Matter & Its Composition: Law of Conservation of Mass

Kinetic Theory of Matter

The ***kinetic theory of matter*** is a theory that tells us about the behaviour of matter.

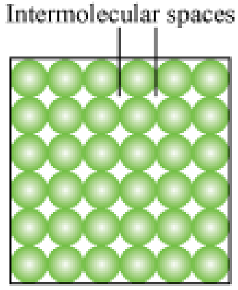
Kinetic Theory of Gases

- All matter is made up of molecules.
- All molecules of a substance are identical.
- Molecules of different substances differ in composition, shape and size.
- Molecules are in continuous motion; they don’t stop for any length of time.
- Intermolecular forces depend on the distance between the molecules and the type of molecules.
- Motion of molecules is affected by the change in temperature; the higher the temperature, the more they move.

Intermolecular force is an attractive force between molecules. It depends on the distance between molecules.

- **Arrangement of molecules in Solids**
- In solids, molecules are very tightly packed because of very strong intermolecular forces between them.
- The molecules can only vibrate, but cannot move from their respective positions. This is because strong intermolecular force holds the molecules at one place. For the same reason, solids are rigid and hard.

An iron weight

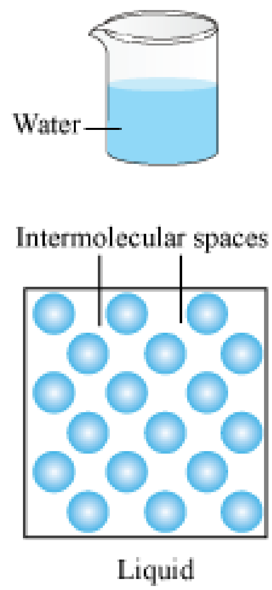


Solid

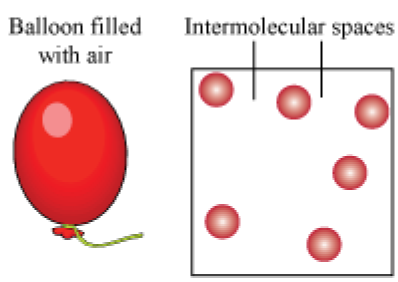
So, solids have a fixed shape and a fixed volume, and thus, cannot be compressed.

When we heat solids, they gain heat energy. This energy increases the vibrations of the molecules. Due to the increase in vibrations, the intermolecular spaces increase, which in turn leads to the expansion of solids. Thus, solids expand on heating.

- **Arrangement of molecules in Liquids**
- Molecules are slightly further apart than in solids.
- Intermolecular forces are less strong than in solids.
- Molecules can move from their positions in liquids.
- Thus, liquids flow, and take the shape of containers.
- Liquids do not have a definite shape, but they do have a definite volume.
- When we heat a liquid, its molecules vibrate. As the intermolecular forces are weaker in liquids than in solids, the molecules of the liquid also move vigorously. Thus, liquids also expand on heating, but only slightly
- As there is more space between the molecules in liquids than in solids, liquids can be compressed a little.



- **Arrangement of molecules in Gases**
- Molecules are very far apart; hence, there is hardly any attraction between the molecules.
- Intermolecular forces in gases are negligible.
- Therefore, molecules of a gas are free to move around.
- As gases are free to move around, they don't have any fixed shape and volume, they can enclose the entire space in which they are kept.
- A gas can easily be compressed.



Changes Among Various States of Matter

Change of State-An Overview

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

The following terminologies are used to describe the changes in the states of matter.

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

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

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

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

Did You Know?

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

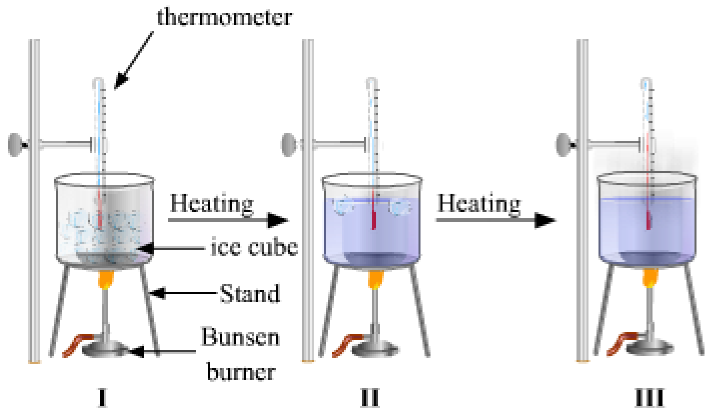
Air contains vapours. When we open the refrigerator, the temperature comes down. This condenses the vapours into tiny drops of water and produces freezing fog.

Temperature Affecting the Change of State

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

Procedure: Take about 150 g of ice in a beaker and use a laboratory thermometer to note the temperature of ice. Start heating the beaker on a low flame and record the temperature when the ice starts melting.

Observe the temperature when all the ice gets converted into water. Stir the water with a glass rod till it starts boiling.



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

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

Temperature Affecting the Change of State

You know that matter, irrespective of its state, consists of particles. What happens to these particles of matter while it is undergoing a change in its state? For us to understand this, we need to first know that:

- The particles of matter possess kinetic energy.
- A force of attraction exists between any two particles.

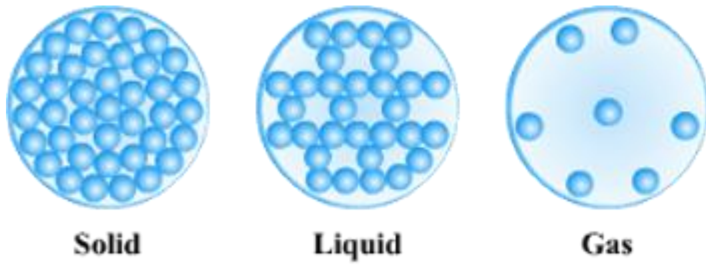
Kinetic energy of the particles of matter: A moving particle/object possesses a certain amount of energy because of its motion. This energy is called kinetic energy. The particles of matter are in constant motion. Therefore, they possess kinetic energy.

Particle-particle force of attraction: Every particle of matter attracts the particles near it. An increase in the distance between particles decreases the force of attraction between them. Conversely, a decrease in distance increases this force of attraction.

The given figure shows the kinetic energy of particles and the particle-particle force of attraction in the three states of matter.

Kinetic energy of particles: Gas > Liquid > Solid

Particle−particle force of attraction: Solid > Liquid > Gas



When a solid substance is heated, there is an increase in the kinetic energy of its constituent particles. As a result, the particles start vibrating with greater speed. This extra energy helps the particles to overcome the particle-particle force of attraction.

Soon, they leave their positions and start moving more freely. Consequently, the substance melts into its liquid state. This is known as **melting point**. The melting point of ice is 0°C.

Liquids have a characteristic temperature at which they turn into solids. This is called **freezing point**. The freezing point of water is 0°C.

Further heating increases the kinetic energy of the liquid particles. This increases the velocity of the particles. At a certain temperature, they obtain enough energy to break free from the particle-particle force of attraction. At this point, the liquid changes into its gaseous state. This is known as **boiling point**. The boiling point of water is 100°C.

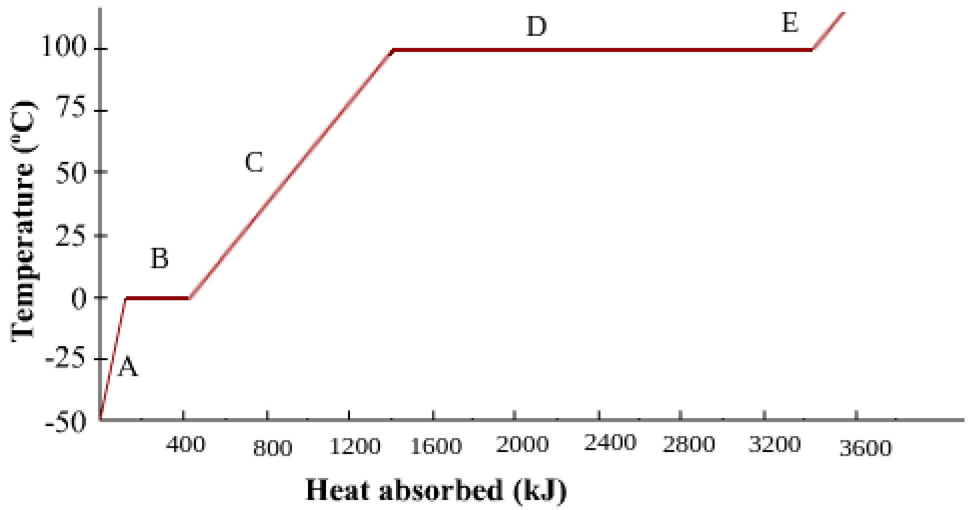
During the conversion of ice into water, the temperature remains constant until all the ice melts into water. The supplied heat is used up for changing water from its solid state to its liquid state. The heat energy is absorbed by the ice without showing any rise in temperature. This heat energy is called **latent heat**.

The amount of heat required to convert 1 kg of a solid into its liquid state without a change in temperature (i.e., at its melting point) is called **latent heat of fusion**. For ice, the latent heat of fusion is 334 kJ kg^{-1}. This implies 334 kJ of heat has to be provided to convert 1 kg of ice at 0°C into 1 kg of water at 0°C. Conversely, 334 kJ of heat is released when 1 kg of water freezes at 0°C to give 1 kg of ice at 0°C.

Know More

Latent heat of vapourization is the amount of heat required to convert 1 kg of a liquid into its vapour state without a change in temperature. For water, the latent heat of vapourization is 2260 kJ kg^{-1}. This means that 2260 kJ of heat must be provided to convert 1 kg of water at 100°C into 1 kg of vapour at 100°C. Conversely, 2260 kJ of heat is released when 1 kg of water vapour condenses at 100°C to give 1 kg of water at 100°C.

Heating curve



If the increase in temperature during heating and the absorbed heat are plotted on a graph, then the curvature which is formed is called the **heating curve**.

In the figure, ‘A’ represents the rise in the temperature of the substance in its solid state from −50°C to 0°C; ‘B’ shows the latent heat of fusion; ‘C’ shows the increase in the temperature of the substance in its liquid state from 0°C to 100°C; ‘D’ shows the latent heat of vapourisation, and ‘E’ shows the increase in the temperature of the substance in its gaseous state.

Solved Examples

Easy

Example 1:

If the melting point of a solid is high, then the ___________ between the particles is stronger.

Solution:

force of attraction

Medium

Example 2:

Which has more energy: solid wax at 42°C or liquid wax at 42°C?

Solution:

Liquid wax at 42°C has more energy than solid wax at the same temperature.

Hard

Example 3:

Choose the process which will absorb heat/energy from the surroundings.

A.Conversion of ice into water

B.Conversion of water vapour into snow

C.Precipitation of water vapour as rain

Solution:

The correct answer is A.

Measuring Temperature

Three scales are commonly used for measuring temperature, namely, the **Celsius scale**, the **Fahrenheit scale**, and the **Kelvin scale**.

The relation between the Celsius and the Kelvin scale can be expressed as C + 273 = K

The relation between the Celsius and the Fahrenheit scale can be expressed as follows:

$$\frac{C}{5} = \frac{F-32}{9}$$

Example: 30°C can be expressed as 303 K and 86 °F.

Celsius to Kelvin: 30 + 273 = 303 K

Celsius to Fahrenheit:

$$\frac{30}{5} = \frac{F-32}{9}$$
$$\Rightarrow 6 = \frac{F-32}{9}$$
$$\Rightarrow 54 = F-32$$
$$\Rightarrow F = 86$$

Did You Know?

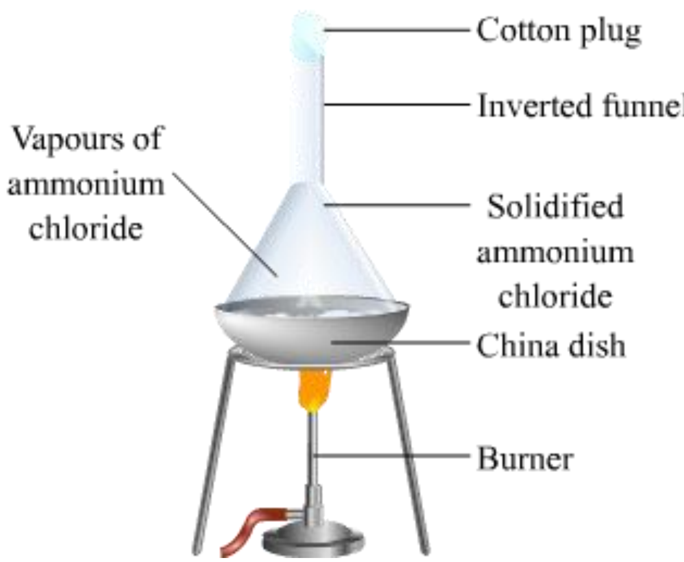
Cool Facts

- The temperature zero Kelvin is known as absolute zero. Nothing can be colder than zero Kelvin.
- Dry ice is frozen carbon dioxide. Its temperature is −78.5°C. It turns directly into carbon dioxide gas without undergoing a liquid phase. Its sublimation characteristic and super-cold temperature make dry ice suitable for refrigeration. It is commonly used to export frozen materials across long distances.

Whiz Kid

Take some ammonium chloride salt in a china dish. Crush the salt and cover the dish with a funnel, as shown in the figure.

Plug the stem of the funnel using some cotton. After this, start heating the dish slowly using a burner.



Result of the activity:

Upon heating, ammonium chloride will vapourise without transforming into its liquid form (**sublimation**). Later, the vapours will get cooled on the walls of the funnel and will directly convert into solid ammonium chloride (**deposition**).

Note: The same activity can be done using camphor or naphthalene.

Pressure Affecting the Change of State

We know that change in temperature affects the state of matter. Change in pressure, too, affects the state of matter. Let us see how.

We have a gas in a closed container. Say, we put some weight on the lid of the container. This increases the pressure on the container, which in turn causes the gas particles to come close to one another. As a result, the kinetic energy of the particles reduces. Nevertheless, the particles are still quite far away from one another and, hence, are still in the gaseous state. When the pressure on the container is increased further, the gas particles come very close to one another. Gradually, the gas **liquefies**.

Did You Know?

Water boils below 100°C (at approx. 92°C) in Mussoorie.

Mussoorie is a hill station set at a height of about 2000 m above sea level. Atmospheric pressure decreases as you go up from the sea level. Decrease in pressure lowers the boiling point of water below 100°C.

Whiz Kid

Liquid crystals are believed to be an independent state of matter as their properties lie in between those of liquids and solid crystals. They exist in a specific temperature range. They behave as solids below that temperature range and as liquids above that temperature range.

Know More

Why we need to liquefy gases

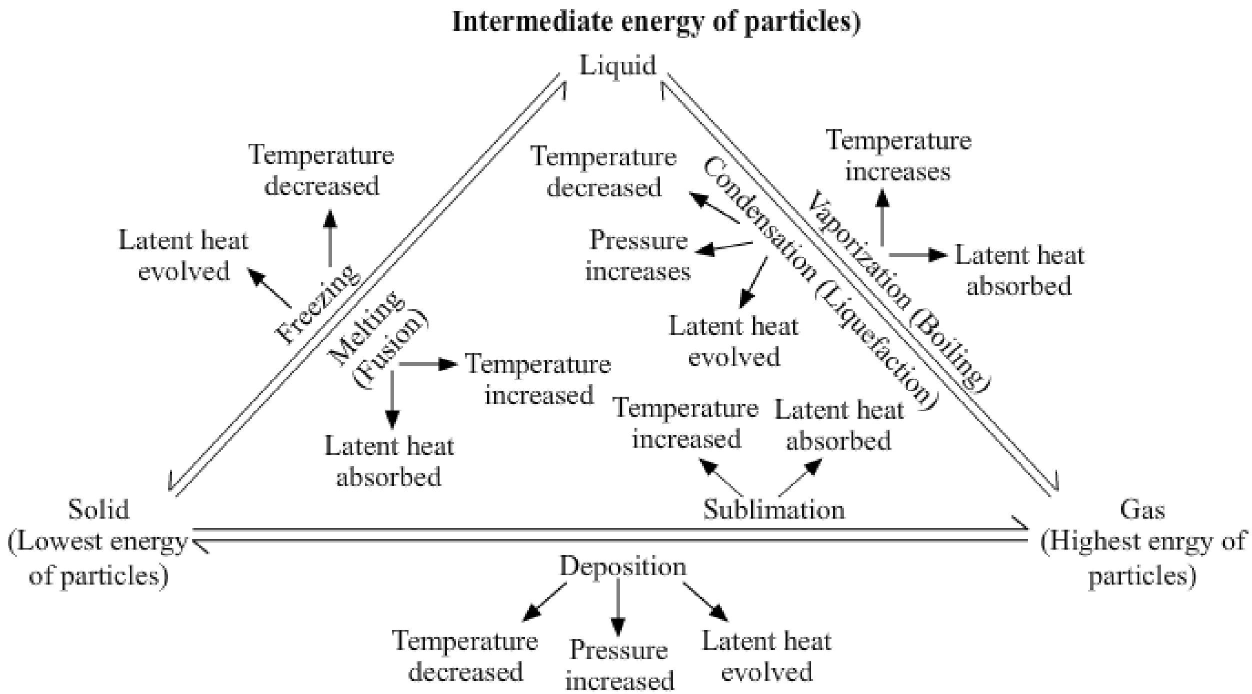
Together with low temperature, high pressure is generally used to liquefy gases.

A highly combustible gas is released during the fractional distillation of crude oil. This gas is known as petroleum gas. Petroleum gas is also trapped over the reserves of oil present beneath Earth's crust. Petroleum gas is liquefied by applying high pressure and low temperature. This is known as liquefied petroleum gas or LPG. LPG is used as a domestic fuel.

Other uses of liquefaction of gases

- Liquefaction of gases is helpful for their easy storage and transportation.
- Liquefied gases can be used in various fields; for example, in air conditioning and refrigeration systems (gases used are liquid ammonia and liquid sulphur dioxide).
- Liquid oxygen is supplied to hospitals for patients. It is also used as a rocket propellant.
- Liquid nitrogen is used in **cryosurgery**.
- Liquid chlorine is supplied to water treatment plants for purification of water.
- Liquid hydrogen in combination with liquid oxygen forms the fuel for rocket propulsion.

Inter-Conversion among Solids, Liquids, and Gases



Law of Conservation of Mass

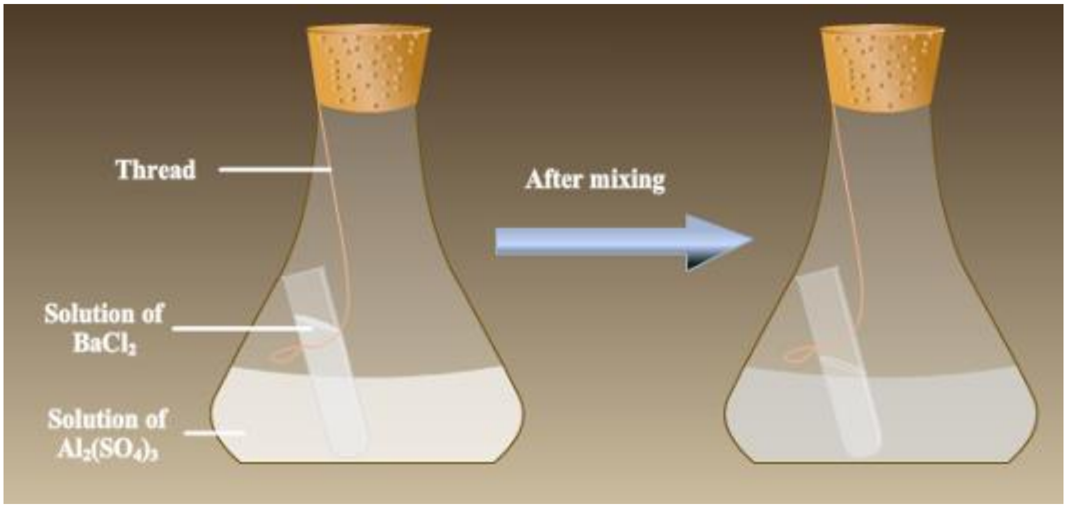
Law of Chemical Combination

Lavoisier and Proust proposed two laws that sought to explain the chemical combinations of elements. These laws are the law of conservation of mass and the law of constant proportions, respectively.

Let us first study about the law of conservation of mass.

According to this law, '**mass can be neither created nor destroyed.**' In other words, for a chemical reaction taking place in a closed system, the total mass of the reactants is the same as that of the products.

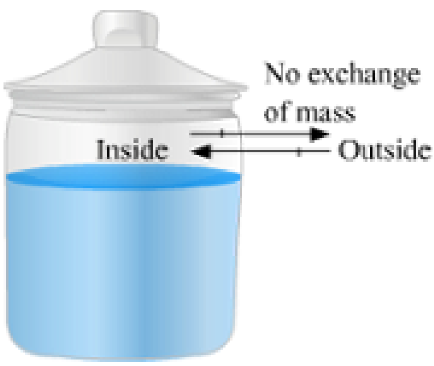
For example, an unmixed solution of barium chloride and aluminium sulphate weighs the same as that of the mixed solution of the two.



Know More

Closed System

A system is said to be closed if there is no exchange of mass across the boundaries of the system and the surroundings. However, it can exchange energy with its surroundings.



Law of Conservation of Mass

Solved Examples

Medium

Example 1:

In a decomposition reaction, 100 g of mercuric oxide—when heated in a closed test tube—decomposes to produce mercury and oxygen gas. If the mass of the produced mercury is 92.6 g, then what is the mass of the produced oxygen?

Solution:

According to the law of conservation of mass:

Total mass of the reactants = Total mass of the products

It is given that:

Mass of the decomposing mercuric oxide = 100 g

Mass of the produced mercury = 92.6 g

Let the mass of the produced oxygen be x.

So, we have:

100 g = 92.6 g + x

$\Rightarrow x = (100 - 92.6)$ g

$\Rightarrow \therefore x = 7.4$ g

Laws of Chemical Combination and Dalton's Atomic Theory

The law of conservation of mass can be explained using the first and third postulates of Dalton's atomic theory.

The law of conservation of mass states that mass can be neither created nor destroyed. According to this law, in case of a chemical reaction taking place in a closed system, the total mass of the reactants equals that of the products.

Mass is the amount of matter in something. As per the first postulate of Dalton's atomic theory, all matter is made up of atoms. The third postulate of the same theory asserts that atoms can be neither created nor destroyed in a chemical reaction, i.e., the total number of atoms and their mass should remain the same before and after the reaction. This is the same as the law of conservation of mass.