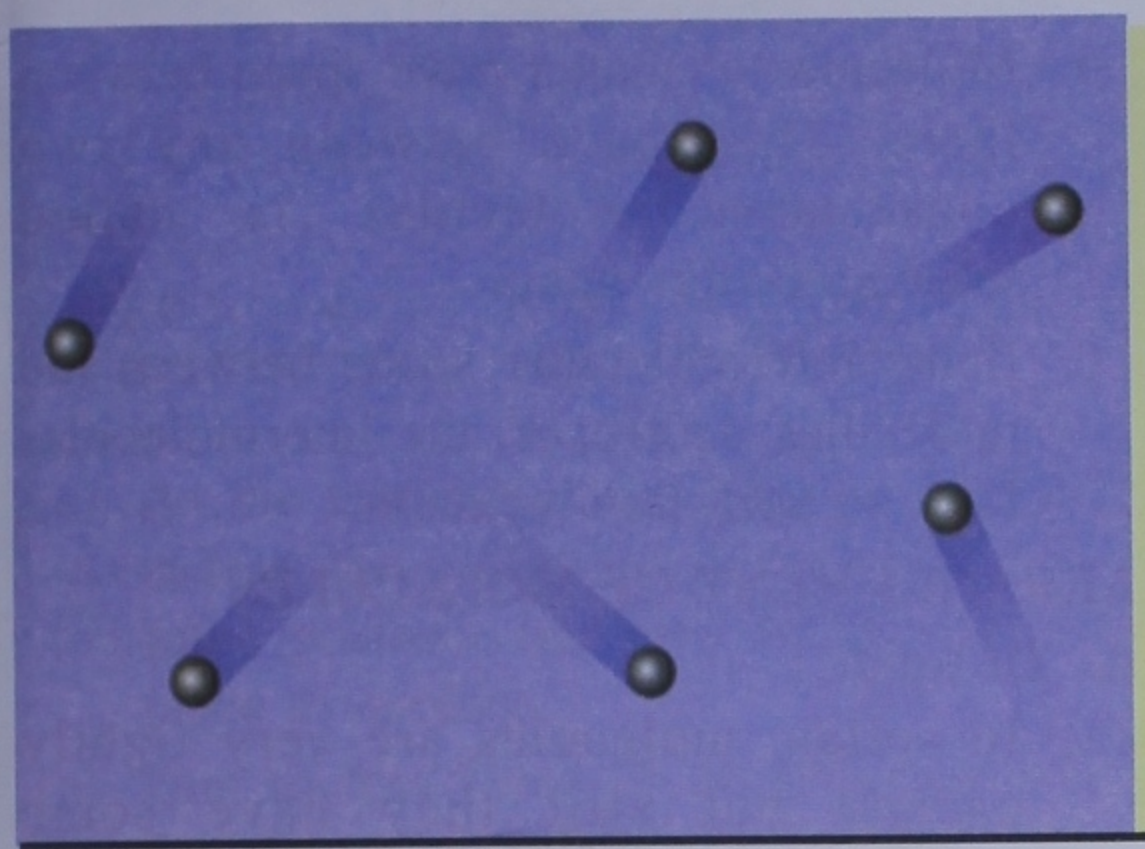

6 Kinetic Theory of Matter

According to Greeks, the basic building blocks of materials are fire, water, air and earth. They believed that the properties of a particular material were due to the different ratios in which these four basic things, (fire, water, air and earth) were mixed.

Indian philosophers, however, believed that all materials are made up of five elements and these elements are : **Akash** (sky), **Tejas** (fire), **Ap** (water), **Vayu** (air) and **Kshiti** (earth). It was the great Rishi Kanada who first gave the idea that "ALL MATTER IRRESPECTIVE OF ITS PHYSICAL STATE IS COMPOSED OF VERY SMALL PARTICLES CALLED **ANU** (ATOM)".

Anything which occupies space and has mass is called ***matter***. Matter is made up of elements.

An **element** is a substance which cannot be subdivided into two or more similar substances by any chemical or physical means.

The smallest unit of an element which may or may not have an independent existence but always takes part in a chemical reaction is known as **atom**.

The smallest unit of matter is called **molecule**. It can exist freely in nature. A molecule is made up of two or more atoms of the same element or of different elements. *For example*, one molecule of oxygen has two atoms of oxygen. Similarly, one molecule of water (H_2O) contains two atoms of hydrogen and one atom of oxygen. Molecules retain the complete physical and chemical properties of that matter.

You cannot see atoms and molecules even with powerful microscopes. Still it is possible to prove that molecules in a matter continuously move from their original position.

Examples of existence of motion of molecules in a substance

1. Take water in a beaker. Place it on a table. Now with the help of a dropper, put a drop of ink in water. Observe it carefully. You will notice that the ink particles gradually move into the entire quantity of water and get mixed with its particles because of which water turns blue.
2. Put some quantity of sugar in a small quantity of water taken in a beaker. After sometime, the sugar particles disappear as the sugar gradually gets dissolved into water.
3. If you open a bottle of perfume in one corner of a room, the fragrance gradually spreads and the whole room is filled with its smell.

All these examples prove that particles continue to move inside a matter and this phenomenon is known as kinetic motion of molecules of matter.

Kinetic Theory of Matter : The following are the assumptions made regarding the motion of molecules in a matter.

1. Molecules are in a state of continuous motion and accordingly, molecules possess **kinetic energy.**
2. The kinetic energy of molecules increases with an increase in temperature and decreases with a decrease in temperature.
3. The molecules of matter always attract each other. The force of attraction between the molecules of a similar kind is called the **force of cohesion**. This force is responsible for keeping the molecules of a substance bind together. The **force of cohesion is maximum between the molecules of solids, less between the molecules of liquids and least between the molecules of gases.**

   The force of attraction between different types of molecules is called the **force of adhesion**.

   When a glass filled with water is emptied, some water particles remain sticking to the glass. This is due to the force of attraction between the water molecules and glass molecules *i.e.* due to force of adhesion between them. Similarly, when we write on the black-board, using a piece of chalk, the molecules of chalk stick to the board, due to the force of adhesion.
4. The force of attraction between the molecules (either cohesive or adhesive) is called the **intermolecular force of attraction**.
5. Molecules of matter have space between them. The space between any two consecutive molecules is called **intermolecular space**.
6. If the intermolecular space between the molecules decreases, the intermolecular force of attraction increases.

ARRANGEMENT OF MOLECULES

A. In solids :

(a) In solids, molecules are very tightly packed but still they have some intermolecular space (Fig. 6.1).

(b) As intermolecular space is very small, the molecules attract one another with a strong force.

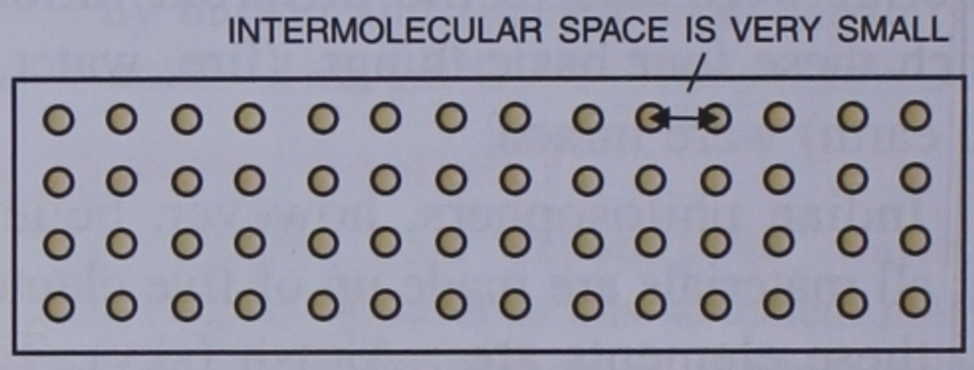

Fig. 6.1

(c) The strong intermolecular force of attraction holds molecules at one particular place with very small vibrations (amplitudes) about their mean position.

(d) Due to the fixed position of molecules, the solids have a definite shape and a definite volume.

(e) As the molecules attract each other with a very strong force, it is therefore, difficult to break the solids, *i.e.* the solids are generally rigid and hard.

B. In liquids :

(a) Molecules are less tightly packed in liquids (Fig. 6.2).

(b) The molecules in liquids attract each other with a lesser force as the intermolecular space is larger as compared to solids.

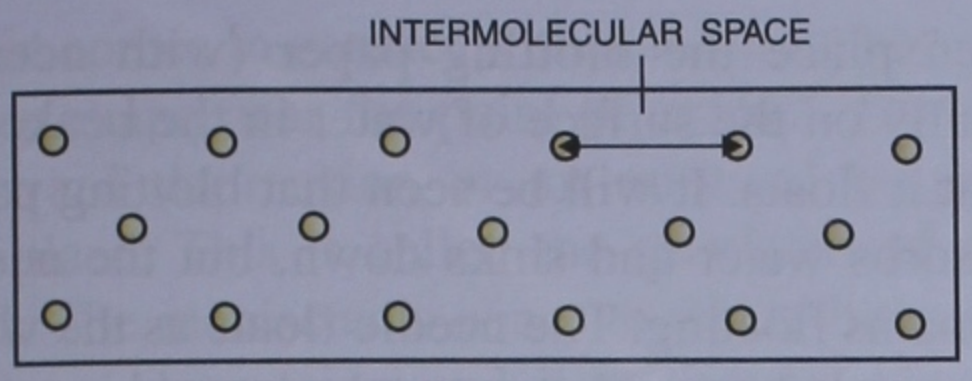

Fig. 6.2

(c) As the intermolecular force of attraction is less, the molecules do not stay at the same position and they move from one place to another.

(d) Due to less force of attraction between the molecules of the liquids, the liquids do not have any particular shape. They acquire the shape of the vessel in which they are kept.

(e) A particular quantity of a liquid has a definite volume at a given temperature. It is because, the number of molecules and intermolecular space in a particular quantity of a liquid (at constant temperature) is always same.

C. In Gases :

(a) The force of attraction between molecules is the least in the case of gases (Fig. 6.3).

(b) The intermolecular force is so less that they can spread in the entire space in which they are enclosed.

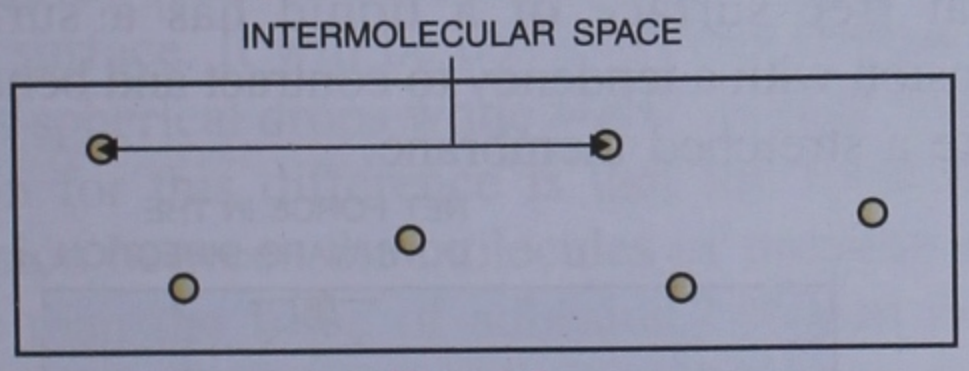

Fig. 6.3

(c) Gases have neither a definite shape nor definite volume as their molecules move independently due to very small intermolecular force between them.

SURFACE TENSION

Every liquid when taken in a container has the property that, its free surface behaves like a stretched membrane with a tendency to contract and acquire the minimum surface area. This property of liquids is called **surface tension**. It is due to surface tension only that the small insects and mosquitoes are able to crawl on the surface of water in a pond.

Surface tension is a phenomenon in which the surface of a liquid, where the liquid in contact with gas, acts like a thin elastic sheet. This term is used only when the liquid surface is in contact with gas (such as the air). If the surface is between two liquids (such as water and oil), it is called "interface tension".

Note : Water has a higher surface tension than most other liquids (Liquid metals are an exception).

— Other molecules in water usually lower the surface tension (some salts are an exception).

— Increased temperature lowers surface tension.

Electrical conditions at interfaces can raise or lower the surface tension.

Surface tension has the dimension of force per unit length. It is measured in dynes/cm in CGS system and N/m (newton per metre) is its SI unit.

SURFACE TENSION EXAMPLES

(1) **Walking on water -** Small insects such as water strider can walk on water because their weight is not enough to penetrate the surface.

(2) **Floating a needle -** If carefully placed on the surface, a small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated, then needle will quickly sink.

(3) **Soaps and detergents** - These help in the cleaning of clothes by lowering the surface tension of water so that it more readily soaks into pores and soiled areas.

(4) **Washing with hot water** - The major reason for using hot water for washing is that its surface tension is lower and it is a better setting agent. But if the detergent lowers the surface tension, the heating may be unnecessary.

(5) **Clinical test for jaundice** - Normal urine has a surface tension of about 66 dynes/cm but if bile is present (a test for jaundice), it drops to about 55 dynes/cm.

(6) **Don't touch the tent** - Common tent materials are somewhat rainproof in that the surface tension of water will bridge the pores in the finely woven material. But if you touch the tent material with your finger, you break the surface tension and the rain will drip through.

(7) Beading of rain water on the surface of a waxy surface, such as an automobile. Water adheres weakly to wax and strongly to itself, so water cluster into drops. Surface tension gives them their near-spherical shape, because a sphere has the smallest possible surface area to volume ratio.

(8) Separation of oil and water is caused by a tension in the surface between dissimilar liquids. This type of surface tension is called "interface tension".

CAUSE OF SURFACE TENSION

An unbalanced cohesive force experienced by molecules on the surface of the liquid is responsible for the surface tension. We may explain it as follows :

Example : Take some water in a beaker. Keep a small-sized needle on a blotting paper and then place the blotting paper (with needle) gently on the surface of water in the beaker so that it floats. It will be seen that blotting paper absorbs water and sinks down, but the needle remains floating. The needle floats as the water surface behaves like a stretched membrane due to its surface tension.

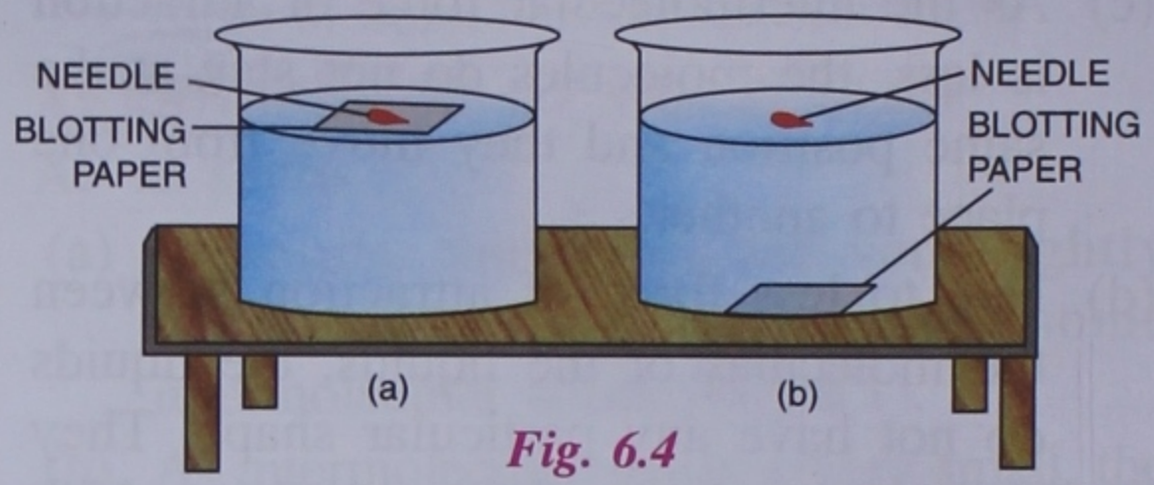

Fig. 6.4

Consider a molecule A somewhere inside the liquid. It is in equilibrium as cohesion forces act on it from all directions. These equal forces acting on molecule A neutralise each other because of which the net force on it is zero. Now consider a molecule B at the surface of the liquid. The molecule B has cohesive forces acting on it in the downward direction. These forces act along the surface of the liquid, as well as in other directions in the liquid but has no force acting on it in the upward direction. As a result, molecule B (or any other molecule on the surface of liquid) experiences an inward cohesive force. This is the reason that free surface of a liquid has a surface tension with a tendency to contract and behaves like a stretched membrane.

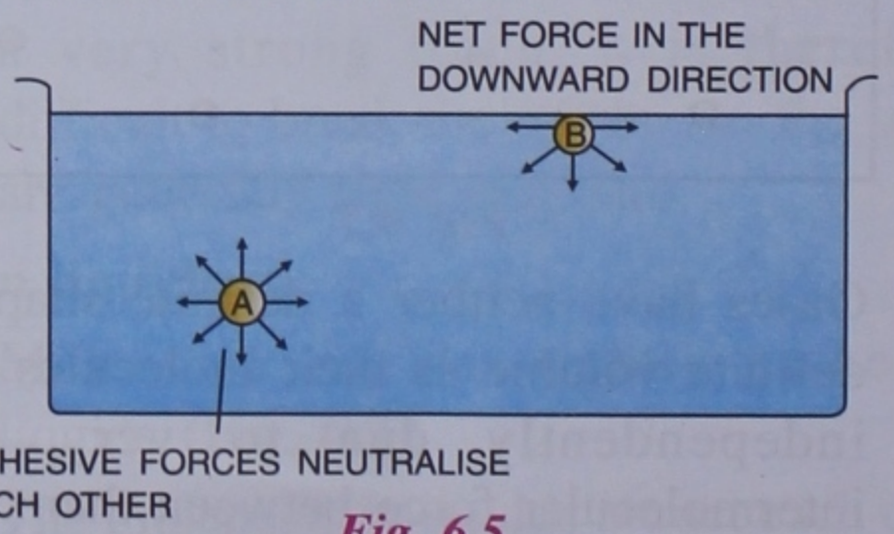

Fig. 6.5

MENISCUS OF A LIQUID

It is observed that when a free surface of

a liquid comes in contact with a solid, it shows a curvy shape near the point of contact. Here, an inward depression or an outward bulge takes place. This is called the **meniscus of a liquid**. The meniscus is concave when there is an inward depression and it is convex when there is an outward bulging [Fig. 6.6(a) & (b)].

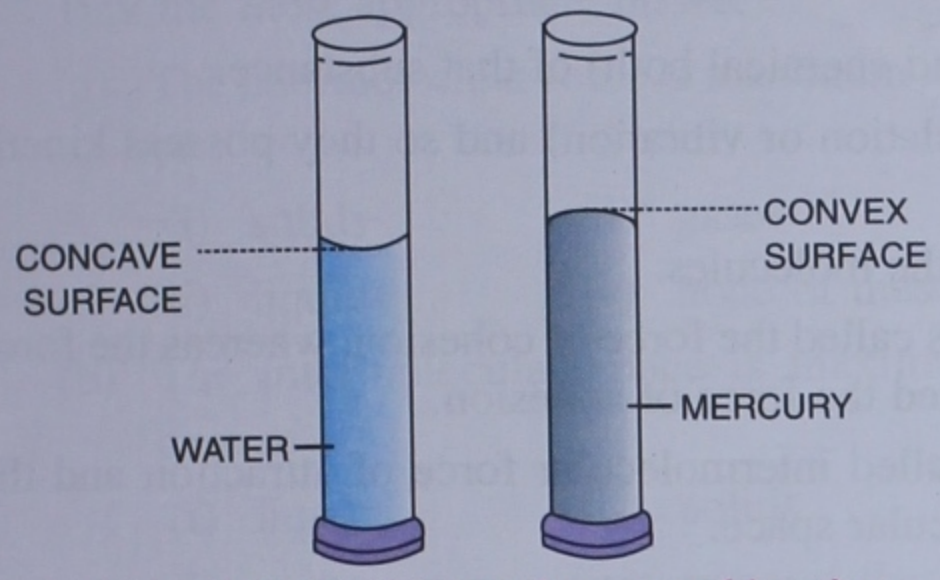

Fig. 6.6 (a) Water glass combination
(b) Mercury glass combination

The meniscus of water in a jar is concave because the forces of adhesion between the molecules of water and glass are stronger than the forces of cohesion between the molecules of water. Whereas, the meniscus of mercury in the jar is convex because the forces of cohesion between the molecules of mercury are more than the forces of adhesion between the molecules of mercury and glass.

FORMATION OF DROPLETS

Spray some mercury and some water on a glass surface. It will be observed that mercury forms spherical drops while water spreads. The reason for this difference is that the force of cohesion between the molecules of mercury is more than the force of adhesion between the molecules of mercury and glass. Whereas, the force of cohesion between the molecules of water is less than the force of adhesion between the molecules of water and glass.

EXPLANATION OF HEAT CONDUCTION ON KINETIC MODEL OF MATTER

Conduction is the process of heat transmission in which heat energy is transferred from one atom or molecule to another, in the direction of higher to lower temperature without the actual movement of the atoms or molecules from their mean positions. This can be explained on the basis of the kinetic model of matter.

When a solid (say a metal rod) is heated at one end, its atoms gain heat energy. The gain of heat energy by the atoms increase their kinetic energy and hence they vibrate about their mean position with greater amplitude. As a result, these energetic atoms strike the neighbouring atoms with larger energy and transfer a part of their energy to the striking atoms. In this way, more and more energy is transferred from one end of the substance having higher temperature towards the other end having lower temperature till the whole substance attains the same temperature.

In the transfer of heat due to conduction, particles (atoms or molecules) of the medium do take part in the process as they vibrate about their mean positions, but there is no net displacement in them.

EXPLANATION OF HEAT CONVECTION ON KINETIC MODEL OF MATTER

The property due to which particles of a medium actually move and carry heat energy from one place to another is known as **convection**. On the basis of the kinetic theory, we can explain it as follows :

When a substance is heated, its molecules come in direct contact with the source of heat, they absorb heat energy and expand. On expansion, they become lighter than the rest of the molecules of the substance and so they rise upwards taking the heat energy along with them. This results in the generation of convectional currents taking the warmer molecules up while sinking the colder molecules down.

RECAPITULATION

- Every matter is composed of atoms.
- Anything which occupies space and has mass is called matter.
- No physical or chemical mean can divide an element to two or more simpler substances.
- An atom may not have an independent existence but it takes part in the chemical reaction.
- Molecule is the smallest unit of matter which can exist independently. A molecule is made up of two or more atoms of same type or of different types.
- A molecule of a substance has all the properties (physical and chemical both) of that substance.
- Molecules in a matter are always in a state of motion (translation or vibration) and so they possess kinetic energy.
- The increase in temperature increases the kinetic energy of the molecules.
- The force of attraction between the molecules of same kind is called the force of cohesion, whereas the force of attraction between the molecules of different kinds is called the force of adhesion.
- The force of cohesion and the force of adhesion are also called intermolecular force of attraction and the space between the molecules of a matter is called intermolecular space.
- In case of solids, intermolecular space is least and so the intermolecular force of attraction is maximum. Whereas in case of gases, the intermolecular space is maximum and so the intermolecular force of attraction is least.
- Surface tension is the property of a liquid by virtue of which its free surface behaves like a stretched membrane with a tendency to contract and acquire the minimum surface area.
- Cause of surface tension is the unbalanced cohesive force acting on the molecules on the surface of the liquid.
- The shape of the meniscus of the liquid, taken in a narrow cylindrical container is :
  - concave, when the forces of adhesion between the molecules of the liquid and the container are strong.
  - convex, when the forces of cohesion between the molecules of the liquid are strong.
- When a small quantity of mercury is spread on a glass plate, spherical droplets are formed due to large force of cohesion between the molecules of the mercury.
- Heat always flows from a place at high temperature to the place at low temperature.
- Conduction is a process of transfer of heat from the hot end to the cold end from particle to particle of the medium.
- Convection is a process of transfer of heat by the actual movement of the medium particles.

TEST YOURSELF

A. Short Answer Questions

1. Fill in the blanks :
   (a) Anything which occupies space and has mass is called .....
   (b) The smallest unit of an element is ..... which may or may not exist in ..... .
   (c) The smallest unit of matter is called ....., which always exist ..... in nature.
   (d) Molecules of a substance are always in a state of ..... and so they possess ..... .
   (e) Force of cohesion is maximum in ....., less in ..... and least in ..... .
   (f) Intermolecular space is maximum in ....., less in ..... and least in ..... .
   (g) Intermolecular force of attraction is maximum in ....., less in ..... and least in .....

(h) The free surface of a liquid behaves like a stretched membrane due to ..... .

(i) All the molecules of a substance are .....

(j) The meniscus of water in a narrow glass tube is ....., whereas that of mercury is .....

2. Tick the most appropriate answer :

(a) The intermolecular force is maximum in case of :
(i) solids (ii) gases
(iii) liquids (iv) none of these

(b) The intermolecular space is maximum in case of :
(i) liquids (ii) solids
(iii) gases (iv) none of these

(c) The molecules can move freely anywhere in
(i) gases (ii) liquids
(iii) solids (iv) none of these

(d) The molecules do not move within the boundary of :
(i) liquids (ii) gases
(iii) solids (iv) none of these

(e) After absorbing heat, the molecules move from the hot end to the cold end due to
(i) conduction (ii) convection
(iii) radiation (iv) none of these

(f) After absorbing heat, the molecules vibrate more frequently about their mean position and transfer their energy to the surrounding molecules in case of :
(i) convection (ii) conduction
(iii) absorption (iv) none of these

(g) The intermolecular forces of attraction in liquids are :
(i) less than in gases
(ii) more than in solids
(iii) same as in solids
(iv) less than in solids

3. Answer the following questions :
(a) Define the term matter.
(b) Define molecule and give an example.
(c) What is force of cohesion ?
(d) What is the force of adhesion ?
(e) Define surface tension.
(f) What is the meniscus of a liquid.

A. Long Answer Questions

1. Differentiate between the force of cohesion and the force of adhesion. Give one example of each.
2. Define :
(a) matter (b) atom
(c) molecule (d) intermolecular space
(e) intermolecular force of attraction
(f) surface tension (g) conduction
(h) convection
3. Give the properties of :
(a) solids (b) liquids (c) gases
4. Which of the following are correct :
(a) solids have definite shape and definite volume.
(b) liquids have definite volume but do not have definite shape.
(c) gases have definite volume but do not have definite shape.
(d) liquids have definite shape and definite volume.
5. Discuss the three states of matter : solid, liquid and gas on the basis of kinetic model.
6. Explain the surface tension in liquids, with reasons.
7. Water wets a glass surface whereas mercury does not wet it. Explain.
8. When a small quantity of mercury and a small quantity of water are spread on a glass surface, the mercury forms spherical droplets. Explain.
9. Discuss the transfer of heat by :
(a) conduction (b) convection
10. Discuss on the basis of molecular movement:
(a) the transfer of heat by conduction.
(b) the transfer of heat by convection.