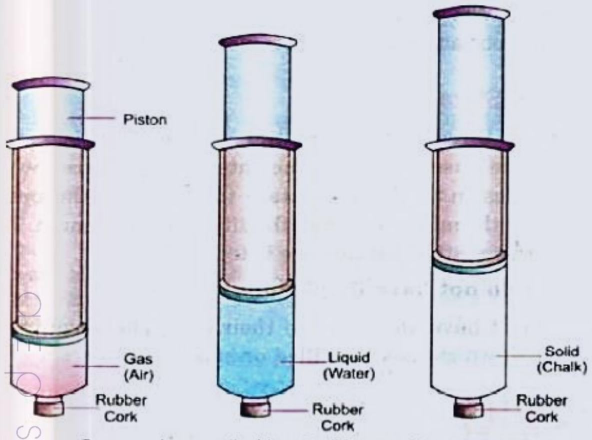
ACTIVITY

All of us are quite familiar with a cooking gas cylinder which contains in it liquefied petroleum gas, often called L.P.G. It is a mixture of different gases which are so highly compressed that they are in the liquefied form. When the regulator is opened, the liquid escapes from the nozzle of the cylinder into a space where pressure is very less. As a result, there is a sudden increase in volume and the liquid changes to gaseous state. The gas gets mixed with oxygen from air and ignites when burnt.

ACTIVITY

We have seen that out of the three states of matter it is easiest to a compress a gas, very difficult to compress a liquid while the solids are almost incompressible In order to demonstrate It, take three glass syringes of the same shape and size (say 100 mL). Close their nozzles by rubber corks as shown in the Figure 1.6.

Rate of diffusion of a gas varies inversely as the square root of its density which means that lighter gases diffuse faster than the heavier gases.



Compressing gas, liquid and solid on applying pressure

Remove the pistons from all the three syringes. Leave the first syringe empty, fill some water in the second and put some pieces of chalk in the third. Insert the pistons back in all the syringes. For their smooth movement, apply some vaseline on all the pistons before inserting them into the syringes. Now try to push all of them inwards by applying pressure with the help of hand. You will observe that the piston could be easily pushed into the syringe which was left untouched. It could hardly be pushed into the syringe containing water. It could not be pushed at all into the syringe containing the chalk pieces. Actually, air present in the first syringe could be readily compressed on applying pressure. It was very difficult to compress the liquid i.e., water in the second syringe. It was impossible to compress chalk pieces made up of solid in the third springe.

4. Gases are generally very light.

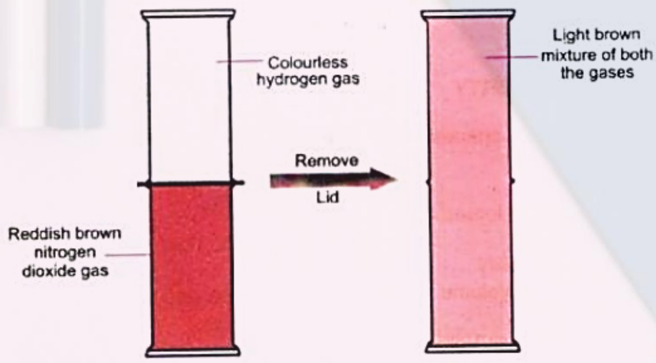
As compared to the solids and liquids, the gases are generally very light. Actually, the interparticle spaces are large. As a result, the particles in a gas are far separated and the volume of a given mass of a gas is quite large. The density of the gas (mass/volume) is very small and the gases are therefore, light.

5. The kinetic energy of the particles in the gaseous state is very high.

Among the three states of matter, the kinetic energy of the particles is the maximum in the gaseous state and the interparticle forces are very weak. As a result, the particles or the molecules of a gas can move quite . freely from one place to the other. This means that their translatory motion is large and kinetic energy is quite high. It can further increase when the temperature of the gas is increased.

6. Gases exert pressure.

Pressure of a gas is because of the hits which their particles record on the walls of the container. Since particles in a gas have high kinetic energy, they strike the walls of the container with force. As a result, they exert pressure. Please note that greater the number of hits recorded per unit area of the wall of the container more will be the pressure of the gas.



Diffusion of Gases.

7. Gases diffuse very rapidly.

Since the interparticle spaces are very large and interparticle forces are quite weak, the particles of one gas can readily move into the empty spaces of another gas.

> In air, all the constituting gases remain uniformly mixed. CO_2 which is heavier than both N_2 and O_2 does not form the lower layer in the atmosphere.

Note : Please note that even the lighter gases can rise upwards and heavier gases can move downwards. This means that the diffusion of the gases is not influenced by gravity- For example, invert a cylinder containing hydrogen gas (colourless) over a cylinder containing nitrogen dioxide (reddish brown) and separate the two cylinders by a lid. Now, remove the lid. What will you observe ? Both the cylinders will acquire the same colour i.e., light brown. This means that hydrogen gas has moved downwards and nitrogen dioxide upwards. Both the cylinders contain a uniform mixture of these two gases and are light brown in colour.

Examples : Air is the common example of the gaseous state. It is a mixture of number of gases like nitrogen, oxygen, carbon dioxide, inert gases etc. A few other examples are of ammonia, sulphur dioxide, chlorine etc.

Do You Know

Due to high compressibility large amount of gas can be filled in a small container, e.g.. Liquefied Petroleum Gas (LPG) used for cooking or Compressed Natural Gas (CNG) used as fuel in vehicles are compressed gases. The oxygen gas supplied to hospitals in cylinders is also in compressed form.

- **Explanation of States of Matter on the Basis of Molecular Structure**
  - In case of solids, the intermolecular spaces are very large. The molecules can vibrate about their mean position, but cannot change their positions. Hence the solids have definite shape, definite volume and are incompressible.
  - In case of liquids, the intermolecular spaces are somewhat large and intermolecular forces fairly small as compared to the solids. The molecules of liquid have more kinetic energy than the solids. Due to large intermolecular spaces and kinetic energy, the molecules can interchange their position. Hence liquids take the shape of the vessel and flow from higher to lower level, and they require a container to keep.
  - In case of gases, the intermolecular spaces are about 1000 times more than the liquids and intermolecular forces of almost negligible magnitude. The molecules are free to move in any direction hence gases have no definite shape or volume. The kinetic energy of molecules of gases is maximum and they move randomly at a high speed. These moving molecules hit the sides of the vessel and exert pressure on the walls of container.

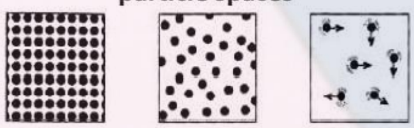
Particle Mode of Three States

Particle Mode of Three States

Following properties of particles decide the state of matter:

- Intermolecular distance
- Force of attraction between the particles
- Kinetic energy of the particles

Comparison of the three states in terms of inter particle spaces



(Solid) (Liquid) (Gas)

Comparison of three states of matter

	Property	Solid State	Liquid State	Gaseous State
1.	Inter particle space	Very small, particles are closely packed	Comparatively large, particles are loosely packed	Very large, particles are very loosely packed
2.	Inter particle force	Very strong	Weak	Very weak
3.	Nature	Very hard and rigid	Fluid	Highly fluid
4.	Compressibility	Negligible	Very small	Highly compressible
5.	Shape and Volume	Definite shape and volume	Indefinite shape but definite volume	Indefinite shape as well as volume
6.	Density (Mass/Volume)	High	Less than the density of solid state	Very low density
7.	Molecular motion or kinetic energy	Low	Comparatively high	Very high
8.	Diffusion	Negligible	Slow	Very fast

Rigidity and Fluidity

- Rigid means inflexible. A solid is a rigid form of matter, hence it does not require a container to keep it.
- Fluid is a material which can flow easily and requires a vessel to keep it. A liquid is a fluid form of matter which takes the shape of container while a gas is a fluid form of matter which fills the container.

Volume

- The space coupled by a substance is called volume.
- The SI unit of volume is cubic metre (m^3). The common unit is litre (L).
  These units are related as: 1 L = 1 dm^3; 1L = 1000 mL; 1 mL = 1 cm^3, where dm $\Rightarrow$ decimeter = 10^{-1} m

Density

- The mass per unit volume of a substance is called density.
  Density = Mass/Volume. Units of density are kg/m^3 or g/cm^3.

ILLUSTRATION

3. Out of solid, liquid and gas which has
(a) maximum inter particle space?
(b) maximum particle motion?
(c) definite volume but no definite shape?
(d) least diffusion of the particles?

Soln. (a) Gas, (b) Gas, (c) Liquid, (d) Solid.

4. Carbon dioxide gas is heavier than both nitrogen and oxygen. Why does not it form lower layer in the atmosphere?

Soln. The diffusion of a gas is not affected by gravity. This means that carbon dioxide (CO_2) remains uniform ally mixed in air. Therefore, the carbon dioxide gas does not form the lower layer in the atmosphere.

5. Liquids generally have low density as compared to solids, but you must have observed that ice floats on water. Find out why?

Soln. Ice is solid, hence it is supposed to be heavier than water which is liquid. But ice has lesser density than water due to its cage like structure with vacant spaces between the molecules while density of water is more, hence ice floats on water.

6. Why does a gas completely fill the container while liquid or solid does not?

Soln. The molecules of a gas have large intermolecular spaces and very less intermolecular forces of attraction. Hence the molecules of gas move away from each other and spread in the entire space available to them.

MATTER IN OUR SURROUNDING

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STORE IN YOUR MEMORY

- Solid liquid and gas are the three states of matter and differ in interparticle spaces.
- Solids have be fixed shapes and definite volume.
- Solids can be hardly compressed on applying pressure.
- Units of density is Kg/L or Kg/dm^3.
- Liquids do not have fixed shapes but occupy definite volume.
- Particles in a liquid can easily diffuse.
- Liquids have lesser density as compared to solids.
- Gases do not have either a fixed shape or definite volume.
- In the gaseous state, fluidity is maximum and rigidity is minimum.
- Gases are highly compressible and can be compressed to large extent on applying pressure.
- Increase in pressure decreases the volume of the gas while decrease in pressure increases the same.
- Gases diffuse very rapidly. The rate of diffusion of a gas is inversely proportional to the square root of its density.
- Lighter gases can move downwards while heavier gases can move upwards.

TEST YOUR ABILITY

1. Which of the following represent matter ?
Chair, oxygen, hatred, pea-nuts, cold, hot drink, smell of perfume, cooking pan, feeling.
2. Arrange the following substances in increasing order of interparticle forces : water, common salt, nitrogen.
3. Among the three states of matter, which has minimum interparticle spaces ?
4. A substance has neither definite shape nor definite volume. What does its physical state represent?
5. Give two characteristics of the solid state.
6. Out of solid, liquid and gas, which has
(a) maximum interparticle spaces
(b) maximum particle motion
(c) definite volume but no definite shape
(d) least diffusion of the particles.
7. A substance can be very easily compressed on applying pressure. Guess its physical state.
8. What is the physical state of water at 10°C ?
9. Why does a gas fill the entire available space ?
10. Explain why are gases compressed but not liquids
11. Give four characteristics associated with the gaseous state.
12. Point out whether the following statements are true or false :
(i) It is not necessary for a matter to have mass.
(ii) Gases always keep their volume.
(iii) It is not possible to compress a liquid on applying pressure.
(iv) A heavier gas can move upwards.
(v) Particle motion is maximum in the gaseous state.
(vi) Interparticle spaces are maximum in the solid state.
13. Write the full names of (a) LPG (b) CNG.

ANSWER TO SELECTIVE PROBLEMS

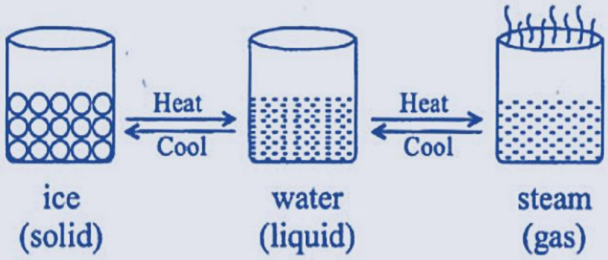
1. Chair, oxygen, pea-nuts, hot drink, smell of perfume, cooking pan. **2.** Nitrogen, water, common salt. **3.** Solid state **4.** It is in the gaseous state. **6.** (a) gas (b) gas (c) liquid (d) solid. **7.** Gaseous state. **8.** Liquid state **9.** Because of rapid diffusion of the particles. **12.** (i) False (ii) False (iii) True (iv) True (v) True (vi) False. **13.** (a) Liquefied petroleum gas (b) Compressed natural gas.

Change of State

Inter conversion of states of matter can be achieved
- by changing the temperature.
- by changing the pressure.

Effect of Change of Temperature on States

The temperature can be increased by heating to change solid into liquid and liquid into gas. The temperature can be decreased by cooling to change gas into liquid and liquid into solid.



❖ **Changing solid state of matter to liquid state (Melting):** When a solid is heated sufficiently, it changes its physical state and becomes a liquid. The process, in which a solid substance changes into liquid on heating is called melting or fusion. For example, when ice is heated it changes into water.
The temperature at which a solid substance melts at atmospheric pressure is called melting point of the substance. The higher the force of attraction between particles of a solid substance, the greater is the melting point of that substance. On heating solid substance, the particles of substance vibrate vigorously. When the melting point is reached, the particles of a solid have sufficient amount of kinetic energy to overcome the force of attraction holding the particles at fixed position. Therefore, the solid melts and turns into liquid state.

The melting point of a solid may be defined as the temperature at which a solid starts melting i.e. starts changing into the liquid state.

Latent Heat of Fusion

The latent heat of fusion or melting of a solid is the amount of heat in joules required to convert 1 kilogram of solid to liquid without causing any change in temperature. For example, the latent heat of fusion of ice is 334 KJ per kg. Which is the amount of heat that converts ice into water without causing any increase in temperature.

the amount of heat energy that is needed to convert one kg of a solid into the liquid state without any rise in temperature.

It is interesting to note that the melting point temperature of a solid is the same as the freezing point temperature of its liquid state. This means that the melting point of ice is the same as the freezing point of water. It is generally 0°C under one atmosphere pressure. At 0°C both ice and water exist together.

matter in our surrounding

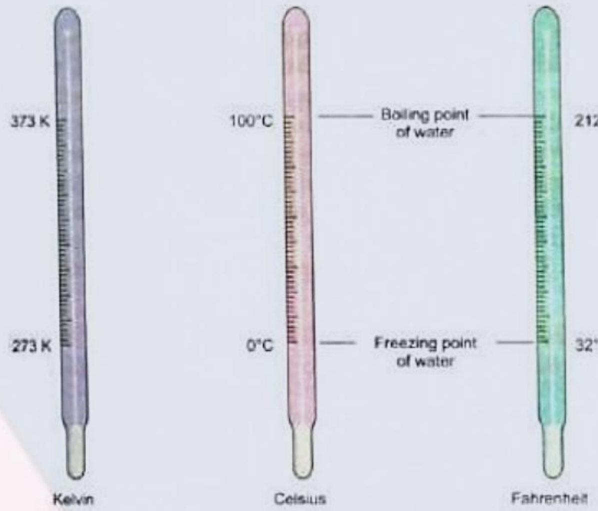
CBSE FOUNDATION

- **Solid to Liquid Change: Melting**
  - The process in which a solid changes into a liquid on heating is called melting or fusion.
  - The temperature at which a solid changes into liquid at atmospheric pressure is called melting point of the substance.
  - Higher the melting point, stronger are the forces of attraction between the particles.

Scales of Measuring Temperature

Three scales are used to measure the temperature.

- **Celsius scale (°C)**
  Freezing point of water is taken as 0°C and boiling point is taken as 100°C.
- **Fahrenheit scale (°F)**
  Freezing point of water is taken as 32°F and boiling point is taken as 212°F.
  Celsius and Fahrenheit scales are related to each other by the relation, $^{o}F = \frac{9}{5}(^{o}C) + 32$
- **Kelvin scale (K) or Absolute scale**
  It is SI unit of temperature.
  Freezing point of water is taken as 273.15 K or 273 K approx. and boiling point is taken as 373 K.
  Celsius and kelvin scales are related to each other by the relation, K = 273 + **°C**



Temperature on the three scales of measurement

- In Kelvin temperature, the symbol (^{o}) is not used.
- Kelvin temperature is represented by capital letter (K) and not by small letter (k)
- Kelvin scale is the best scale for measuring temperature as it has no negative sign.

Significance of the Melting Point Temperature

The melting point temperature of a solid gives an idea of the interparticular forces which bind the constituents in a solid. Thus, greater the melting point temperature, more will be the magnitude of intermolecular forces. For example,

- Melting point temperature of sodium = 370 K
- Melting point temperature of potassium = 336 K

This means that the attractive forces in atoms of sodium in the solid state of the metal are more than the forces that are present in the atoms of potassium also in the same state.

❖ **Example 1.1.** The room temperature on celsius scale is 25°C. Convert it into the other two scales of measurement.

Solution. Temperature on Kelvin scale = 25 + 273 = 298 K

Temperature on Fahrenheit scale $= \frac{9}{5} \times 25 + 32 = 77^{o} F$

❖ **Example 1.2.** The body temperature of a normal and healthy person is $98 \cdot 4^{o} F$. What is the temperature on the celsius scale ?

Solution. $9/5(^{o}C) = {}^{o}F - 32^{o} = (98 \cdot 4 - 32)$

$= 66 \cdot 4^{o}$

or $(^{o}C) = 66 \cdot 4 \times 5/9$

$= 36 \cdot 89^{o} C$

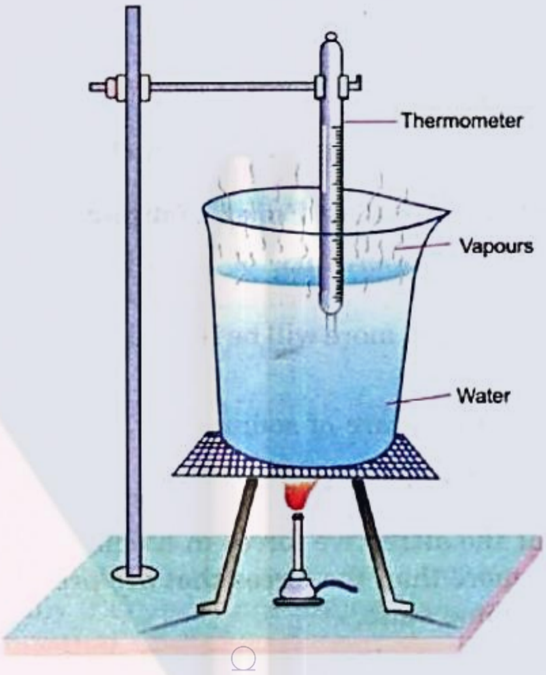
❖ **Changing liquid state of matter to gaseous state (Vapourisation):** When a liquid is heated sufficiently, it changes its physical state and becomes gas. The process, in which a liquid substance changes into a gas is called evaporation. For example, when water is heated it changes into water vapour.

The temperature, at which a liquid changes its state to vapours at atmospheric pressure, is called boiling point of the liquid. On heating liquid substance, the particles of substance vibrate vigorously. When the boiling point is reached, the particles of a liquid have sufficient amount of kinetic energy to overcome the force of attraction holding the particles at its position. Therefore, the liquid boils and turns into gaseous state.

Latent Heat of Vaporization

The latent heat of vaporization of a liquid is the quantity of heat in joules required to convert 1 kilogram of liquid to vapour or gas without causing any change in temperature. For example, the latent heat of vapourisation of water is 2258 KJ per kg which is the amount of heat that converts water into vapours without causing any increase in temperature.

the amount of heat energy that is needed to convert one kg of a liquid into its vapour state without any rise in temperature.



Demonstration of change of water into vapours

For example, the boiling point temperature of water is 100°C or 373 K.

It is interesting to note that what we have noticed in the melting of a solid, also happens in the boiling of a liquid. It means that once the liquid starts boiling, its temperature does not change although it is still being heated. The explanation is also similar. As long as the liquid has not boiled, the heat energy which is supplied increases the kinetic energy of the particles (or H_2O molecules) present in water. As a result, the temperature rises. Once the liquid starts boiling, the heat energy is now being used to bring about a change in state from liquid to gas or

- **Liquid to Gas Change: Boiling or Vaporization**
  - The process in which a liquid substance changes into a gas on heating is called boiling or vaporization.
  - The temperature at which a liquid boils and changes into gas at atmospheric pressure is called boiling point of the liquid.
  - Impurities increase the boiling point of liquids.
  - If pressure is increased, the boiling point increases. Boiling point of water is taken as 373 K at 1 atm pressure.
  - Higher the boiling point, stronger are the forces of attraction between the particles.

DIFFERENCE BETWEEN GAS AND VAPOURS

We have been using the terms gas and vapours both to represent the gaseous state of a substance. Are the two terms same or there is some difference in them ? a careful look indicate that these are not same.

We can use the term vapours to represent the gaseous state of a substance which is a liquid at room temperature. For the rest, the term gas is to be sued. For example, we can use the terms water vapours and alcohol vapours because both of them are liquids at room temperature. However, it is not correct to use the term ammonia vapours and hydrogen vapours because these are not liquids at room temperature. Both of them are gaseous in nature. Therefore, we must call these as ammonia gas and hydrogen gas.

SIGNIFICANCE OF BOILING POINT TEMPERATURE

Just like melting points, the boiling point temperatures of the liquids also help in comparing the magnitude or strength of the interparticle or intermolecular forces present in them. Greater these forces, more will be the boiling point temperature of the liquid. In general, low boiling liquids like petrol, ether, acetone, alcohol etc. have weaker intermolecular forces as compared to high boiling liquids like water, carbon tetrachloride etc. The low boiling liquids are also known as volatile liquids.

EFFECT OF DECREASE IN TEMPERATURE ON THE PHYSICAL STATE

We have seen that the rise in temperature brings about a change in the physical state of a substance from solid to liquid and then to gas (or vapours). This is mainly because of increase in the interparticle spaces or decrease in the strength of interparticle forces. The process can be reversed if the temperature is lowered or decreased. The gas (or vapours) will be first converted to the liquid state and then on further cooling, the liquid state will change to the solid state. This happens because the interparticle distances decrease and interparticle forces increase when the temperature is lowered. The reversible phenomenon may be shown as:

Solid State	Heat → / ← Cool	**Liquid State**	Heat → / ← Cool	**Vapour State**

❖ **Changing gaseous state of matter to liquid state (Condensation):** When a gas or vapour is cooled sufficiently, it changes its physical state and becomes a liquid. For example, when steam or water vapour is cooled, it is converted into liquid water.
On cooling, particles of gaseous substance lose kinetic energy, therefore; they vibrate slowly and move closer until the particles become attracted towards each other and form a liquid.

❖ **Changing liquid state of matter to solid state (Freezing):** When a liquid is cooled sufficiently, it changes its physical state and becomes a solid. For example, when water is cooled, it is converted into ice.

On cooling particles of liquid substance lose kinetic energy, therefore; they stop moving and move closer until the particles become attracted towards each other and acquires a fixed position to turn into a solid.

- **Gas to Liquid Change : Condensation**
  - The process of changing a gas to a liquid on cooling is called condensation.
  - Condensation is the reverse of vaporization.

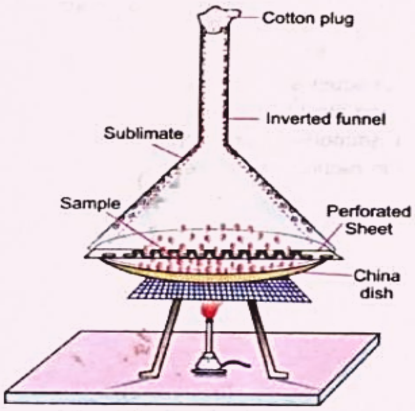
- **Liquid to Solid Change : Freezing**
  - The process of changing a liquid into solid by cooling is called freezing.
  - Freezing is also called solidification and is reverse of melting.
  - The temperature at which a liquid freezes to become a solid at atmospheric pressure is called the freezing point.
  - Impurities lower the freezing point of liquids.

CHANGE OF STATE FROM SOLID TO GAS AND VICE VERSA (SUBLIMATION)

The strength of the interparticle or intermolecular forces varies inversely as the interprticle spaces. Thus grater the interparticle spaces lesser will be the interparticle forces and vice versa.

We have so far studied that upon heating, a solid initially changes to the liquid state and then to the gaseous state when the temperature is increased. The process or the change of state can be reversed when the temperature is decreased. However, there are some exceptions. Certain solids directly change to the gaseous state upon heating without passing through the liquid state. Similarly, the gas changes back to the solid, state by–passing the liquid state. This is called sublimation. Thus sublimation may be defined as:

the change of solid directly into the gaseous state without passing through the liquid state upon heating and back to the solid state when the temperature is lowered.



Demonstration of sublimation.

Example : Naphthalene, camphor, iodine, ammonium chloride are some common examples of the substances which undergo sublimation.

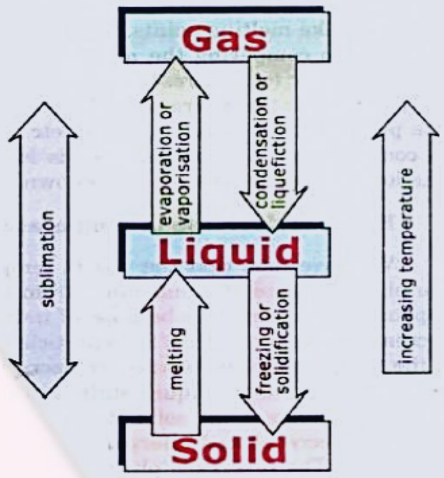
ACTIVITY

Let us demonstrate the sublimation process by taking the example of naphthalene. In a china dish take a small amount of the substance. The dish is covered by a perforated sheet. A glass funnel in the inverted position is placed over the dish so as to cover it.

The stem of the funnel is plugged with cotton. The dish is heated from below. As a result, naphthalene undergoes sublimation i.e., it changes into vapours which pass through the holes or perforations of the perforated sheet. The vapours get cooled in change to the solid form. The latter gets deposited on the inner walls of the funnel and can be suitably removed later on. The cotton plug does not allow any vapours of the substance to escape.

Application of sublimation. The process of sublimation can be used to purify the impure samples of substances which undergo sublimation and are associated with non-volatile impurities. An impure sample of naphthalene can be purified in this way. The non-volatile impurities which are present will not change into vapours. They will remain in the dish. Pure naphthalene can thus be recovered as a result of sublimation.

While preserving woolen clothes in summer we generally put some naphthalene balls in the boxes where these clothes are kept. Since temperature is quite high during summer naphthalene present in the balls slowly sublimes to give vapours. These are germicidies in nature and kill the germs and bacteria's which are likely to damage these clothes.



Effect of temperature on the physical states of a substance.

Representation of the effect of temperature on the physical states of substance

We have studied in details the changes in physical

- **Sublimation (Solid to Gas or Gas to Solid Change)**
  - The process of change of a solid state directly to gaseous state on heating, and vice-versa on cooling without passing through the intervening liquid state is called sublimation.

$$\text{Solid} \underset{\text{on cooling}}{\overset{\text{on heating}}{\rightleftharpoons}} \text{Vapour}$$

matter in our surrounding

• A substance is said to be in the solid state if under normal pressure, its melting point is above the room temperature.

• A substance is said to be in the liquid state if under normal pressure. its melting point is below the room temperature.

• A substance is said to be in the gaseous state if under normal pressure, its boiling point is below the room temperature.

The value of room temperature is normally not fixed and it depends mainly upon the conditions of weather However the standard room temperature is taken as 25°C or 298 K.

STORE IN YOUR MEMORY

• Inter conversion of the states of a substance can be brought about by change in temperature or pressure.

• Increase in temperature increases the kinetic energy of the particles. As a result, interparticle spaces become more.

• When a solid starts melting, its temperature becomes constant till whole of it has melted.

• The temperature at which a solid starts melting is known as its melting point temperature.

• The amount of heat energy needed to convert one kg of a solid into the liquid state without any rise in temperature, is known as latent heat of fusion.

• The temperature at which liquid starts boiling is known as its boiling point temperature.

• The amount of heat energy needed to convert one kg of a liquid into the vapour state without any rise in temperature, is known as latent heat of vaporisation.

• Vapours represent the gaseous state of a substance which is liquid at room temperature.

• Low bojling liquids are known as volatile liquids.

TEST YOUR ABILITY

1. Does the temperature of a solid change when it starts melting ?

2. Are the melting point temperature of solid and the freezing point temperature of liquid same or different

3. Out of Celsius and Kelvin temperatures, which is considered better ?

4. A solid melts at 20°C. Convert this temperature into Kelvin temperature.

5. Convert the following temperatures to Kelvin scale :
(a) 30°C (b) 273°C

6. Convert the following temperatures to Celsius scale :
(a) 200 K (b) 450 K

7. What is the physical state of water at:
(a) 25°C (b) 0°C (c) 100°C ?

8. The melting points of two solids [A] and [B] are 300 K and 350 K respectively. Which has more interparticles forces ?

9. Briefly discuss the changes which take place when ice melts.

10. Which of the following solids undergo sublimation upon heating :
(a) Sugar (b) Urea (c) Ice (d) Camphor (e) Sodium chloride (f) Iodine ?

11. What happens to the heat energy supplied when a solid has already melted ?

12. Define melting point of a solid and boiling point of a liquid.

13. How will you differentiate between gas and vapours ?

14. Discuss the significance of the boiling point temperature of a liquid.

15. The melting point of a substance is below the room temperature. Predict its physical state.

16. Is it proper to regard the gaseous state of ammonia as vapours ?

17. What is the name of the process in which a solid directly changes into a gas ?

18. Define condensation.

19. Which of' the following energy is absorbed during change of state of a substance ?
(a) Specific heat (b) Latent heat (c) Heat of solution.

20. Name one common substance which can undergo a change in state upon heating or cooling.

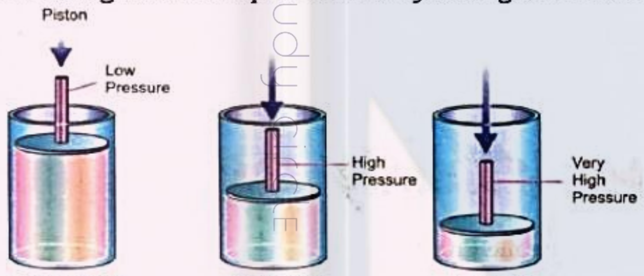
ANSWER TO SELECTIVE PROBLEMS

1. No, it remains the same **2.** Same **3.** Kelvin temperature **4.** (20 + 273) = 293 K **5.** (a) 30 + 273 = 303 K (b) 273 + 273 = 546 K **6.** (a) (200 - 273) = - 73°C (h) 450 - 273 = 177°C **7.** (a) Liquid state (b) Solid state or ice (c) Gaseous state **8.** [B] 10. Camphor and iodine **11.** It is converted into latent heat of fusion **15.** It is a liquid. **16.** No, it is not. **17.** It is called sublimation **19.** Latent heat **20.** Water.

Effect of Change of Pressure

The physical state of matter can also be changed by changing the pressure. Gases can be changed into liquids by increasing pressure along with decreasing temperature. Similarly some solids such as solid carbon dioxide can be changed into gases on decreasing the pressure and increasing the temperature.

We have learnt that the three states of matter differ with respect to interparticle spaces as well as interparticle forces. We have also discussed the effect of temperature in bringing about the change in state. In addition to temperature, pressure is an another tool available which can cause a change in physical state of a substance. Actually, the increase in pressure also brings the particles of a substance closer. As a result, the interparticle spaces decrease. At the same time, the interparticle or intermolecular forces increase. This leads to a change in the physical state. In order to illustrate the effect of pressure, take a gas in a cylinder and apply pressure on it by a piston as shown in the Fig. 1.13. At low pressure, the volume of the gas as well as interparticle spaces are very large. Under high pressure, the gas gets compressed. The interparticle spaces become less and interparticle forces become strong. As a result, the gaseous state may change to the liquid state. Under very high pressure, there is a further decrease in volume. The interparticle forces become so strong that the liquid state may change to the solid state.



Demonstration of the effect of pressure on the physical state

Scale of Measuring the Pressure

Pressure is normally expressed in atmospheres

- 1 atmosphere = 76 cm = - 760 mm

Pressure is also measured in Pascals (Pa)

- 1 atmosphere $= 1 \cdot 01 \times 10^5$ Pa

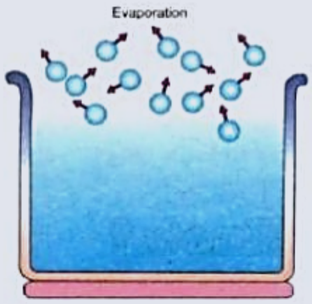
The pressure at sea level is 1 atmosphere and is regarded as normal atmospheric pressure.

Simultaneous Effect of Temperature and Pressure on the Physical State of a Substance

We have studied that both temperature and pressure can lead to a change in the physical state. They have rather opposing effects. The decrease in temperature brings the particles of a substance closer while the same can be achieved by increasing the pressure. Thus, at low temperature and under high pressure, a gas can be liquefied easily. In case, temperature is high and pressure is low, it may not be possible to liquefy the gas. It is interesting to note that the effect of temperature is more important as

Solid Carbon Dioxide or Dry Ice

Carbon dioxide gas can be liquefied or even solidified at very low temperature and under high pressure. It looks like ice but does not wet a piece of paper or glass. It is therefore, called dry ice. It is interesting to note that if the pressure on the surface of solid carbon dioxide is reduced nearly to one atmosphere, it directly changes to the vapour state without passing through the liquid state. The change is similar to sublimation which we have discussed in solids. Dry ice is used as a refrigerant under the name Drikold compared to that of pressure. For every gas, there is a certain temperature above which the gas cannot be changed to the liquid state however large may be the pressure on its surface. This temperature is known as critical temperature and the corresponding pressure is called critical pressure. For example, the critical temperature of carbon dioxide (CO_2) is $304{\cdot}15$ K and it a critical pressure corresponding to this temperature is $73{\cdot}9$ atmosphere (atm). This means that above $304{\cdot}15$ K temperature, the gas cannot be liquefied.



Evaporation of a liquid in an open container

EVAPORATION

During the study of the change of states, we have seen that a liquid changes to gaseous state either by increasing the temperature or by decreasing the pressure. Have you come across a case where the liquid may
change to vapour state of its own ? If not, go to your place and take some water or any other liquid in a trough or open container. Leave it as such exposed to air for a day or two. What will you observe ? The level of liquid in the container has decreased. Where has some of the liquid gone ? It has actually changed to the vapour state of its own. This process is known as evaporation. The evaporation may be defined as
the phenomenon of change of liquid to the vapour state at any temperature below the boiling point of the liquid.

Explanation for Evaporation

In a liquid, the particles or molecules experience mutual forces of attraction. However, these are not stationary and have some kinetic energy at all temperature. The particles of a liquid are also colliding with one another and exchanging energy during the collisions. Above the liquid surface, atmosphere or air is present which is a mixture of several gases, The particles of the liquid present on the surface have a tendency to come out from the surface so that they may acquire more freedom to move and become part of the atmosphere. This is also known as randomness. To overcome the interparticle forces of attraction, they need some energy which they take up from the rest of the particles or molecules of the liquid. As a result, their temperature gets lowered and cooling in caused.

ILLUSTRATION

• During summer or on a hot sunny day, poor people generally sprinkle water on the roof or on the ground. As water evaporates, it takes up heat from the surface. As a result, cooling is caused. They sleep comfortably during the night.

• We normally prefer cotton clothes during summer. Actually, we perspire a lot in the hot and humid weather. Since cooling is caused during evaporation, the body temperature gets lowered. We feel more comfortable. Now, cotton is of porous nature and is a good absorber of water coming out of the pores as sweat. The synthetic clothes are less porous and do not absorb sweat so quickly. We therefore, feel uncomfortable in nylon and terylene clothes.

Evaporation of a liquid is always accompanied by decrease in temperature or cooling.

FACTORS AFFECTING EVAPORATION

The evaporation of liquids is influenced by the following factors.

1. Surface area available for evaporation : Evaporation is a surface phenomenon which means that only the particles or molecules of the liquid present on its surface change into vapours- Thus, greater the surface area of the liquid more will be the rate or extent of evaporation. For example,

• Sometimes we are in a hurry and we often put hot milk or tea in a saucer before sipping it. Since the surface area has increased, the evaporation becomes fast. As a result, the temperature of the liquid in the saucer gats lowered and we can sip the same quite comfortably.

• We often spread wet clothes in order to dry them in air. By doing so, there is again an increase in surface area available for the evaporation of water. The clothes soon get dry.

2. Increase in temperature : We observe that the evaporation of water or of any other liquid becomes fast if the atmospheric temperature is high or we can say that the evaporation of a liquid is fast in summer as compared to winter. Actually, the increase in temperature also increases the kinetic energy of the particles or molecules of the liquid. They acquire greater tendency to change to the vapour state. As a result, the evaporation becomes fast.

3. Decrease in humidity : Humidity represents the amount of water vapours present in air. Please note that at a certain temperature or weather conditions, air around us can hold only a certain definite amount of water as vapours. In case, the humidity level or amount of water vapours in air is already high, then the rate of evaporation decreases.

For example, we sweat a lot in hot and humid weather. Under the conditions, the air around us has already high percentage of water vapours. This means that the sweat that comes out of our skin gets less opportunity to evaporate and remains sticking to our body. Therefore, we are likely to sweat more in this weather.

Do your Know ?
Surgeons quite often perform minor surgeries on a portion of skin by spraying ether. It is a low boiling liquid (308 K) an evaporates at a very fast rate from the skin. As a result, the temperature of skin becomes is low that it gets almost numb. Under the circumstance, a minor cut can be easily made on the skin in order to perform the surgery. The patient will not feel any pain because of the numbness that has been created.

4. Increase in the speed of wind : The speed of the wind around us has also some effect on evaporation of the liquid. We often notice that the wet clothes dry fast on a windy day. Actually, with the increase in wind speed, the particles of water vapours present in air also move away and the air which replaces it, is comparatively dry. This will enhance or increase the rate of evaporation.

5. Nature of the liquid : We have so far discussed the external factors which influence the extent of evaporation. Apart from these, another factor which is of great importance is the nature of the liquid which is evaporating. We often see that alcohol evaporates at a faster rate than water. In fact, the boiling point of alcohol (350 K) is less than that of water (373 K). This means that interparticles forces of attraction in alcohol are less than in water. Therefore, alcohol will evaporate faster than water. Thus, we conclude that **lesser the boiling point of a liquid, more is its tendency to change into vapours or to evaporate.**

DIFFERENCE BETWEEN BOILING AND EVAPORATION

We have studied that both evaporation and boiling represent change of state from liquid to gas or vapours. But still they are different in certain respect. The major points of distinction are listed in a tabular form.

Difference between Boling and Evaporation

Boiling	Evaporation
1. Boiling occurs only when the liquid is heated.	Evaporation of a liquid takes place of its own.
2. Boiling takes place at a specific temperature known as the boiling point of the liquid.	Evaporation takes place at all temperatures.
3. Boiling occurs from the surface as well as from below the surface of the liquid.	Evaporation is a surface phenomenon and occurs only from the surface of the liquid.
4. No cooling is caused during boiling.	Cooling is always caused during evaporation.

STORY IN YOUR MEMORY

- Temperature and pressure have opposing effects on the physical state of a substance.
- A gas can be liquefied by either decreasing the temperature or by increasing Pressure.
- The temperature above which a gas cannot be liquefied is known as critical temperature (Tc). The corresponding volume and pressure are called critical volume (Vc) and critical pressure (Pc).
- Evaporation occurs from the surface of the liquid at all temperatures.
- Cooling is always caused during evaporation of a liquid.
- Low boiling liquids have a greater tendency to evaporate as compared to high boiling liquids.
- Evaporation is generally slow under humid weather conditions.
- Boiling occurs only at a specific temperature known as the boiling point temperature.
- Unlike evaporation, no cooling is observed when a liquid boils.

TEST YOUR ABILITY

1. Pressure on the surface of a gas is increased. What will happen to the interparticle forces ?
2. What is the value of normal atmospheric pressure ?
3. Will the atmospheric pressure be more at the sea level or on a hill ?
4. Convert pressure of 1·5 atmospheres into pascals.
5. Suggest the ideal conditions to liquefy a gas.
6. Define critical temperature of a liquid.
7. Explain the term evaporation.
8. Enlist the main points of distinction between the evaporation and boiling.
9. Suggest the different factors which favour the evaporation of a liquid.
10. Out of alcohol and ether which will evaporate faster ?
11. What is the purpose of sipping coffee from a saucer instead of sipping from a glass or cup ?
12. Is cooling caused in boiling also ?
13. Are dry ice and ordinary ice same ?
14. Do we sweat more on a dry day or on a humid day ?
15. Discuss the effect of (i) surface area (ii) nature of the liquid on the rate of evaporation.

ANSWERS TO SELECT PROBLEMS

1. They will increase **2.** 1 atmosphere **3.** It is more at the sea level **4.** $1{\cdot}5\times1{\cdot}01\times10^5 = 1{\cdot}515\times10^5$ Pa **5.** By increasing the pressure and decreasing the temperature **10.** Ether **11.** To lower its temperature by increasing evaporation **12.** No, it is not **13.** No, these are different **14.** On a humid day.

Plasma and Bose - Einstein Condensate - Two more states of matter

We have 80 far studied that solid, liquid and gas are the three states of matter.

Scientists have discovered two more states of matter. These are : Plasma and Bose- Einstein condensate.

Plasma : We all know that the sun glows during the day while stars shine during the night. This is because of plasma which is a mixture of free electrons and ions. Actually, inside the sun and the stars, the temperature is very high. As a result, the atoms break releasing electrons and the residual particles are called ions which carry positive charge. The mixture of highly energetic electrons and ions is known as plasma and is responsible for the glow or shine. The fluorescent tubes and the neon sign bulbs also glow due to plasma. In the fluorescent tube there is helium or some other gas while neon is present in neon sign bulbs. As electricity flows through them, the atoms of these gases break into charged electrons and ions. They constitute plasma which glows.

Bose-Einstein condensate : The main work for the discovery of the fifth state of matter was done by Indian physicist Satyendra Nath Bose and well known scientist. Albert Einstein. But this was actually shown to exist when three American scientists, Eric A Cornell, Wolfgang Ketterie and Carl E Weiman in the year 2001 cooled certain gases of extremely low density to very low temperature known as super low temperature. The particles which constitute this state of matter are often called Bose-Einstein condensate (BEC). All the three scientists were awarded Noble prize for their achievement.

The End