PERIOD–VI

P10CH6

Topic

6 Properties of Matter

6.1. INTRODUCTION

Look at all the things in your surroundings. You see a large variety of things with different shapes, sizes, and appearances. Of these things some are natural, others are man-made. Look at the photographs shown in Fig. 6.1. You may have come across various objects, things, materials as seen in these photographs. They are all made of different kinds of materials. The food is made of different kinds of chemicals. The kitchenware is made of different metals. Items of daily use such as bucket and dustbins may be made of plastic or metal. The objects in junkyard or scrapyard may be made of plastic, wood, and metal. We see that these things have different shapes, sizes and textures and also occupy space. *Anything that occupies space and has mass is matter.*

In this unit we shall learn about the Kinetic theory and physical properties of matter.

Food items | Some items of daily use | Kitchenware | Scrapyard with variety of materials

Fig. 6.1. Some objects made of materials

6.2. SIMPLE KINETIC THEORY

Kinetic energy is energy that an object has because of its motion. The **kinetic theory of matter** attempts to explain the physical properties of matter (in its various states) in terms of the motion of its particles and the kinetic energy possessed by them.

The main aspects of this theory are:

1. **Matter is made up small particle (atoms, molecules and ions):**

   Atoms: Atom is the smallest particle of matter and has all its properties.

   Molecules: Two or more than two atoms combine to form a molecule.

   Ions: These are positively or negatively charged atom or group of atoms.

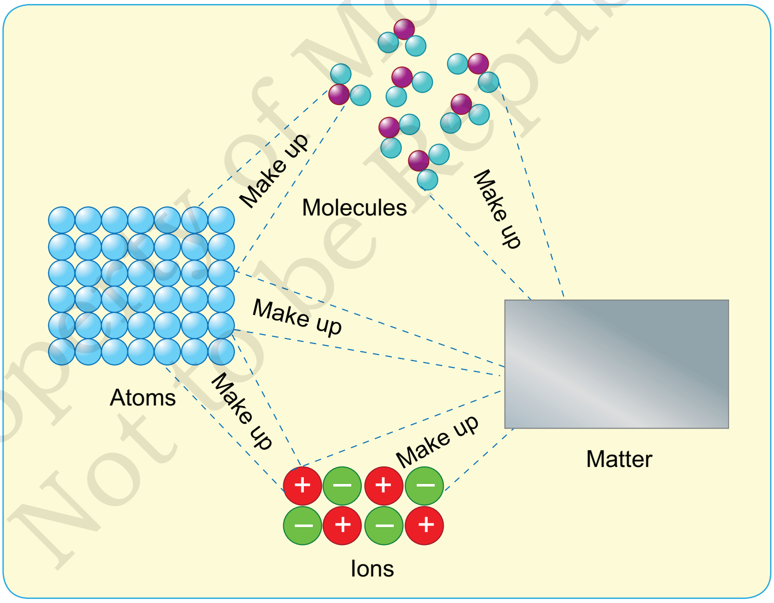

Fig. 6.2. Model of structure of matter

The following table shows the difference between atom and molecule.

Table 6.1. Difference between atom and molecule

Atom	Molecule
• An atom is the smallest particle of an element.	• A molecule is the smallest particle of an element or compound.
• An atom consists of subatomic particles: protons, electrons, neutrons.	• It consists of more than two atoms which can be either of the same element or of different elements.
• An atom may not always be stable in nature due to presence of electrons in the outer shells.	• A molecule is formed to attain stability.
• An atom cannot be separated by chemical reactions.	• A molecule can be separated by chemical reactions.

2. **Particles of matter have space between them:** You may have noticed that when we make tea, coffee or lemonade, particles of one type of matter get into the spaces between particles of the other. This shows that there is enough space between the particles of matter.
3. **Particles of matter are continuously moving:** Let us perform an activity.

Activity 6.1

- Put an unlit incense stick in a corner of your class. How close do you have to go near it so as to get its smell?
- Now light the incense stick. What happens? Do you get the smell sitting at a distance?
- Record your observations.

This activity shows that particles of matter are continuously moving, that is, they possess what we call the kinetic energy. As the temperature rises, particles move faster. So, we can say that with increase in temperature the kinetic energy of the particles also increases.

4. Particles of matter attract each other:

ACTIVITY 6.2

- Take an iron nail, a piece of chalk and a rubber band.
- Try breaking them by hammering, cutting or stretching.
- In which of the above three substances do you think the particles are held together with greater force?

ACTIVITY 6.3

- Open a water tap, try breaking the stream of water with your fingers.
- Were you able to cut the stream of water?
- What could be the reason behind the stream of water remaining together?

The activities 6.2 and 6.3 suggest that particles of matter have force acting between them. This force keeps the particles together. It is the highest when particle are closely packed and least when they are at a distance from each other. Thus, this force decreases with an increase in distance between them and vice-versa. The strength of this force of attraction varies from one kind of matter to another.

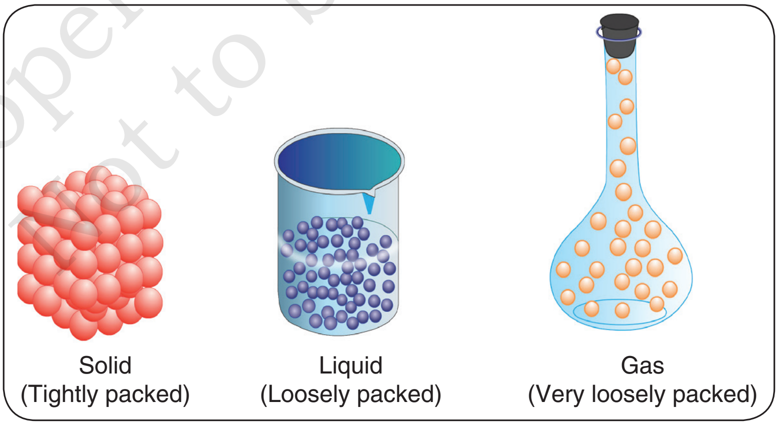

Fig. 6.3. Arrangement of particles in solids, liquids and gases

6.3. STATES OF MATTER

Observe different types of matter around you. What are its different states? We can see that matter around us exists in three different states—solids, liquids and gases.

Ice is solid Water is liquid Steam is a gas

Fig. 6.4. Three states of matter

These states of matter arise due to the variation in the characteristics of the particles of matter.

Now, let us study about the properties of these three states of matter in detail.

6.4. THE SOLID STATE

ACTIVITY 6.4

- Collect the following articles—a pen, a book, a needle and a piece of wooden stick.
- Sketch the shape of the above articles in your notebook by moving a pencil around them.
- Do all these have a definite shape, distinct boundaries and a fixed volume? What happens if they are hammered, pulled or dropped?
- Try compressing them by applying force. Are you able to compress them?

All the above are examples of solids. We can observe that all these have a definite shape, distinct boundaries and fixed volumes, that is, have negligible compressibility. Solids have a tendency to maintain their shape when subjected to outside force. Solids may break under force but it is difficult to change their shape, so they are rigid.

Consider the following:

(a) What about a rubber band, can it change its shape on stretching? Is it a solid?

(b) What about sugar and salt? When kept in different jars these take the shape of the jar. Are they solid?

(c) What about a sponge? It is a solid yet we are able to compress it. Why?

All the above are solids as:

- A rubber band changes shape under force and regains the same shape when the force is removed. If excessive force is applied, it breaks.
- The shape of each individual sugar or salt crystal remains fixed, whether we take it in our hand, put it in a plate or in a jar.
- A sponge has minute holes, in which air is trapped. When we press it, the air is expelled out and we are able to compress it.

6.5. PHYSICAL PROPERTIES OF SOLIDS

The physical properties of solids are given below:

(i) Hardness: Hardness measures a solids resistance to permanent shape change when a compressive force is applied. Some materials, such as metals are harder than others. Diamond is the hardest natural substance found on Earth.

Some solids, such as steel or concrete, are difficult to break, even if they are made to carry a heavy weight. Such materials are said to have high strength and are used to construct bridges and buildings.

Due to its hardness, iron is used in making tools and iron ropes. According to the kinetic theory, this is because the particles of solids are very close together and have no space to move.

(ii) Malleability: Malleability measures a solid's ability to be beaten into thin sheets. Aluminum is a highly malleable metal. Aluminum foil and beverage cans are two good examples of how manufacturers take advantage of the malleability of aluminum.

Gold and silver are the most malleable metals known. It helps jewellery designers create intricately carved ornaments and decorative articles.

(iii) Ductility: The ability of solids to be drawn into thin wires is called ductility. Generally all metals are ductile. For example silver, gold, copper, aluminum, tin, mild steel, platinum etc. Gold is the most ductile metal. You will be surprised to know that a wire of about 2 km length can be drawn from one gram of gold. It is because of their malleability and ductility that metals can be given different shapes according to our needs.

(iv) Brittleness: Brittleness measures a material's tendency to shatter upon impact. Brittleness is considered a hazardous property in the automobile industry, where, for instance, shattering glass can cause serious injuries. Examples of brittle solids include glass, ceramics and stones.

(v) Melting Point: As solid matter is heated the internal energy of the solid increases which increases the substance's temperature to the melting point. At the melting point, the ordering of ions or molecules in the solid breaks down to a less ordered state, and the solid **melts** to become a liquid. Ice (a solid form of water) melts at 0°C and changes to the liquid state. Tungsten has the highest melting point and is therefore used in making bulb filament.

(vi) Conductivity: Conductivity of a solid is defined as its ability to transmit heat or electricity. On the basis of conductivity, the solids can be broadly classified as conductors, insulators and semiconductors.

6.6. ELASTICITY

Activity 6.5

Take a rubber band and stretch it. The length of rubber band is increased.

1. Do you feel a force that resist any change in its shape?
2. On releasing the force on rubber band what do you observe?

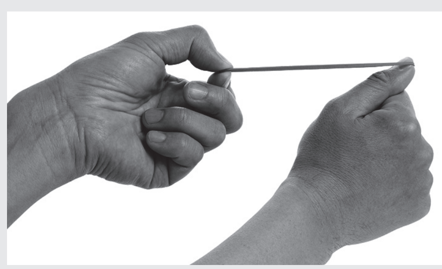

Fig. 6.5. Stretching rubber band

When we apply an external force upon a body then there is a change either in size or shape or both of the body. This force is called 'deforming force'. On removing it, the body again acquires its original size and shape. This property of the substances is called 'elasticity', and the body in which this property is found is called 'elastic'.

6.6.1. Elastic, Plastic and Rigid Bodies

The bodies which recover completely their original state on the removal of the deforming forces are called 'perfectly elastic'. On the other hand, the bodies which do not recover their original state when deforming forces are removed but retain their modified form are called 'perfectly plastic'. Actually, no body is perfectly elastic or perfectly plastic, but all bodies behave in between these two limits.

6.6.2. Limit of Elasticity

Elastic bodies recover their original state when the deforming forces are removed. But they show this property upto a certain value of the deforming force. If we go on increasing the deforming force then a stage will be reached when on removing the force the body will not return to its original state. For example, if a small load is applied at the lower end of a wire suspended vertically from a rigid support, the length of the wire is increased; when the load is removed, the wire acquires its original length. If we increase the load step by step, then a stage is reached when on removing the load, the wire does not recover its original length but its length is permanently increased. Thus, its property of elasticity is destroyed. The maximum deforming force upto which a body retains its property of elasticity is called the 'limit of elasticity' of the material of the body.

6.6.3. Stress

When an external force applied to a body changes the size or shape of the body then at each cross-section of the body an internal reactionary force is developed which tends to restore the body to its original state. The internal restoring force acting per unit area of cross-section of the deformed body is called stress. If an external force F is applied to the cross-sectional area A of a body, then

$$\text{Stress} = F/A$$

The unit of stress is 'newton/metre^2, (N m^{-2}) and its dimensional formula is [ML^{-1} T^{-2}].

The stress developed in a body depends upon how the external forces are applied over it. On this basis, there are three types of stress: longitudinal stress, normal stress and tangential stress.

Example 1: *The femur, which is the principal bone of the thigh, has a minimum diameter, in an adult male, of about 2.8 cm, corresponding to a cross-sectional area A of 6 × 10^{-4} m^2. At what compressive load would it break? Given: The ultimate strength for bone is 170 × 10^6 N m^{-2}.*

Solution:

$$F = 170 \times 10^6 \times 6 \times 10^{-4} \text{ N}$$
$$= 1.02 \times 10^5 \text{ N}$$

Example 2: *A 1000 kg lift is tied with metallic wires of maximum safe stress of 1.4 × 10^8 N m^{-2}. If the maximum acceleration of the lift is 1.2 m s^{-2}, then find the minimum diameter of the wire.*

Solution:

$$T = 1000 \, [9.8 + 1.2] \text{ N}$$
$$= 11000 \text{ N}$$

Maximum stress

$$= \frac{11000 \times 7}{22 \times r_{\text{min.}}^2}$$

or $$r_{\text{min.}}^2 = \frac{11000 \times 7}{22 \times 1.4 \times 10^8} = \frac{50^2}{(10^4)^2}$$

or $$r_{\text{min.}} = 50 \times 10^{-4} \text{ m}$$
$$D_{\text{min.}} = 100 \times 10^{-4} = 0.01 \text{ m}$$

6.6.4. Strain

The strain produced in a body is measured as the ratio of change in configuration to the original configuration of the body. Since strain is the ratio of two like quantities therefore it is a pure number *i.e.*, it has neither units nor dimensions.

Following are the three types of strain :

(a) Tensile or Longitudinal or Linear Strain : When the deforming force produces a change in length, the strain is called longitudinal strain. *Within elastic limit, it is the ratio of change in length to original length.*

If l be the original length and Δl be the change in length, then

$$\text{longitudinal strain} = \frac{\Delta l}{l}.$$

(b) Bulk or Volumetric Strain : If the deforming forces produce a change in volume, then the strain is called volumetric strain. Within elastic limit, it is the ratio of change in volume to the original volume.

$$\text{volumetric strain} = \frac{\Delta V}{V}.$$

(c) Shear Strain : If the deforming forces produce a change in the shape of the body, then the strain is called shear strain. Within elastic limit, it is measured by the ratio of the relative displacement of one plane to its distance from the fixed plane. It can also be measured by the angle through which a line originally perpendicular to the fixed plane is turned [Fig. 6.6]. This angle is called angle of shear.

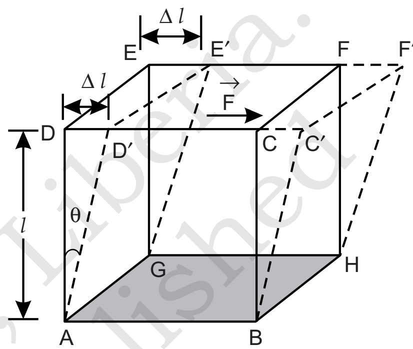

Fig. 6.6. Shear strain

Shear strain = $\theta \approx \tan\theta$ [Within elastic limit, θ is small.]

$$= \frac{\Delta l}{l}$$

If $l = 1$, then shear strain = Δl.

So, shear strain is the relative displacement between two parallel planes a unit distance apart.

6.7. HOOKE'S LAW

Hooke's Law is stated as follows :

Within elastic limit, the extension of an elastic body is directly proportional to the force that is producing it.

Thomas Young, an English scientist modified the law to a general form.

This modified form, given below, is now the accepted form of Hooke's law.

Within elastic limit, stress is proportional to strain.

Mathematically, Stress $\propto$ Strain (within elastic limit)

or $$\frac{\text{Stress}}{\text{Strain}} = \text{Constant}.$$

This constant is known as **modulus of elasticity** or **coefficient of elasticity**. It depends upon the nature of the material of the body and the manner in which it is deformed.

Activity 6.6

To investigate Hooke's Law

The apparatus (involving a spring) has to be set up like the shown diagram.

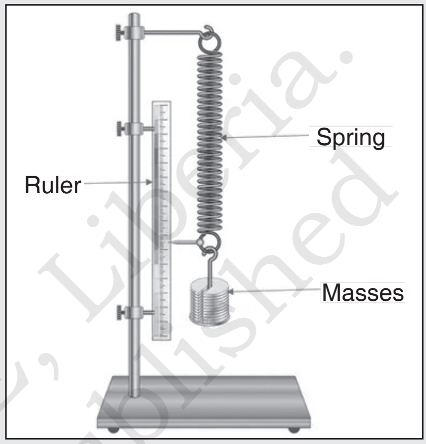

Fig. 6.7. Hooke's law apparatus

To verify Hooke's law experimentally do the following activity:

1. Set up the mass carrier attached to the spring.
2. Attach an empty mass carrier to the bottom end of the spring and measure the length of the spring in centimetres (cm).
3. Add slotted masses (in gram) *e.g.*, 100 g, 200 g, 300 g, etc., and calculate the Force (F) for each mass using formula.

$$F = mg$$

where m is mass and g is gravitational constant.

4. Measure the length of spring for each additional weight is added.
5. Measure the extension using the formula:

(Length of spring before adding mass – Length of spring after adding mass)

6. Record each result in the table given below.

Mass (g)						
Force (N)						
Length (cm)						
Extension (cm)						

7. Now plot the graph with force on the vertical (y) axis and extension on the horizontal (x) axis.

You will get a graph of straight line similar to the graph shown below.

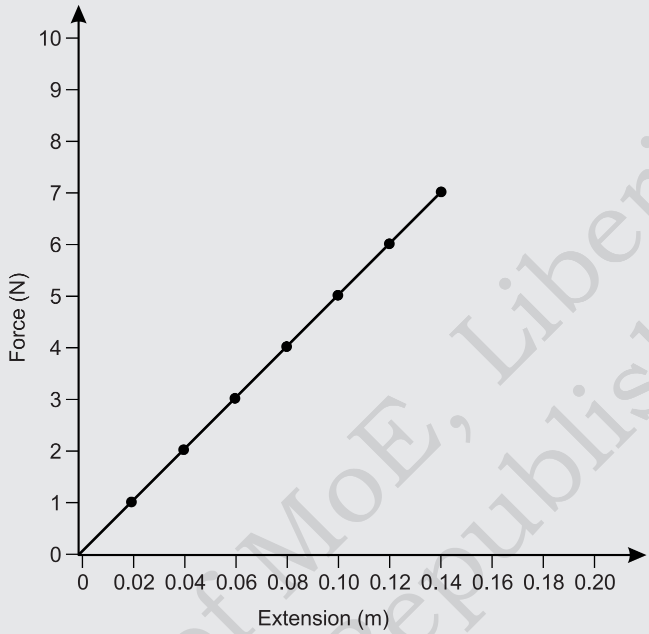

Fig. 6.8. Graph between extension and force

This graph shows us that the force applied is directly proportional to the extension of the object.

This is the Hooke's law and hence verified.

6.7.1. Graphical Representation of Elasticity

According to the Hooke's law, the stress produced in a body is proportional to the strain. But this proportionality exists for small strains only. Suppose, a wire of uniform cross-section is clamped at its upper end by a rigid support and a load is applied at its lower end which is gradually increased. As a result, the length of the wire goes on increasing. A graph between the longitudinal stress and the corresponding strain is a curve as shown in Fig. 6.9.

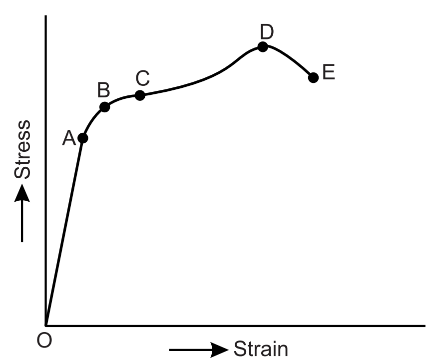

Fig. 6.9. Graph representing elasticity

The initial part OA of the graph is a straight line, indicating that up to the point A the increase in length is directly proportional to the load. Thus, in the part OA Hooke's law is obeyed. The stress corresponding to the point A is called the 'limit of proportionality',

Beyond the point A, the graph begins to be curved. This indicates that on further increasing the load, the increase in length is no longer proportional to the load, but is greater than allowed by proportionality. However, upto a point B, the elastic property exists in the wire, that is, the wire returns to its original length when the load is removed. The stress at the point B is called the 'elastic limit', and the point B is called the 'yield point'. The elastic limit is close to the proportionality limit. The region from the point O to the point B is called the 'elastic region'.

Beyond the point B, with increasing load, the length of the wire increases very rapidly. At one stage, say at point C, on removing the load, the wire does not return to its original length, but its length is permanently increased.

Beyond the point C, on increasing the load *slowly*, the length of the wire continues to increase rapidly. At point D, the stress reaches at its maximum value. At this point, the material of the wire flows like a viscous liquid and the wire becomes thin. Now, even if the load is decreased, the wire goes on thining down until it breaks at a point E. The maximum stress that a wire can bear before breaking is called 'breaking stress' or 'tensile stress'. The region from the point B to the point E is called the 'plastic region'.

Example 3: *The stress-strain graphs for two materials A and B are shown in the figure. The graphs are drawn to the same scale.*

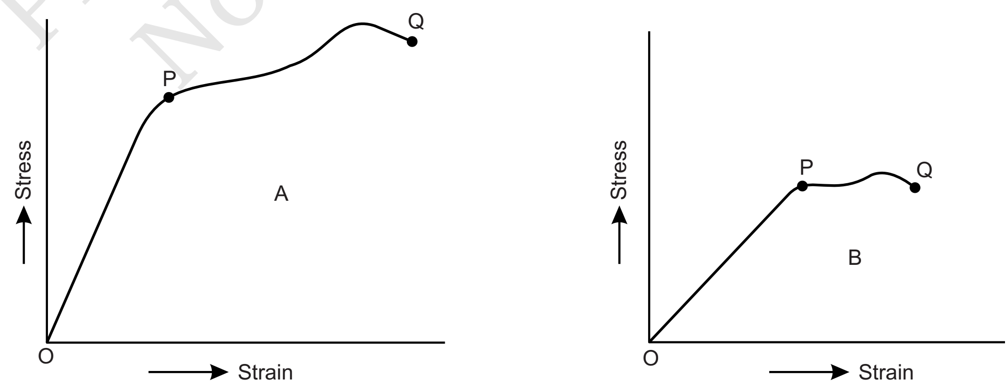

Fig. 6.10. Stress-strain graph of material A and B

(a) *Which material is more ductile?*

(b) *Which material is more brittle?*

(c) *Which of the two is the stronger material?*

Solution:

(a) Material A is more ductile, because it has a greater plastic region (from elastic limit P to breaking point Q than materials B.

(b) Material B is more brittle, because it has a small plastic region.

(c) Material A is stronger, because it can withstand greater stress before it breaks.

Example 4: *Is rubber more elastic than steel?*

Solution: No; steel is more elastic because more force is required to produce equal increase in length in a steel wire than in a rubber wire of same length and same thickness.

6.8. YOUNG'S MODULUS OF ELASTICITY

Within elastic limit, it is the ratio of longitudinal stress to longitudinal strain. It is denoted by Y.

$$\therefore \qquad Y = \frac{\text{longitudinal stress}}{\text{longitudinal strain}}$$

Consider a wire of length l and cross-sectional area A stretched by a force F through a distance Δl.

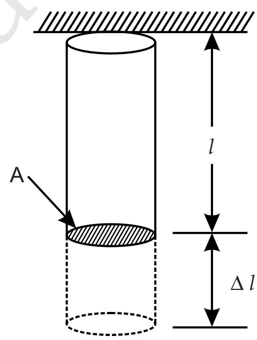

Fig. 6.11. Young's modulus of elasticity

$$\text{Then,} \qquad Y = \frac{F / A}{\Delta l / l} = \frac{Fl}{A\Delta l}$$

If $A = 1$, $l = 1$ and $\Delta l = 1$, then Y = F.

So, *Young's modulus of elasticity is equal to the force required to extend a wire of unit length and unit cross-sectional area through unity. It may also be defined as the longitudinal stress required to double the length of the wire.*

The SI unit of Young's modulus of elasticity is N m^{-2} or Pa. Its cgs unit is dyne cm^{-2}. Its dimensional formula is $[ML^{-1} T^{-2}]$.

Example 5: *What mass must be suspended from a steel wire 2 m long and 1 mm diameter to stretch it by 1 mm ? Give : Young's modulus of steel = 2 × 10^{12} dyne cm^{-2}, g = 981 cm s^{-2}.*

Solution: l = 200 cm,

$$r = \frac{1}{2}\text{ mm} = 0.05\text{ cm}$$

$$\Delta l = 1\text{ mm} = 0.1\text{ cm},$$

$$Y = 2 \times 10^{12}\text{ dyne cm},$$

$$M = ?$$

$$\therefore \quad Y = \frac{F \times l}{A \times \Delta l} = \frac{Mg \times l}{\pi r^2 \times \Delta l}$$

$$\text{or} \quad M = \frac{Y \times \pi r^2 \times \Delta l}{g \times l}$$

> *Note that the weight of the suspended mass acts as the 'external applied force'.*

$$\therefore M = \frac{2 \times 10^{12} \times 22 \times 0.05 \times 0.05 \times 0.1}{7 \times 981 \times 200}\text{ g}$$

$$= 8009\text{ g} = 8.009\text{ kg}$$

Example 6: *How much will a 3.0 m long copper wire elongate if a weight of 10 kg is suspended from one end and the other end is fixed ? The diameter of the wire is 0.4 mm. Given : Y for copper = 10^{11} N m^{-2} and g = 9.8 m s^{-2}.*

Solution:

$$M = 10\text{ kg},$$

$$F = Mg = 10 \times 9.8\text{ N} = 98\text{ N}$$

$$r = 0.2\text{ mm} = 0.2 \times 10^{-3}\text{ m},$$

$$Y = 10^{11}\text{ N m}^{-2},$$

$$l = 3\text{ m}, \Delta l = ?$$

$$\text{Now,} \quad Y = \frac{F \times l}{A \times \Delta l}$$

$$\text{or} \quad \Delta l = \frac{F \times l}{\pi r^2 \times Y}$$

> *In this problem, it is understood that the weight of the copper wire is to be neglected.*

$$\therefore \Delta l = \frac{98 \times 3 \times 7}{22 \times (0.2 \times 10^{-3})^2 \times 10^{11}}\text{ m}$$

$$= \frac{98 \times 21}{88 \times 10^3}\text{ m} = 0.02339\text{ m}$$

$$= 2.339\text{ cm}$$

Example 7: *What is the percentage increase in the length of a wire of diameter 2.5 mm stretched by a force of 100 kg weight ? Young's modulus of elasticity of the wire is 12.5 × 10^{11} dyne cm^{-2}.*

Solution: r = 1.25 mm

$$= 0.125\text{ cm},$$

$$F = 100 \times 9.8\text{ N}$$

$$= 980\text{ N} = 98 \times 10^6\text{ dyne}$$

$$Y = 12.5 \times 10^{11}\text{ dyne cm}^{-2}$$

$$\therefore \quad Y = \frac{Fl}{A \times \Delta l} \quad \text{or} \quad \frac{\Delta l}{l} = \frac{F}{AY}$$

$$\text{or} \quad \frac{\Delta l}{l} \times 100 = \frac{F}{\pi r^2 Y} \times 100$$

$$= \frac{98 \times 10^6 \times 7 \times 100}{22 \times (0.125)^2 \times 12.5 \times 10^{11}}$$

$$= 15.965 \times 10^{-2} = 0.16\%$$

Example 8: *A structural steel rod has a radius of 10 mm and a length of 1 m. A 100 kN force F stretches it along its length. Calculate (a) the stress, (b) elongation, and (c) strain on the rod. Given that the Young's modulus E, of the structural steel, is 2.0×10^{11} N m^{-2}.*

Solution: We assume that the rod is held by a clamp at one end. Then the force F is applied at the other end, parallel to the length of the rod. Now, the stress on the rod is given by

$$\text{Stress} = \frac{F}{A} = \frac{F}{\pi r^2} = \frac{100 \times 10^3 \text{ N}}{3.14 \times (10^{-2} \text{m})^2}$$

$$= 3.18 \times 10^8 \text{ N m}^{-2}$$

Elongation,

$$\Delta L = \frac{(F / A)L}{E}$$

$$= \frac{(3.18 \times 10^8 \text{N m}^{-2})(1 \text{ m})}{2 \times 10^{11} \text{ N m}^{-2}}$$

$$= 1.59 \times 10^{-3} \text{ m} = 1.59 \text{ mm}$$

$$\text{Strain} = \Delta L / L$$

$$= 1.59 \times 10^{-3} \text{ m/1m}$$

$$= 1.59 \times 10^{-3}$$

$$= 0.159\%$$

6.9. THE LIQUID STATE

ACTIVITY 6.7

Collect the following:

(a) water, cooking oil, milk, juice, a cold drink.

(b) containers of different shapes. Put a 50 mL mark on these containers using a measuring cylinder from the laboratory.

What will happen if these liquids are spilt on the floor?

Measure 50 mL of any one liquid and transfer it into different containers one by one. Does the volume remain the same?

Does the shape of the liquid remain the same?

When you pour the liquid from one container into another, does it flow easily?

We observe that liquids have no fixed shape but have a fixed volume. They take up the shape of the container in which they are kept. Liquids flow and change shape, so they are not rigid but can be called fluid.

6.10. PHYSICAL PROPERTIES OF LIQUIDS

The physical properties of liquids are as follows.

(i) Boiling Point: It is the temperature at which a liquid changes into vapour. As the liquid matter is heated it eventually boils or vaporizes into a gas at the boiling point. Liquid water boils and changes into a gas, usually called steam or water vapour at 100°C. In all three states the same molecules of water (H_2O) are present.

(ii) Freezing Point: Liquids have a characteristic temperature at which they turn into solids, known as their **freezing point**. Freezing point of water is 0°C.

(iii) Density: Density of a liquid of mass m occupying volume V, is given by the equation $\rho = m/V$. Its SI unit is kg m^{-3}. It is a positive scalar quantity. A liquid is largely incompressible and its density is therefore, nearly constant at all pressures. The density of water at 4°C (277 K) is 1.0×10^3 kg m^{-3}. The density of a liquid can vary with temperature. Temperature has a significant effect on density. In general, liquids expand as temperature increases, and, therefore, the density decreases.

(iv) Viscosity: Viscosity is defined as a liquid's resistance to flow. When the intermolecular forces of attraction are strong within a liquid, there is a larger viscosity.

ACTIVITY 6.8

Comparing Viscosity

Take a sheet of glass at least 10 by 15 cm in size. Using a water-proof marker draw a straight line across the width of the glass about 2 cm from each end.

Place the glass flat on top of two pencils, then carefully put a drop of water on one end of the line. Put a drop of honey on the other end of the line.

Slowly and carefully remove the pencil from the end opposite the drops (make sure you don't tilt the glass to either side in the process).

- Which drop moves faster and reaches the end line first?
- Which drop moves slower?

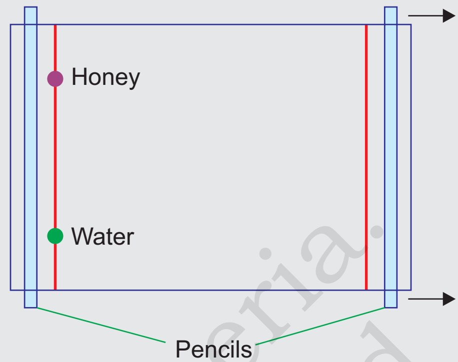

Fig. 6.12. Sheet of glass

The faster moving substance has less resistance to flow, and therefore has the less viscosity (is less viscous). The slow moving substance has more resistance to flow, and therefore has more viscosity (is more viscous).

6.11. TYPES OF INTERMOLECULAR FORCES : COHESION AND ADHESION

The molecular forces between two molecules of a substance are called **intermolecular forces**.

Following are the two types of intermolecular forces :

(i) Force of Cohesion : It is the force of attraction between the molecules of the same substance. It is also known as **cohesive force**. The corresponding phenomenon is called **cohesion**. It is the force of cohesion which keeps the particles of solids packed very close together and gives them rigidity and definite shape. The forces of cohesion are very strong in solids, weak in liquids and extremely weak in gases.

Example: We can suspend a heavy weight by a thin steel wire because of strong forces of cohesion between the molecules of steel wire.

(ii) Force of Adhesion : It is the force of attraction between the molecules of two different substances. It is also known as

adhesive force. The corresponding phenomenon is called **adhesion**.

Example: It is due to the force of adhesion that ink sticks to paper while writing.

Similarly, graphite from lead pencil sticks to paper. Strong adhesion is shown by materials like fevicol, cement, gum etc.

ACTIVITY 6.9

1. Pour some water in a glass.

   Why water wets glass?

2. Pour small amount of mercury in a glass.

   Why mercury does not wet glass?

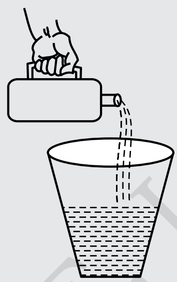

Fig. 6.13. Glass with water

Fig. 6.14. Glass with Mercury

Water wets glass because the force of cohesion between the water molecules is less than the force of adhesion between water and glass molecules.

Mercury does not wet glass because the force of adhesion between mercury and glass molecules is less than the force of cohesion between the mercury molecules.

6.12. SURFACE TENSION

ACTIVITY 6.10

Take a wire frame and tie loosely a closed loop of cotton thread between its two points. Dip it in a soap solution. A thin film of soap solution is formed in an irregular manner (Fig. 6.15).

Broke the film inside the loop by a needle.

What do you observe?

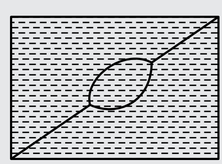

Fig. 6.15. Wire frame in a soap solution

In above activity when the film inside the loop is broken, the film outside the loop contracts, thus pulling the thread into a circle and the thread assumes a circular form as shown in figure 6.16. We know that for a given perimeter the circle has the largest area. This means that the film outside the loop contracts to a smallest area.

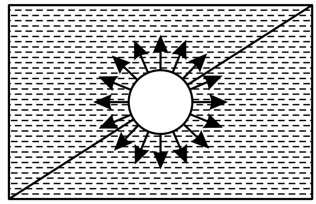

Fig. 6.16. Film inside the loop is broken

This shows that the free surface of a liquid tends to have a minimum possible area. In this respect it behaves like a *stretched* elastic membrane which also has a natural tendency to contract. Thus, a liquid surface is always in a state of tension. This tension in the surface is known as 'surface tension'.

Thus, *surface tension is a property by virtue of which the free surface of a liquid at rest behaves like a stretched elastic membrane tending to contract to possess minimum surface area.*

Imagine a line AB in the free surface of a liquid at rest (Fig. 6.17). The force of surface tension is measured by the force acting per unit length on either side of the imaginary line. The direction of this force is perpendicular to the line and tangential to the liquid surface. If F be the force acting and l the length of the imaginary line, then the surface tension is given by

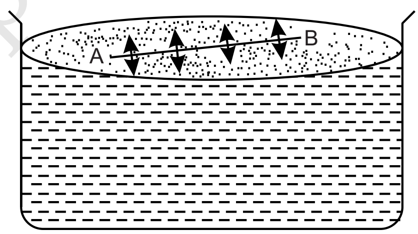

Fig. 6.17. Force of surface tension

$$S = \frac{F}{l}$$

Units: In cgs system, it is expressed in **dyne cm^{-1}**. In SI, it is expressed in **N m^{-1}**.

The dimensional formula of surface tension is $[ML^0T^{-2}]$.

Example 9: *A wire ring of 0.03 m radius is rested on the surface of a liquid and then raised. The pull required is 0.003 kg weight more before the film breaks than it is after. Find the surface tension of liquid.*

Solution: The additional pull (f) of 0.003 kg weight is equal to the force due to surface tension.

Force due to surface tension, F = S × length of ring in contact with the liquid = $S \times 2 \times 2\pi r = 4\pi S r$

$$\therefore \quad 4\pi S r = 0.003 \times 9.81$$

$$\text{or} \quad S = \frac{0.003 \times 9.81}{4 \times 3.142 \times 0.03} \text{ N m}^{-1}$$

$$= 0.078 \text{ N m}^{-1}$$

Example 10: *A soap film is formed on rectangular frame of length 0.03 m dipping in soap solution. The frame hangs from the arm of a balance. An extra mass of 2.20×10^{-4} kg must be placed in the other pan to balance the pull of the film. Calculate the surface tension of the soap solution.*

Solution: Force acting on the frame due to surface tension,

$$F = S \times l$$

where l is the length of the frame in contact with the liquid.

Since the soap film has two surfaces,

$$\therefore \quad l = 2 \times 0.03 \text{ m}$$

$$= 0.06 \text{ m}$$

$$\therefore \quad F = 0.06 \text{ S newton}$$

This must be equal to the extra weight.

$$\therefore \quad 0.06 \text{ S} = 2.20 \times 10^{-4} \times 9.81$$

$$\text{or} \quad S = \frac{2.20 \times 9.81}{0.06} \times 10^{-4} \text{ N m}^{-1}$$

$$= 0.036 \text{ N m}^{-1}$$

6.12.1. Experiments to Illustrate Surface Tension

1. Take a camel hair paint brush and dip it into water. Its hair get separated from each other. Now take the brush out of water. Its hair will cling together as the free surfaces of water films try to contract due to surface tension.

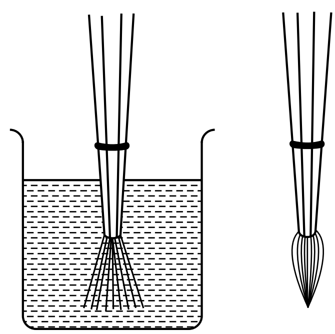

Fig. 6.18. Contraction due to surface tension

2. When a sewing needle is gently placed on the surface of water, it floats. The water surface below the needle gets slightly depressed. The force of surface tension does not act horizontally but along an inclined direction. (Fig. 6.19). The vertical component of the force of surface tension balances the weight of the needle.

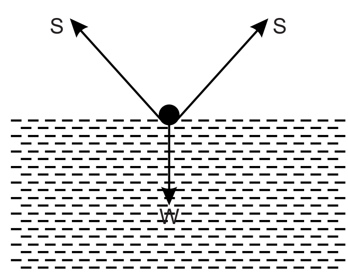

Fig. 6.19. Behaviour of free surface as stretched membrane

6.12.2. Surface Energy

The free surface of a liquid at rest is always in a state of tension. The force of surface tension tends to decrease the surface area to the minimum. If the surface area of the liquid is to be increased, work shall have to be done against the force of surface tension. This work done is stored in the liquid surface film as its potential energy.

The potential energy per unit area of the surface film is called the ***surface energy***.

Another Definition: It is the amount of work done in increasing the area of a surface film through unity under isothermal conditions.

$$\therefore \quad \text{Surface energy} = \frac{\text{Wrok done in increasing the surface area}}{\text{Increase in surface area}}$$

In SI, the surface energy is measured in J m^{-2}.

Example 11: *Calculate the work done in blowing a soap bubble from a radius of 0.02 m to 0.03 m. The surface tension of soap solution is 0.03 N m^{-1}.*

Solution:

Initial radius, $r_1 = 0.02$ m

Final radius, $r_2 = 0.03$ m

Increase in surface area,

$$\Delta A = 2 \times 4\pi (r_2^2 - r_1^2)$$
$$= 8\pi [9 \times 10^{-4} - 4 \times 10^{-4}] \text{ m}^2$$
$$= 40\pi \times 10^{-4} \text{ m}^2$$

Work done

$$= S \times \Delta A$$
$$= 0.03 \times 40\,\pi \times 10^{-4} \text{ J}$$
$$= 3.77 \times 10^{-4} \text{ J}$$

Example 12: *Calculate the energy required to split a drop of water of radius 1×10^{-3} m into one thousand million droplets of the same size. Surface tension of water = 0.072 N m^{-1}.*

Solution:

Radius of big drop,

$$R = 1 \times 10^{-3} \text{ m}$$

Number of droplets,

$$n = 10^3 \times 10^6 = 10^9$$

Surface tension,

$$S = 0.072 \text{ N m}^{-1}$$

Let r be the radius of a droplet.

Now, volume of 10^9 droplets = volume of big drop

$$\therefore \quad 10^9 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

or $\quad 10^9 \times r^3 = R^3$

or $\quad (10^3 r)^3 = (10^{-3})^3$

or $\quad r = \dfrac{10^{-3}}{10^3}$ m

or $r = 10^{-6}$ m

Increase in surface area,

$\Delta A = 10^9 \times 4\pi r^2 - 4\pi R^2$

or $\Delta A = 4\pi [10^9 \times (10^{-6})^2 - (10^{-3})^2]$

$= 4\pi [10^{-3} - 10^{-6}]$ m^2

or $\Delta A = 39.96 \times 10^{-4} \pi$ m^2

Work done

$= S \times \Delta A$

$= 0.072 \times 39.96 \times 10^{-4} \times 3.142$ J

$= 9.0399 \times 10^{-4}$ J

6.13. THE GASEOUS STATE

ACTIVITY 6.11

- Take three 100 mL syringes and close their nozzles by rubber corks, as shown Fig. 6.20.
- Remove the pistons from all the syringes.
- Leaving one syringe untouched, fill water in the second and pieces of chalk in the third.
- Insert the pistons back into the syringes. You may apply some vaseline on the pistons before inserting them into the syringes for their smooth movement.

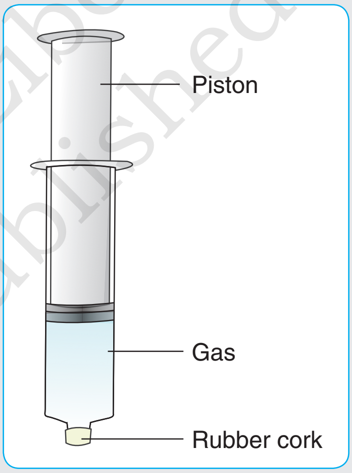

Fig. 6.20. Syringe

- Now, try to compress the content by pushing the piston in each syringe.
- What do you observe? In which case was the piston easily pushed in?
- What do you infer from your observations?

We have observed that gases are highly compressible as compared to solids and liquids. The Liquefied Petroleum Gas (LPG) cylinder that we get in our home for cooking or the oxygen supplied to hospitals in cylinders is compressed gas. Compressed Natural Gas (CNG) is used as fuel these days in vehicles. Due to its high compressibility, large volumes of a gas can be compressed into a small cylinder and transported easily.

In the gaseous state, the particles move about randomly at high speed. Due to this random movement, the particles hit each other and also the walls of the container. The pressure exerted by the gas is because of this force exerted by gas particles per unit area on the walls of the container.

6.14. PHYSICAL PROPERTIES OF GASES

The gaseous state is characterized by the following physical properties.

- Gases are highly compressible.
- Gases exert pressure equally in all directions.
- Gases have much lower density than the solids and liquids.
- Gases mix evenly and completely in all proportions without any mechanical aid.
- The volume and the shape of gases are not fixed. These assume volume and shape of the container.

ACTIVITY 6.12

Objective

To show that gases do not have a fixed shape or volume.

Materials Used

Two balloons of different shapes—one round and one heart shaped.

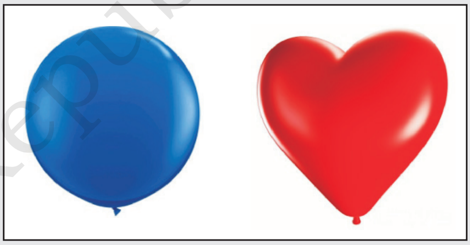

Fig. 6.21. Balloons of different shapes

Procedure

Fill both the balloons with air.

Observations

You will observe that air takes up the shape of the balloon.

Conclusion

This shows that gases have no fixed shape or volume. They assume volume and shape of the container.

6.15. DIFFUSION

What happens to sugar when it is added to water? It seems to disappear. Where does the sugar go? Similarly, when your parents spray perfume on their clothes, you may feel its fragrance. Can you explain how? Both the sugar and spray are made of tiny particles that disperse into water and air respectively. Thus sugar disperses into the water and spray disperses into the air so as to mix into each other. The process of dispersion of different particles among each other, so that they become mixed uniformly is called **diffusion**. In this process, the particles of substances at higher concentration move to the substances at lower concentration. Thus, *diffusion is the spontaneous movement of molecules from a region of higher concentration to one of lower concentration to form a uniform concentration.* It is faster in gases than in solids or liquids. There are many examples in our day-to-day life where diffusion between two substances takes place. For example, when your mother cooks something in the kitchen, the smell of cooking reaches you even though you are sitting in a nearby room.

6.15.1. The Process of Diffusion

The process of diffusion can be explained by dissolving a solid in a liquid or by mixing of two gases. When a solid is dissolved in a liquid, the particles of solid disperse into the liquid. When a gas dissolves in another gas, the particles of the gas disperse into the gas. Let us perform Activity 6.13 and 6.14 to demonstrate the process of diffusion.

ACTIVITY 6.13

To Demonstrate Diffusion by Dissolving Crystals of Potassium Permanganate in Water

Materials Required

Glass beaker and crystals of potassium permanganate

Procedures

1. Take a glass beaker, fill it with water.
2. Carefully place the crystals of potassium permanganate at the bottom of the glass beaker.
3. Observe and explain what happens.

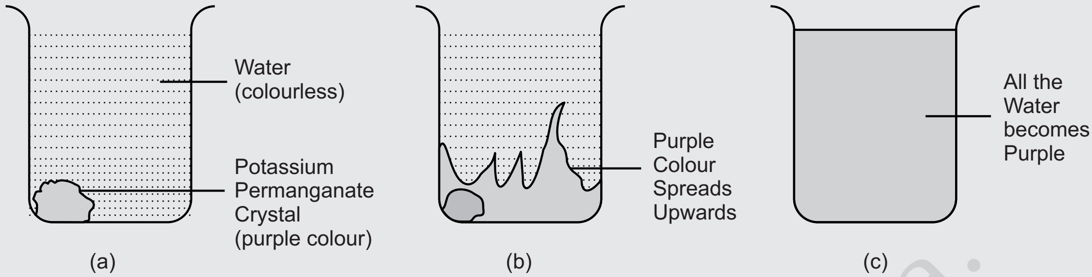

Fig. 6.22 Setup to Demonstrate Diffusion by Dissolving Colour Crystals

Observation

The crystals are no longer visible in the beaker and colour of the water changed to purple.

When the crystals of potassium permanganate are placed in the beaker of water, the water slowly turns purple. This happens because both water and sodium permanganate are made of tiny particles. The particles of potassium permanganate are purple coloured whereas the particles of water are colourless. When the crystals of potassium permanganate are put in water, the particles of both move and spread into each other and mix up on their own. Thus, it can be concluded that the particles are moving and they are in motion. If the particles were not moving, the colour could not spread throughout the beaker on its own. This movement of different particles among each other, so that they become mixed uniformly, is called diffusion.

Activity 6.14

To Demonstrate Diffusion by Spraying Perfume in the Corner of Classroom

Materials Required

A bottle of perfume

Procedures

1. Take a bottle of perfume.
2. Gently spray it in one corner and walk to the other corner of the classroom.
3. Observe and explain what happens.

Observation

The fragrance of perfume is felt throughout the whole classroom.

When we spray the perfume in one corner of the classroom, its fragrance spreads in the whole room quickly. It is due to the process of diffusion. The particles of perfume move rapidly in all directions, mix with the moving particles of air in the room, and reach every part of the room quickly. When the gaseous particles of perfume reach our nose with air, we can smell the fragrance. If, however, the particles of perfume and the particles of air were not moving, then the fragrance of perfume could not spread in the whole room quickly. So, the observation that the fragrance of perfume spreads in the entire room very quickly tells us that the particles of gases diffuse into each other.

6.15.2. Application of Diffusion

There are various phenomena in the animal and plant world that involve the process of diffusion. Two such examples which you are very much familiar with are absorption of the end products of digestion from the alimentary canal and absorption of nutrients from the soil by the roots of the plants.

(i) Absorption of the End Products of Digestion from Alimentary Canal

You know that the food is digested in the alimentary canal of the humans, but the nutrients are required by the whole body. Thus, there must be a mechanism in the body to absorb the end products of food substances from the alimentary canal. The absorption of end products of food substances from the alimentary canal takes place through the process of diffusion. When the end products of food substances get accumulated in higher concentration in the alimentary canal, as compared to the blood flowing in the vessels associated with the alimentary canal, they diffuse into the blood stream.

(ii) Absorption of Nutrients by Plant Roots

The plants absorb the nutrients from the soil through the process of diffusion. The nutrients absorbed by plants are found in ionic forms dissolved in the soil

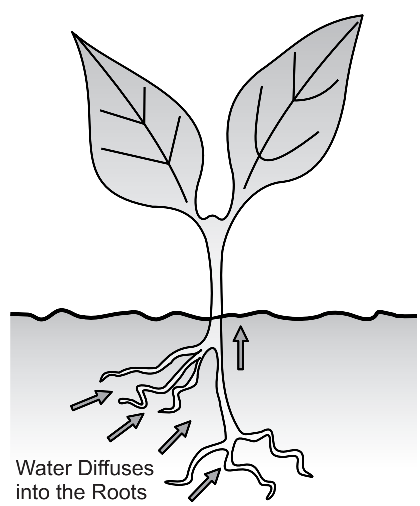

Fig. 6.23. Diffusion in Plant Roots

water surrounding the roots. The nutrients get accumulated in high concentration in the soil water. While in the plant cells, the concentration of nutrients is low as compared to the soil water. As soon as there is a difference of concentration of nutrients between the plant cells and soil water, nutrients move into the cell, i.e. from region of high concentration to the region of low concentration, by the process of diffusion.

(iii) More Applications of Diffusion

During respiration, oxygen and carbon dioxide exchange in lungs and tissues in animals takes place by the process of diffusion. Carbon dioxide intake by plants for the process of photosynthesis also takes place by the process of diffusion.

GLOSSARY

Boiling point: The temperature at which a liquid changes into vapour.

Conductivity: A measure of a material's ability to conduct heat or electricity.

Distillation: It is the process of removing dissolved impurities from a liquid.

Elasticity: A measure of a solid's ability to be stretched and then return to its original shape.

Filtration: It is a process used to separate a mixture of solid and liquid.

Freezing Point: The temperature at which a liquid turns into solid.

Hardness: It is a measure of a solid's resistance to permanent shape change when a compressive force is applied.

Malleability: It measures a solid's ability to be beaten into thin sheets.

Matter: Anything that has mass and occupies space.

Melting point: The temperature at which a solid melts to become a liquid.

Viscosity: A liquids resistance to flow.

REVIEW EXERCISES

Do the review exercises in your notebook.

A. Choose the correct option.

1. Arrangement of particles in solids is
   (a) Tightly packed (b) Loosely packed
   (c) Very loosely packed (d) None of these
2. Which of the following solids is malleable?
   (a) Rubber (b) Gold
   (c) Glass (d) Ceramic
3. Which of the following solids has property of elasticity?
   (a) Rubber (b) Gold
   (c) Glass (d) Ceramic
4. Which of the following is a good conductor of electricity?
   (a) Copper (b) Rubber
   (c) Chalk (d) Coal
5. The temperature at which a liquid changes to vapour is called its ________.
   (a) Melting point (b) Boiling point
   (c) Freezing Point (d) None of these
6. The temperature at which a liquid changes to a solid is called its ________.
   (a) Melting point (b) Boiling point
   (c) Freezing point (d) None of these
7. Which of the following solid has highest melting point?
   (a) Gold (b) Iron
   (c) Tungsten (d) Copper
8. The force between atoms and molecules is
   (a) Electric (b) Magnetic
   (c) Gravitational (d) None of these
9. The intermolecular forces are
   (a) Short range (b) Attractive only
   (c) Long range (d) Repulsive only

10. Viscosity is the internal property of the liquid and gases. It is more closely related to

(a) Friction (b) Inertia

(c) Elasticity (d) All of these

11. Cough syrup flows sluggishly because of

(a) Cohesion (b) Adhesion

(c) Viscosity (d) Surface tension

12. Figure 6.24 shows the stress-strain graph of a certain substance. Over which region of the graph is Hooke's law obeyed?

(a) EP (b) PQ

(c) QR (d) RS

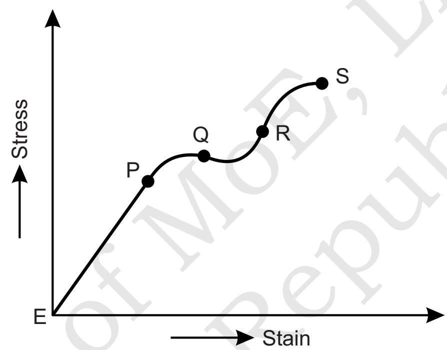

Fig. 6.24. Stress-strain graph

B. Fill in the blanks.

1. __________ is the smallest particle of matter.

2. Two or more than two atoms combine to form a __________ .

3. Three states of matter is solid, __________, and gas.

4. __________ measures a solid's ability to be beaten into thin sheets.

5. The internal restoring force acting per unit area of cross section of the deformed body is called __________ .

6. Within elastic limit, stress is proportional to __________ .

7. Liquids have a characteristic temperature at which they turn into solids, known as their __________ .

8. Liquid's resistance to flow is called __________ .

9. Force of attraction between the molecules of the same substance is known as __________ .

10. The process of dispersion of different particles among each other, so that they become mixed uniformly is called __________ .

C. State True or False.

1. Atom is the smallest particle of matter.
2. Diamond is the hardest natural substance found in nature.
3. Density of a liquid can vary with temperature.
4. Water is more viscous then Honey.
5. Gases cannot be compressed.
6. SI unit of Young's modulus is N m^{-2}.
7. Elasticity is the property of material of a body.
8. Surface tension is the property of a liquid in motion but viscosity is the property of a liquid in rest.
9. The breaking stress of a wire depends on length of the wire.
10. Diffusion is faster in gases than in solids or liquids.

D. Answer the following questions.

1. State the simple kinetic theory of matter.
2. Distinguish between atoms and molecules.
3. Describe the physical properties of solids.
4. Describe the physical properties of liquids.
5. Describe the physical properties of gases.
6. Write short notes on
   (a) Malleability (b) Elasticity
   (c) Viscosity (d) Compressibility of gases
   (e) Melting point of solids (f) Boiling point of liquids
7. Distinguish between cohesion and adhesion.
8. State Hooke's law.
9. What do you mean by Young's modulus of elasticity? Write SI unit of Young's modulus of elasticity.
10. Define surface tension and write its SI unit.
11. What do you mean by diffusion? Write some application of diffusion.

E. Numericals.

1. A steel cable with a radius of 1.5 cm supports a chairlift at a ski area. If the maximum stress is not to exceed 10^8 N/m^2. What is maximum load the cable can support.
2. Steel rod of length 1.0 m and radius 10 mm has been stretched along its length by a force of 100 kN. Calculate (a) stress, (b) elongation and (c) strain on the rod. The Young's modulus of steel is 2.0×10^{11} N m^{-2}.

3. A 4.0 m long copper wire of cross-sectional area 1.2 cm^2 is stretched by a force of 4.8×10^3 N. If Young's modulus for copper is $Y = 1.2 \times 10^{11}$ N/m^2, calculate (i) stress, (ii) strain and (iii) increase in length of the wire.

4. Figure 6.25 shows the strain-stress curve for a given material. What are (a) Young's modulus, and approximate yield strength for this material?

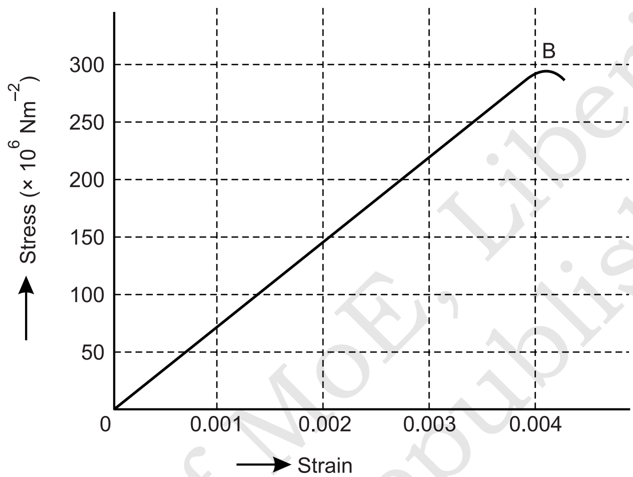

Fig. 6.25. Stress-strain curve

5. A wire increases by 10^{-3} of its length when a stress of 10^8 Nm^{-2} is applied to it. What is Young's modulus of the material of the wire?

6. A wire 50 cm long and 1.0 Sq. mm in cross section has Young's modulus $Y = 2 \times 10^{10}$ Nm^{-2}. How much work is done in stretching the wire through 1 mm?

7. Water is kept in a beaker of radius 5.0 cm. Consider a diameter of the beaker on the surface of the water. Find the force by which the surface on one side of the diameter pulls the surface on the other side. Surface tension of water = 0.075 N m^{-1}.

8. A soap film is formed on a rectangular frame of wire of size 3 cm × 3 cm. If the size of the film is changed to 3 cm × 4 cm, then calculate the work done in this process. The surface tension of soap film is 3×10^{-2} N/m.

9. The surface tension of a soap solution is 0.03 N/m. How much work is required to form a bubble of 1.0 cm radius from this solution?

10. A mercury drop of radius 1.0 mm breaks up into 64 droplets of equal volumes. Calculate the work done in this process. (Surface tension for mercury is 0.465 N/m).

11. A big drop is formed by coalesing 1000 small droplets of water. What will be the change in surface energy? What will be the ratio between the total surface energy of the droplets and the surface energy of the big drop?

F. Questions based on Higher Order Thinking Skills (HOTS).

1. Explain why a small volume of water in a kettle can fill a kitchen with steam.

2. When a beam of sunlight enters a room through a window, we can see tiny particles X suspended in a gas (or rather a mixture of gases) Y which are moving rapidly in a very haphazard manner.

(a) What could particles X be?

(b) Name the gas (or mixture of gases) Y.

(c) What is causing the movement of particles X?

(d) What conclusion does the existence of this phenomenon give us about the nature of matter?

3. Why is a liquid (the hydraulic fluid) used to operate the brakes in a car?