Foundation Chemistry for Class IX Part A for IIT JEE Foundation by K K Anand Chennai SmartEdu

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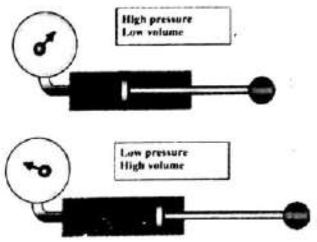
PART A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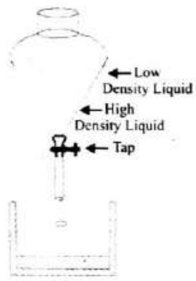
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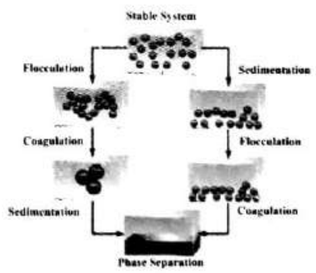
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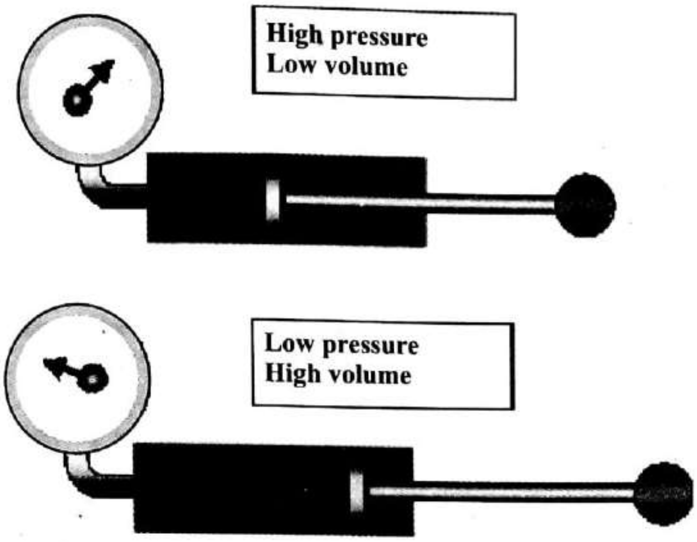


CHAPTER 1

Matter in Our Surroundings

INTRODUCTION

Chemistry can be defined as the study of matter and the changes it undergoes.

Matter is defined as anything that occupies space and has mass. It is the stuff our universe is made of, and all the chemicals that make up tangible things, from rocks to pizza to people, are examples of matter.

The early sceintists thought that there were only four kinds of matter, or elements - Earth, Air, Fire and Water.

All of the different kinds of matter we see around us were believed to come from mixtures of these four. While this was a good start, four elements alone did not seem to provide enough diversity to account for all matter.

The forms of matter that we see on the earth are often changing. Trees grow, die, and decay. Rocks undergoes weathering thus crumble, and form the fertile soil of the plains or deposits in the oceans. The changes that matter undergoes are another concern of chemistry. But there is even more. In addition to matter, the universe is also composed of energy. When a log burns in the fireplace, it is obvious that a change in matter has occurred. The log seems to have disappeared, leaving a small pile of ash. But the burning of the log warms us as it has given off heat. The heat and light that were liberated by the burning process are forms of energy. Energy is a more abstract concept than matter.

GENERAL CHARACTERISTICS OF MATTER

There are various forms of matter in the nature. The various forms of matter have some common characteristics. The general characteristics have been discussed below :

(i) The Matter has Mass :

If we take two pieces of bricks of different size, we will find that one is lighter while the other is heavy. The small sized brick is lighter because it contains less matter, while big sized brick is heavier because it contains more matter. Hence, the amount of matter present in anything is called its mass.

The things may be invisible even then they will have some mass e.g., the air. Although air is invisible even then it has some mass.

✓ CHECK POINT | Take one football bladder filled with air and hang it on one side of the beam of a physical balance and put weight on the pan hanging on other side untill balance becomes horizontal. Now remove the air from the bladder. What will you find and what does it indicates?

Check Your Answer

You will find that the end of beam (on which the bladder has been hanged) moves upward. This indicates that air has a mass. Therefore, all the forms of matter have mass.

(ii) The Matter Occupies Space :

You must have experienced this phenomenon during your everyday life. If one stool is placed in the corner of your drawing room, you know another stool cannot be placed in the same corner. If the space on your bookshelf is completely filled with the books, you cannot keep more books on it. The two trucks coming from the opposite directions in a narrow lane cannot cross each other as there is space only for one. If they will try to cross each other they will collide. Therefore, it is clear that matter occupies space.

(iii) The Matter has Inertia :

If any thing is lying on any place, it will remain there until and unless some external force disturbs its position. Similarly if anything is in motion, it will remain in motion till some external force stops it. This is known as property of inertia. The matter itself cannot change its position. Suppose if a foot ball is placed in the centre of a playground, it will remain there till it is pushed by anybody. Similarly if the football is pushed by a player it will move on till it is stopped by other players or by the friction of the play-ground.

(iv) The Matter is Effected by the Gravity :

If anything is thrown upward with a certain force it will automatically come to the ground because of force of attraction exerted by the earth. This attraction is called gravity.

When you throw a ball upward with a certain force, it will automatically come down on the earth because of earth's gravity. The fruits always fall downwards from the trees because of this gravity. Similarly water always flows from higher level to lower level.

(v) The Matter cannot be Destroyed :

In all physical and chemical changes, total mass of the matter before and after the change remains the same. This can be proved by a simple experiment performed by Lavoisier.

Lavoisier's experiment – Lavoisier took tin metal in an airtight flask. The flask (with tin) was weighed. It was then heated. Tin metal reacted with the oxygen present in the air of the flask and was converted into tin oxide. The flask was cooled and again weighted. It was found that the weight practically remains unchanged.

Law of conservation of mass – This law was given by Lavoisier after carrying out experiment. According to this law " In any chemical reaction mass of reactants always remains equal to the mass of products. i.e. during any chemical reaction mass remain conserved.

IDEA BOX

Perform this experiment in your school chemistry lab. Take few ml of aqueous solution of NaCl in a test tube (20ml) tied with a thread. Also take few ml of $CuSO_4$ aqueous solution in 250 ml conical flask. Now put test tube containing NaCl solution in conical flask containing $CuSO_4$ solution. One end of the thread is tied with test tube while other end is kept out of conical flask and flask is closed with rubber cork and then weigh the flask. Now pull the free end of thread to tilt the test tube so that content of test tube and flask get mixed (chemical change). Now again weigh the flask and record your observations what you conclude from this activity?

PHYSICAL NATURE OF MATTER

Every substance has a unique set of properties that allow us to recognize it and to distinguish it from other substances. The properties of matter can be categorized as physical or chemical. Physical properties can be measured without changing the identity and composition of the substance. These properties include color, odour, density, melting point, boiling point, and hardness. Chemical properties describe the way a substance may change or react to form other substances. A common chemical propertys is flammability, the ability of a substance to burn in the presence of oxygen.

PARTICLE NATURE OF THE MATTER

The concept about the nature of matter is very old. According to the ancient Hindu and Greek philosophers the matter is composed of very small particles which cannot be further sub-divided. John Dalton was the first person who gave scientific explanation about the nature and the composition of the matter.

Evidences for Particles in Matter :

Most of the evidence for the existence of particles in matter and their motion comes from the experiments on *diffusion* and *Brownian motion*.

(a) Dissolving a solid in a liquid :

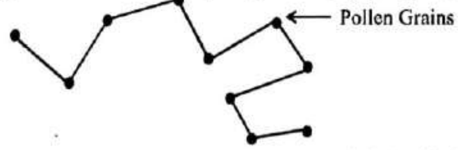
Potassium permanganate is a purple coloured solid substance and water is a liquid.
Take 2-3 crystals of potassium permanganate and dissolve them in 100 ml of water.
Now take out 10 ml of this solution & put into another 90 ml of clear water.
Keep diluting the solution like this 5 to 8 times. Everytime solution will become purple colour.
This experiment shows that just a few crystals of potassium permanganate can colour a large volume of water.
It means a crystal of $KMnO_4$ is made up of millions of tiny particles. They divide themselves into smaller & smaller particles. So we concluded that matter is made up of small (tiny) particles. Particles of $KMnO_4$ and particles of water spread into each other, it means they are moving. This self movement of different particles among each other, so they become mixed uniformly, is called *diffusion*.

Do You Know!!

Reason for diffusion of particles of matter is that they are continuously in random motion as they possess kinetic energy. As kinetic energy depends upon temperature. Thus rate of diffusion becomes faster with increase in temperature.

(b) Movement of pollen grains in water :

Pollen grains move rapidly throughout the water in a very irregular way (zig-zag way).



The pollen grains move on the surface of water because they are constantly being hit by fast moving particles of water. This type of zig-zag movement of the small particles suspended in a liquid (or gas) is called *Brownian motion*.

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Do You Know!!

Brownian motion increases on increasing the temperature because of increase in kinetic energy of particles of matter.
The existence of Brownian motion gives two conclusions.
(i) *Matter is made up of tiny particles.* **(ii)** *Particles of matter are constantly moving.*

✓ CHECK POINT **What is nature of matter is it continuous or particulate?**

Check Your Answer

Particulate

Characteristics of Particles of Matter:

(i) The particles of matter are very, very small :

The matter is composed of small particles : To understand particle nature of the matter, let us perform one experiment. Take a beaker full of water. Now place a small crystal of blue vitriol (copper sulphate) in the water. You will observe that the water begins to become blue coloured and slowly the size of the crystal becomes smaller and smaller. The crystal has divided itself into number of smaller particles and ultimately it dissolves in water. This experiment suggests that matter is composed of small particles.

(ii) The particles of matter have spaces between them:

Is there vacant space between the particles of matter ? Let us perform the following experiments –

Experiment (1) – Take a piece of chalk (used for writing on black board) and dip it into water. Some water is absorbed by the chalk. There are vacant spaces or pores in the chalk which are occupied by the water.

Experiment (2) – Take a wide mouthed test tube, almost half filled with water. Now put a sugar cube in the test tube and mark the water level with a glass marking pencil. The sugar cube will dissolve in water and the level of water will go down to a small extent. Why it so happened ? There are vacant spaces between the particles of water. This vacant space is occupied by the particles of the sugar and water level goes down.

IDEA BOX

Perform this experiment in your school chemistry lab. Take a big sized test tube and fill it with water. Add a few drops of Phenolphthalein solution. Now tie a cellophane paper on the mouth of the test tube. Invert the test tube on the open mouth of a bottle containing ammonium hydroxide. Record your observation and discuss your observation with your friends and teacher.

(iii) The particles of matter are constantly moving :

This property can be explained by Brownian motion and diffusion.

Diffusion **:** It is the phenomenon in which the movement of molecules or particles occur from their higher concentration towards the lower concentration. *"Intermixing of particles of two different types of matter on their own is called diffusion".*

For eg : When a perfume bottle is open in one corner of a room, its fragrance spreads in the whole room quickly. The particles of perfume move rapidly in all directions and mix with the moving particles of air in the room.

✓ CHECK POINT **Why liquids diffuse slowly as compared to gases?**

Check Your Answer

In liquids, the molecules are less free than in a gas, i.e., the intermolecular forces (van der Waals forces) in a liquid are greater than in a gas.

Do You Know!!

We have seen that the particles of matter in liquid and gaseous state are mobile. But it is difficult to visualise that the particles of solid matter are also mobile. We do not find any movement of the particles in case of solid matter like wood, iron, gold, copper etc. even if these substances are placed in water or air. If you dip a zinc rod in mercury, you will find that after sometime the particles of mercury enters into the zinc metal. Similarly if a gold rod is placed in mercury, the mercury particles slowly enters into gold. This process is very slow.

Both heat as well as temperature are responsible for the motion. When the temperature is increased there will be increase in the motion also. We may conclude that particles of matter are mobile, whether the matter is in solid, liquid or gaseous state. The motion of the particles is fast in case of gaseous state, slow in liquid state and very slow in solid state.

IDEA BOX

Take two 250 ml beakers. Now fill one beaker with cold water and the other with hot water. Now with the help of dropper add 1-2 drops of ink in both the beakers. Record your observations and draw a conclusion on the basis of your observations.

(iv) Particles of matter attract each other :

There are some forces of attraction between the particles of matter which bind them together.

Cohesive force : *The force of attraction between the particles of same substances is called Cohesive Force.*

Adhesive force : *The force of attraction between the particles of different substances is called Adhesive Force.*

For eg : If we take a piece of chalk, a cube of ice and an iron nail and beat them with a hammer.

Observation : Chalk will easily break into smaller pieces.

More force is required to break a cube of ice. Iron nail does not break.

Conclusion : Force of attraction is quite weak in between the chalk particles.

Force of attraction in between the particles of ice cube is a bit stronger.

Force of attraction in between the particles of iron is very, very strong.

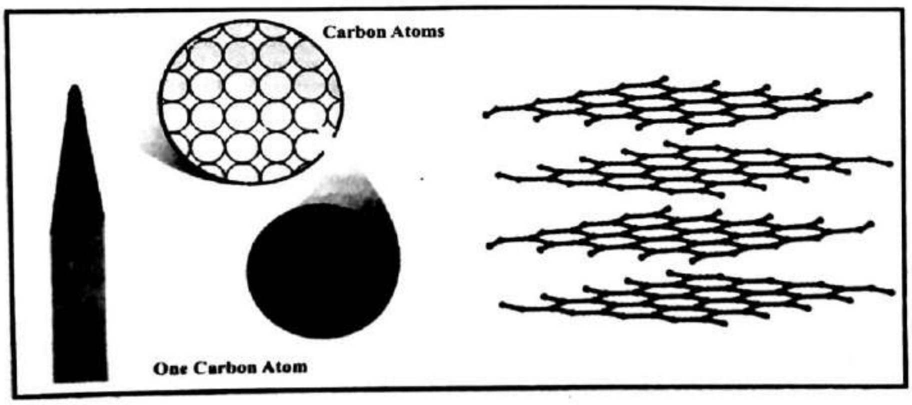
THEORIES RELATED TO MATTER :

(1) Atomic Theory of Matter :

The earliest ideas about matter and atoms were developed by Greek philosophers between 380 and 450 B.C. At that time, the question under discussion was whether matter had the property of being continuous or discontinuous. These concepts can be visualized if you took the "lead" or graphite of a broken pencil point and divided it in half, then divide that piece in half and again half of that piece. This process could be continued as long as possible. If matter was continuous, the process could be continued indefinitely without ever "running out" of graphite. If matter was discontinuous, then at some point, the dividing process would end when the last particle which could still be called graphite was all that remained. A further division would result in destroying the matter called graphite.

Democritus used the word "*atomos*" meaning "*indivisible*" or "*uncuttable*" to describe the ultimate building blocks of matter. Later word atoms is used for atomos. Atoms result from the repeated division of matter to very very tiny, permanent, indivisible, invisible bits of matter with definite size and shape. This Atom Theory was applied in support of the *Discontinuous Theory of Matter*. The Continuous Theory of Matter received wide spread support until the 1800's when *John Dalton* revived the atom concept to explain certain aspects of chemical reactions.

The final division of matter such as graphite results in atoms of the element carbon.



(2) Kinetic Theory of Matter :

The Kinetic Theory explains the differences between the three states of matter. It states that all matter is made up of moving particles which are molecules or atoms. In solids, the particles are so tightly bound to each other that they can only vibrate but not move to another location.

In liquids, the particles have enough free space to move about, but they still attract one another. In gases, the particles are far apart and can move about freely since there is much free space. Solids change into liquids, and liquids into gases, when the particles gain more kinetic energy, like when being heated and are able to move apart from one another. When the molecules vibrate more quickly upon heating, some of it escapes from the matter.

The main postulates of kinetic Theory of matter are following :

- Matter consists of molecules. These are the smallest particles, which are capable of free existence and retain all the chemical properties of the parent substance.
- The molecules are always in a state of random continuous motion.
- The molecules exert forces on one another. These forces depend upon intermolecular distance
- All collision between the particles of matter are perfectly elastic.

Illustration 1 :

What would have happened to the gas if the molecular collisions were not elastic?

On every collision, there would have been loss of energy. As a result, the molecules would have slowed down and ultimately settle down in the vessel. Moreover, the pressure would have gradually reduced to zero.

KNOWLEDG ENHANCER

MOLECULAR NATURE OF THE MATTER :

Matter is composed of the molecules formed by combination of atoms. As already stated, the molecules are very minute in size and mass. These molecules cannot be seen even with the most powerful microscope of your school. A substance appears to be composit, but there are wide gaps (interstices) between molecules which may expand or contract, the expansion or contraction of the bodies on heating or cooling is due to the change in the distances between the molecules.

The molecules of the substances are always in the state of constant motion. The molecules of the different substances move with the different speed while molecules of the same substance move with the same speed. The lighter molecules move with greater speed as compared to the heavier molecules. Further with the increase of temperature motion of the molecules also increases.

At high temperature the molecules move faster and push one another with greater force and the distance between the molecules increase. This explains why the bodies expand on heating. When a solid substance is heated upto its melting point, it changes to liquid state because the force of attraction between the molecules decreases and the distance between the molecules increase.

The molecules of a liquid have a random motion, i.e., they can move from one place to another or in other words liquid can flow easily. If a liquid substance is heated upto its boiling point it changes to gaseous state. In this state the force of attraction becomes negligible. The distances between the molecules increase to a very great extent. Therefore, the molecules in gaseous state have free movement.

INTER-MOLECULAR FORCES :

The particles of the matter are bonded together with a force called Inter-molecular force. In solid, the particles are bonded together with strong inter-molecular forces. When energy (say in the form of heat) is given, the bonds break, the arrangement of the molecules is disturbed and the solid is converted into liquid. If more energy is given, the inter-molecular forces are further decreased, the arrangement of the molecules is further disturbed and the liquid is converted into gas. Different solids possess inter-molecular force of different magnitude. If this force is more in any solid, more energy will be required to break the bonds between the molecules, i.e., more energy will be required to convert it into liquid.

As stated above there are forces of attraction between the molecules and these forces continuously scatter them because of their velocity. However, these forces are not uniform in the molecules of all the substances. In solids the force of attraction between the molecules is maximum and in gases it is minimum or negligible. In liquids the molecules are held together less firmly as compared to the solids. Therefore, liquid molecules get separated from one another easily. This explains that why some liquids evaporates even at low temperature.

✓ CHECK POINT

1. **Arrange the solids, liquids and gases in the increasing order of inter molecular forces of attraction.**
2. **Arrange solid, liquid and gas in order of energy, giving reasons.**

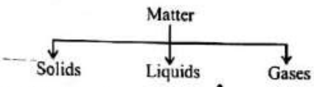
Check Your Answer

1. Gases < Liquids < Solids.
2. Solid < Liquid < Gas. This is because a solid absorbs energy to change into a liquid which further absorbs energy to change into a gas.

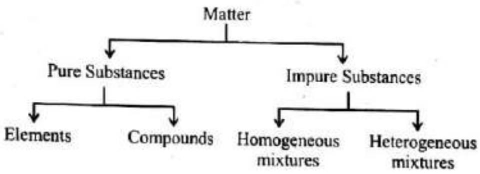
CLASSIFICATION OF MATTER :

Matter can be classified into different categories depending upon their physical or chemical nature.

(i) Based on state (Physical Classification)



(ii) Based on purity/composition (Chemical Classification)



STATES OF MATTER :

Matter is everything around us. Matter is anything made of atoms and molecules. Matter is anything that has mass and occupy space. Matter is also related to light and electromagnetic radiation. Up to 1995 scientists have identified five states of matter. These five main states of matter are solids, liquids, gases, plasmas and Bose-Einstein condensates. These all are different states of matter.

Each of these states is also known as a phase. Elements and compounds can move from one phase to another phase when special physical forces are present. One example of those forces is temperature. The phase or state of matter can change when the temperature changes. Generally, as the temperature rises, matter moves to a more active state. Phase describes a physical state of matter. The keyword to notice is physical. Things only move from one phase to another by physical means.

In the solid state, substances are rigid and have definite shapes. Volumes of solids do not vary much with changes in temperature and pressure. In the liquid state, the individual particles are confined to a given volume but they do not have definite shape. A liquid flows and assumes the shape of its container up to the volume of the liquid. Volumes of liquids changes to appreciable extent with change in temperature and pressure. Gases neither have definite shape nor volume. They occupy all parts of any vessel in which they are confined.

SOLID :

The solids are characterised by incompressibility, rigidity and mechanical strength. It indicates that the molecules, atoms or ions that make up a solid are closely packed or in other words they are held together by strong forces and cannot move about. Due to the strong intermolecular attractive forces between the constituent particles, solids are rigid and possess a definite shape and volume. These have definite melting point, high density and low compressibility. Solids are classified into two groups based on the arrangement of constituent particles.

(a) Crystalline solids (b) Amorphous solids

Crystalline solid is the one in which the constituent particles are arranged in a regular manner throughout the entire three dimensional network. A crystalline solid consists of a large number of repeating units termed as unit cells. A crystal is defined as a solid figure having planar surfaces, sharp edges and a definite geometrical shape.

Do You Know!!

The smallest three dimensional portion of a complete space lattice which when repeated over and again in different directions produces the complete space lattice is called the unit cell.

Amorphous solids are those solids in which the constituent particles are arranged in haphazard manner and not in a regular fashiop. These resemble liquids as they flow very slow at room temperature and thus termed as **super cooled liquids.**

The properties showing the difference between the crystalline and amorphous solids are listed in table.

Table: Difference between crystalline and amorphous solids.

	Properties	Crystalline solids	Amorphous solids
1	Crystal geometry	These have a definite crystal shape due to orderly arrangement of atoms, molecules or ions in three dimensional network	These do not have a definite geometrical shape due to haphazard order of constituent particles
2	M.P.	These show sharp m.p.	These do not have sharp m.p.
3	Physical state	These are hard and rigid solids	These are comparatively soft and not very rigid
4	Symmetry	Crystalline solids have (a) plane of symmetry (b) centre of symmetry (c) axis of symmetry	Amorphous solids do not have any symmetry
5	Crystal system	Crystalline solids have a definite crystal system e.g., cubic, tetragonal, hexagonal, etc.	These do not have any crystal system i.e. these do not have a regular repeating units
6	Anisotropic or Isotropic nature	Crystalline solids show of the physical properties different in different directions of the crystal e.g., refractive index and electrical conductivity. So these are termed as anisotropic	Their physical properties are same in all directions. Thus these are termed as isotropic
7	Examples	Crystals of NaCl, CsBr, CaF_2 and Zns	Rubber, plastic, glass, *etc.*

✔ CHECK POINT **Why urea has a sharp melting point but glass does not?**

Check Your Answer

Urea is a crystalline solid whereas glass is amorphous. Crystalline solids have sharp melting points whereas amorphous solids do not possess that melting points.

TYPES OF CRYSTALS :

The molecules, atoms or ions are the constituent particles of crystals. Shape and appearance of the crystal depend upon the arrangement of these constituent particles. There are three types of crystals :–

(i) Covalent crystals :

These crystals are formed by molecules. Molecular forces of attraction are comparatively weaker in these crystals. Organic compounds form such type of crystals. However, some giant molecules are also known, e.g., diamond and graphite.

(ii) Ionic crystals :

These crystals are formed by ions. Structural unit of these crystals is ion. There exists a strong force of attraction between the particles (i.e., ions). Crystals of sodium chloride, copper sulphate, potassium chloride etc. belong to this class.

The ionic solids are usually quite hard, having high melting point. In solid state these are non-conducting but in fused or molten state these conduct electricity.

(iii) Metallic crystals : These crystals are formed by the atoms of metals.

(iv) Molecular crystals :- The structural units for this type of crystal are molecule which do not carry any charge. There exists a weak force of attraction between these particles.

Illustration 2 :

Classify the following substances into ionic, covalent, molecular or metallic :
MgO, SO_2, I_2, H_2O (ice), SiO_2(quartz), brass.

MgO = Ionic, SO_2 = Polar molecular, I_2 = non-polar molecular, H_2O = Hydrogen bonded molecular, SiO_2 = Covalent or network, brass = metallic.

KNOWLEDGE ENHANCER

Interesting Property of Some Solids : Elasticity :

When a piece of rubber is stretched its length is increased, but on removing the force, the rubber gains its original shape. Similarly if a weight is hanged with a spring, the length of the spring is increased, but on removing the weight, the spring gets its original length. This property of a solid body by virtue of which it tends to regain its original state, when the deforming forces are removed, is known as elasticity. The bodies in which complete restoration of the initial state takes place, are called perfectly elastic bodies, while those bodies which do not show any such tendency are termed as non-elastic or plastics.

The property of elasticity can be explained on the basis of the molecular force between the molecules. The molecular force works between the molecules in such a way as if they are joined together by a spring. In normal conditions the solid retaining its shape and size. The molecules remain balanced unless some external force is applied. When force is applied the molecules begin to move towards the direction of the force. When the distance between the molecules increases they experience force of attraction and when the distance between the molecules decreased, they experience repulsion. When the external force is removed the molecules regain their original position.

Ice a Unique Solid :

Ice is considered as unique solid because it is less dense as a solid than it is as a liquid. Normally, a liquid becomes denser as it freezes and its molecules pack closer together. However, as water freezes, its molecules form a lattice network of hexagons containing empty spaces. These hexagons cause water to expand about 11% in volume when it freezes. This expansion means that ice has fewer molecules per cubic centimeter than water has, so it is less dense than water. To be precise, ice's density is 0.917 g/cm^3 and water's maximum density is 1.00 g/cm^3 at 3.98° C.

The unique properties of ice can cause problems on land and sea. The expansion of ice is responsible for the weathering of paved surfaces, such as roads and parking lots. Ice expands in crevices in these surfaces, opening cracks that spread and eventually create potholes. When ice floats in water, about 90% of it remains below the water's surface. This is one reason why icebergs pose a problem for ships in sea, especially at night or in weather that limits visibility

LIQUID :

Liquids have definite volume but do not have definite shape. They take the shape of the vessel in which they are kept. Molecules of liquid are more close to each other in comparison to the gas molecule due to strong attractive forces. Liquids have enough vacant space in comparison to solids. Thus liquid is an intermediate state between the complete disorder found in gas and highly ordered molecular state in solid. Example: water and milk.

Properties of Liquids :

Important properties of liquid can be described as follows :

(1) Shape and volume :

Molecular forces between the liquid molecules are not so strong to keep molecules in a fixed position i.e., intermolecular attraction between molecules is less than that of solids. Therefore, liquids do not have a definite geometric shape. Due to appropriate attractive force they have definite volume in comparison to gas.

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(2) Density :

In comparison to the gas, in liquids the molecules are more close to each other. Therefore, density of liquids is higner than that of gaseous state. For example, at one atmospheric pressure and 100°C the density of water is 0.958 gm cm^{-3} whereas under same conditions steam (gaseous water) has a density of 0.00059 gm cm^{-3}. That is water is almost 1600 times more dense than vapour.

It can be concluded that density of liquid is more in comparison to the gas due to their more closely packed molecules. There is negligible effect of pressure on the density of liquid. Liquids are incompressible.

$$\text{Density of any substance} = \frac{\text{Mass of that substance}}{\text{Volume of that substance}}$$

(3) Diffusion :

When two soluble liquids are placed close to each other then molecules of one liquid enter in between the molecules of the other and the two liquid mixed with each other. It is called diffusion. Diffusion is seen in liquids like gases.

It is a comparatively slow process, because the velocity of liquid molecules is very less in comparison to the gas molecules. Moreover vacant space is comparatively quite less in liquid than gas.

(4) Compressibility :

Due to very large vacant spaces between the molecules the property of compressibility is very high in gases. But the vacant space in between the molecules of liquids is very less, so the compressibility of liquids is very less, as compared to gases. For example at 300K when the pressure of an ideal gas is changed from one atmosphere to two atmosphere then its volume reduces by 50% whereas when the same pressure is increased on water (liquid) its volume decreases by only 0.0045%.

(5) Evaporation :

Though the molecules of liquid are bonded to each other by, attractive force still they have a tendency of evaporation. Therefore evaporation is that process in which liquid changes into vapour at room temperature. The kinetic energy of all liquid molecules is not same. But it is equal to the average value or near about it i.e. some molecules have more or some less. That is known that kinetic energy of molecules of liquid opposes the intermolecular force of attraction which keeps them close. Therefore some molecules evaporate from the surface and go to the vapourous state. We will learn more about evaporation later in this chapter.

The pressure exerted by the vapours in equilibrium with its liquid at a given temperature is called vapour pressure of that particular liquid. This is also called saturated vapour pressure. The magnitude of vapour pressure depends upon the following two factors.

*(i) **Nature of liquid :** The vapour pressure of a liquid depends upon the nature of the liquid.*

*(ii) **Temperature of liquid :** The vapour pressure of a liquid increases with increase in temperature.*

✓ CHECK POINT | A liquid is transferred from a smaller vessel to a bigger vessel at the same temperature. What will be the effect on the vapour pressure?

Check Your Answer

No effect as it depends only on the nature of the liquid and temperature.

(6) Surface Tension :

It is an important property of liquids, which directly related to the intermolecular forces between the molecules. Liquid surface feel stretched due to surface tension. As mentioned previously, the molecules in liquids are held closely and hence attract each other. A molecule in the bulk of the liquid is attracted equally on all sides so that the net attractive pull on the molecule is zero. However, a molecule which lies at the surface (known as surface molecule) is subjected only to the attractive forces of the molecules below it. This is because there are no molecules above it. Therefore, surface molecules experience a resultant downward attractive force within the liquid. This creates an imbalance of forces at the surface. In other words, the liquid surface is under tension due to imbalanced forces. This effect is called **surface tension**.

Effect of temperature :

Surface tension decreases with rise in temperature. The decrease of surface tension with increase of temperature is because of the fact that the kinetic energy (or speed) of the molecules increases. As a result, the intermolecular forces decrease and therefore, surface tension also decreases. For example, the clothes are washed more efficiently in hot water than in cold water due to decreased surface tension in hot water.

Surface tension and nature of liquid :

Since, surface tension of a liquid is due to intermolecular attractive forces, therefore, the magnitude of surface tension is a measure of intermolecular attractive forces. When the attractive forces between the molecules are large, the surface tension is large.

Importance of Surface Tension

(i) **Capillary action.**

When one end of a capillary tube is put into a liquid that wets glass the liquid rises into the capillary tube to a certain height and then stops. The rise of a liquid in capillary is called **capillary action.** The rise of liquid in a capillary is due to the inward pull of surface tension acting on the surface which pushes the liquid into the capillary tube. This phenomenon is very important. For example, water below the surface of the earth rises to the plants through the roots, oil rises into the wick of an oil lamp, ink rises in a blotting paper, are examples of capillary action.

(ii) **Spherical shape of drops :**

The liquid drops have nearly spherical shapes. We have learnt that surface tension tries to decrease the surface area of a liquid to the minimum. Since the sphere has minimum surface area for the given volume of liquid.

(7) Viscosity :

It is commonly observed that certain liquids flow faster than others. For example water and kerosene oil flow rapidly while honey and castor oil flow slowly. The flowing liquid may, therefore, be regarded as composed of a number of concentric tubes sliding past one another. Each layer exerts a drag on the next and the work must be done to maintain the flow. Similarly in a liquid flowing over a glass plate, the layer in contact with the plate remains stationary, the velocity of different layers increases continuously with the distance from the fixed surface, being the highest in the free surface of the liquid, On account of relative motion each layer experiences a frictional force and behaves as if it is being dragged in backward directions. This internal resistance to flow in liquids which arises due to the internal friction between layers of liquid as they slip past one another while liquid flows is known as *viscosity*.

Glycerine does not flow as easily as water or alcohol. Thus, glycerine is said to have more viscosity than water or alcohol.

The reason of this internal resistance (viscosity) is molecular force working between the molecules of the liquid. It depends on cohesive force between the molecules.

Viscosity and nature of liquid : The viscosity is also related to the intermolecular forces in the liquid. If the intermolecular forces are large, the viscosity will be high. For example, water has higher viscosity than methyl alcohol because intermolecular forces in water are more than in methyl alcohol.

Effect of temperature : Viscosity of a liquid decreases with rise in temperature. With the increase in temperature, the average kinetic energy increases and the intermolecular forces can be easily overcome. Therefore, the liquid starts moving faster.

Importance of Viscosity

Study of viscosity helps in many ways :

(i) The shape of ships, aeroplanes, rockets etc. is designed in such a manner, so that they may have least effect on their velocity due to the friction of water, air, etc.

(ii) In order to decrease the friction in the various types of machines, a suitable lubricants are selected on the basis of viscosity.

(iii) Viscosity is very helpful in determining the pressure required for sending liquids like petrol, water, etc. through pipe lines.

✓ CHECK POINT **What is the effect of temperature on (i) Surface tension and (ii) Viscosity ?**

Check Your Answer

Both decrease with increase of temperature.

GAS :

Gas is the third state of matter. A gas differs from a solid and a liquid in a number of ways. A gas fills entire space available to it and therefore it has no definite shape or volume.

The molecules in a gas are in a continuous motion in all possible directions in the complete space available within the container in which it is enclosed. The average velocity of a gas particle is nearly 15000 ms^{-1} at ordinary temperature.

In the beginning of the 17^{th} century, scientists started realising that some form of matter can exist in a form that is similar to air. The Belgian Chemist *Jan Baptista van Helmont* coined the word Gas by altering the Greek word "Chaos" which means "Space". This word explains the ability of a gas to fill any amount of space.

Due to very weak inter-molecular forces in gases its molecules are in greater motion and show irregular movement. Therefore gases do not posses definite size, shape and volume, gases have very low density and high compressibility.

Gases show diffusion. The behaviour of the gases can be explained by showing the certain quantitative relationship between mass, pressure, volume and temperature. The state of a gas can be explained by these four variables. Their relationships are known by laws of gases.

SI Units of Mass (M) Volume (V), Pressure (P) and Temperature (T).

1. **Unit of Mass :**

   Mass is represented in kilograms (kg) or gram (10^3 gram = 1 kg.).
   But mass of gases is represented in terms of number of moles (n).

   $$n = \frac{\text{w (mass in gms)}}{\text{m (molar mass)}}$$

2. **Unit of Volume :**

   Volume is represented in litre (L) millilitre (ml) or centimetre cube (cm^3). In SI units the volume is represented in meter (m^3)
   $1\ m^3 = 10^3\ dm^3 = 10^6\ cm^3$
   $1\ ml = 1\ cm^3$
   $1\ litre = 10^3 cm^3 = 1\ dm^3 = 10^{-3}\ m^3$

3. **Unit of Pressure :**

   A standard or normal atmospheric pressure is defined as the pressure exerted by a mercury column of exactly 76 cm at 0°C. This is the pressure exerted by the atmosphere at the sea level.
   1 atm = 76 cm = 760 mm or 760 torr
   1 atm = 1.01325 bar
   or 1 bar = 0.987 atm
   $1\ Pa = 1\ N\ m^{-2} = 1\ kg\ m^{-1}\ s^{-2}$
   $1\ atm = 101{,}325\ Pa\ or\ N\ m^{-2}$
   $= 1.01325 \times 10^5\ Pa\ or\ N\ m^{-2}$
   $1\ bar = 10^5\ Pa\ or\ N\ m^{-2}$
   $1\ bar = 10^2\ kPa$

4. **Unit of Temperature :**

   In SI unit temperature is represented in Kelvin scale (K) i.e., $(C + 273.15) = K$

GENERAL CHARACTERISTICS OF GASES

Compressibility :

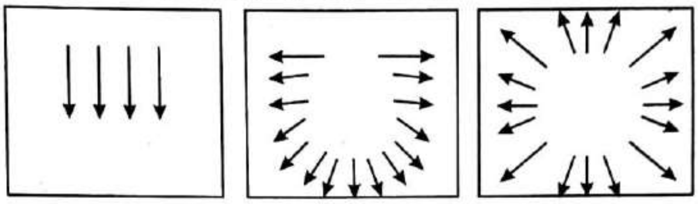
The gases can be compressed on applying external pressure. In case of gases the distances between the molecules are much greater as compared to the solids and liquids. Therefore, on applying external pressure the gases can be compressed easily and under such conditions the gas molecules come closer to each other and they occupies less space than before.

Relatively it is difficult to compress liquids and solids, since the molecules are already very close to each other. When some external pressure or force is applied to compress the solids or liquids, the molecules are repelled due to molecular repulsion. Thus the molecules of solids and liquids cannot be compressed easily.

The property of liquids of incompressibility is useful for us in hydraulic machines. A simple system of automobile hydraulic brakes are a good example of this. The brake system cannot work correctly if there is any air (gas) in the system because the gas is compressible.

Exertion of Pressure :

Solids exert pressure only in downward direction. Liquids exert pressure downward as well as to the sides. But gases exert pressure in all directions (a good example is a balloon) as shown in figure below. This pressure is due to bombardment of the particles against the walls of the container. Thus gases exert pressure equally in all directions.



Solid **Liquid** **Gas**

Homogeneous nature :

Gases have similar composition in all parts and are therefore homogeneous in nature.

Liquefication :

Gases can be liquefied by colling and by applying pressure.

DIFFUSION :

When a bottle of ammonia is opened in one corner of the laboratory, its pungent smell can be experienced all over the laboratory. Similarly, when a bottle of perfume is opened in the drawing room its smell spreads and can be detected all over the room. In fact all gases possess this property of intermixing with one another without any mechanical aid to form a homogeneous mixture called diffusion.

Uses of Gaseous Diffusion :

1. **Separation of gases :**
   Gases can be separated from the mixture of gases by the use of process of diffusion. When a mixture of gases is diffused, the lighter gases will diffuse quickly than the heavier gases. In this way by repeating the process of diffusion, gases can be separated from the mixture.

2. **Relative densities and molecular weights of the gases :**
   Graham's Law of diffusion (explained later in this chapter) can be used for the determination of relative densities and molecular weights of the gases.

Harmful effect of gaseous diffusion in air becomes inpure because of process of diffusion. Poisonous and foul smelling gases diffuses in the air and because of this dispersion, the air becomes foul smelling.

Gas laws :

By changing the pressure or temperature of any gas its volume also changes. The nature of the change is almost same for all gases.

Therefore many scientists studied them in detail and gave some laws which are known as Gas Laws.

Boyle's Law :

Boyle's Law is useful when we compare two conditions of the same gas with no change in temperature. (Remember, "Always Boyle's at the same temperature!")

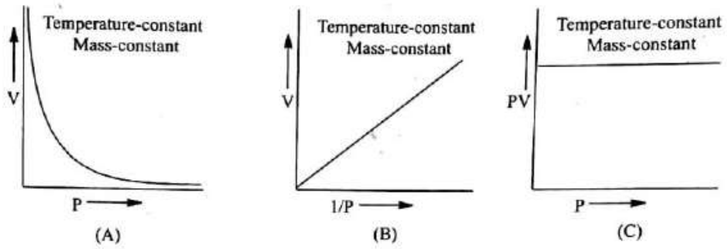
Boyle's law states that, "at constant temperature, the volume of a sample of a gas varies inversely with the pressure".

$\therefore \quad P \propto \frac{1}{V}$ (when temperature and number of moles are kept constant)

The proportionality can be changed into an equality by introducing a constant k, i.e.,

$$P = \frac{k}{V} \text{ or } PV = k$$

Boyle's law can be verified by any one of the following three ways graphically.



Alternatively, Boyle's law can also be stated as follows :

"Temperature remaining constant, the product of pressure and volume of a given mass of a gas is constant".

The value of the constant depends upon the amount of a gas and the temperature.

Mathematically, it can be written as, $P_1V_1 = P_2V_2 = P_3V_3 = ,$............

It may be noted that Boyle's law is obeyed only by a hypothetical gas called ideal gas. However, gases like nitrogen, oxygen, carbon dioxide, etc. obey Boyle's law at low pressures and high temperatures and behave as ideal gases. At higher pressures and low temperatures, these gases donot obey Boyle's law.

IDEA BOX

Take a small baloon it should be so small that you can push all sides of it together between your hands without any of the baloon pouching out at any point. Now increase the pressure on air inside the baloon by squeezing one end of baloon. Record your observation and draw a conclusion on the basis of that.

Illustration 3 :

A given mass of a gas occupies 240 ml at 800 mm of Hg. What volume will the gas occupy if the pressure is increased to 1200 mm of Hg, temperature remaining constant?

$P_1 = 800$ mm $P_2 = 1200$ mm, $V_1 = 240$ ml, $V_2 = ?$

Applying Boyle's Law $P_1V_1 = P_2V_2$

Substituting the values

$$800 \times 240 = 1200 \times V_2$$

$$V_2 = \frac{800 \times 240}{1200}$$

Hence the new volume = 160 ml.

Illustration 4 :

A sample of gas occupies 10 litre under a pressure of 1 atmosphere. What will be its volume if the pressure is increased to 2 atmospheres? Assume that the temperature of the gas sample does not change.

Mass and temperature is constant hence we can use Boyle's law

$P_1V_1 = P_2V_2$

Given $P_1 = 1$ atm, $V_1 = 10$ litre, $P_2 = 2$ atm, $V_2 = ?$

$1 \times 10 = 2 \times V_2 \Rightarrow V_2 = 5$ litre

Charle's Law :

It relates the volume and temperature of a given mass of a gas at constant pressure.

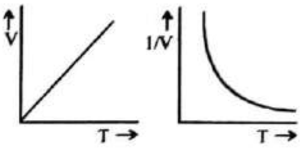
Charles' law can be stated as follows :

"The volume of a given amount of a gas at constant pressure varies directly as its absolute temperature".

$V \propto T$ (if pressure is kept constant)

or $\frac{V_t}{T} = \frac{V_0}{T_0}$

The graphs between V and T are shown.



IDEA BOX

Take a baloon such that at point of time between the begining of filling of a ballon and the maximum streching of a baloon, the change in internal pressure of a baloon is negligible as the baloon increases in size. Now fill that baloon partially with air and first place it in a car on a hot day in summer. Now take that ballon out of car and put in to a refrigerator for some period of time. Record your observations and draw a conclusion on the basis of that.

Gay-Lussac Law :

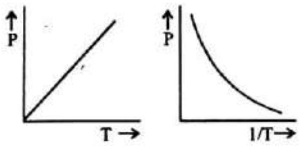
It relates the pressure and absolute temperature of a given mass of a gas at constant volume.

$P \propto T$ (if volume and number of moles are kept constant)

At constant volume, the pressure of a given amount of a gas is directly proportional to its absolute temperature.

At constant volume $\frac{P}{T}$ = constant or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

The graphs between P and T are shown :



Avogadro's Law :

(i) For solid, liquid and gas :

1 mole of any substance contains Avogadro's number (N_A) of Particles (molecules/atoms/ions etc.

$$N_A = 6.023 \times 10^{23}$$

(ii) For gases:

In 1812, Amadeo Avogadro stated that samples of different gases which contain the same number of molecules (any complexity, size, shape) occupy the same volume at the same temperature and pressure. It follows from Avogadro's hypothesis that $V \propto n$ (T and P are constant).

$V \propto n$ (T, P constant) $\Rightarrow \frac{V_1}{n_1} = \frac{V_2}{n_2}$

STP : 273.15 K (0°C) 1 atm ; STP : 298.15 K (25°C) 1 bar

GRAHAM'S LAW OF DIFFUSION :

Diffusion is the tendency of any substance to spread throughout the space available to it. Diffusion will take place in all directions and even against gravity. The streaming of gas molecules through a small hole is called effusion.

According to Graham, the rate of diffusion (or effusion) of a gas at constant pressure and temperature is inversely proportional to the square root of its molecular mass.

$$r \propto \sqrt{\frac{1}{M}}\text{, at constant P and T} \qquad \therefore \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}\text{, at constant P and T}$$

Since, molecular mass of gas = 2 × vapour density, $\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$, at constant P and T

Illustration 5 :

N_2O and CO_2 have the same rate of diffusion under same conditions of temperature and pressure. Why?

Both have same molar mass (=44 g mol^{-1}). According to Graham's law of diffusion, rates of diffusion of different gases are inversely proportional to the square root of their molar masses under same conditions of temperture and pressure.

Illustration 6 :

Pure O_2 diffuses through an aperture in 224 seconds, whereas mixture of O_2 and another gas containing 80% O_2 diffuses from the same in 234 sec under similar condition of pressure and temperature. What is molecular weight of gas?

The gaseous mixture contains 80% O_2 and 20% gas.

$\therefore$ Average molecular weight of mixture $(M_{mix}) = \frac{32 \times 80 + 20 \times m}{100}$ ... (i)

Now for diffusion of gaseous mixture and pure O_2

$$\frac{r_{O_2}}{r_m} = \sqrt{\frac{M_{mix}}{M_{O_2}}} \text{ or } \frac{V_{O_2}}{V_{mix}} \times \frac{t_{mix}}{t_{O_2}} = \sqrt{\frac{M_{mix}}{32}} \text{ or } \frac{1}{224} \times \frac{234}{1} = \sqrt{\frac{M_{mix}}{32}} \quad \text{... (ii)}$$

$\therefore$ $M_{mix} = 34.92$

By (i) and (ii) mol weight of gas (m) = 46.6.

DALTON'S LAW OF PARTIAL PRESSURES :

The total pressures of a mixture of gases, which do not react with each other,filled in a vessel is equal to the sum of partial pressures of the mixed gases.

$$P = P_1 + P_2 + \ldots\ldots\ldots\ldots + P_n$$

THE COMBINED GAS LAWS

Step I. Let us change the pressure of the gas from P_1 to P_2 at a constant temperature T_1 the volume will change from V_1 to new volume say V_x . Since temperature remains constant, therefore, by applying Boyle's law,

$$P_1V_1 = P_2V_x \quad \text{...(i)}$$

or $$V_x = \frac{P_1V_1}{P_2}$$

Step II. Let the temperature of the gas be now changed to T_2 at constant pressure P_2 so that volume may change from V_x to V_2. Thus, according to Charles' law,

$$\frac{V_x}{T_1} = \frac{V_2}{T_2} \text{ or } V_2 = \frac{V_xT_2}{T_1} \quad \text{(ii)}$$

Substituting the value of V_x from Eq. (i), we get

$$V_2 = \frac{P_1V_1}{P_2} \times \frac{T_2}{T_1}$$

Rearranging, we get

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Thus, $\frac{PV}{T}$ = Constant (K)

Illustration 7 :

At 25° C and 760 mm of Hg pressure, a gas occupies 600 mL volume. What will be its pressure at a height where temperature is 10°C and volume of the gas is 640 mL.

$P_1 = 760$ mm Hg $\quad P_2 = ?$
$V_1 = 600$ mL $\quad V_2 = 640$ mL
$T_1 = 273 + 25 = 298$ K $\quad T_2 = 273 + 10 = 283$ K

According to combined gas law equation,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

or $$P_2 = \frac{P_1V_1T_2}{V_2T_1} = \frac{(760\,\text{mm Hg}) \times (600\,\text{mL}) \times (283\,\text{K})}{(640\,\text{mL})(298\,\text{K})} = 676.6 \text{ mm Hg}$$

IDEAL GAS EQUATION

According to Boyle's laws, for a fixed mass of a gas at constant temperature

$$V \propto \frac{1}{P} \quad \text{(Constant T and } n\text{)} \quad ...(i)$$

According to Charles' law

$$V \propto T \quad \text{(Constant P and } n\text{)} \quad ...(ii)$$

According to Avogadro's law

$$V \propto n \quad \text{(Constant P and T} \quad ...(iii)$$

Combining equations (i), (ii) and (iii), the combined gas law can be written as:

$$V \propto \frac{nT}{P}$$

or $PV \propto nT$ or $PV = nRT$

where R is a constant of proportionality and is known as molar gas constant. The value of R is same for all gases. Therefore, it is also called universal gas constant. The above equation is known as ideal gas equation.

Numerical Value of R

(1) 0.821 L atm K^{-1} mol (2) 82.1 atm m L K^{-1} mol^{-1} (3) 8.314 J mol^{-1} K^{-1}

Illustration 8 :

5g of ethane is confined in a bulb of one litre capacity. The bulb is so weak that it will burst if the pressure exceeds 10 atm. At what temperature will the pressure of gas reach the bursting value?

$$PV = nRT \Rightarrow 10 \times 1 = \frac{5}{30} \times 0.082 \times T$$

$$T = \frac{60}{0.082} = 731.70 \text{ K} = 458.70°C$$

Illustration 9 :

When 3.2 g of sulphur is vapourised at 450°C and 723 mm pressure, the vapours occupy a volume of 780 ml. What is the molecular formula of sulphur vapours under these conditions? Calculate the vapour density also.

$$PV = nRT \Rightarrow \frac{723}{760} \times 1000 = \frac{3.2}{M} \times 0.082 \times 723 \Rightarrow M = 255.9$$

No. of atoms of sulphur in one molecule = $\frac{M}{32} = 8$

$\therefore$ Molecular formula of sulphur = S_8

$$V.D. = \frac{M}{2} = \frac{255.9}{2} = 127.9$$

APPLICATION OF IDEAL GAS EQUATION TO DALTON'S LAW OF PARTIAL PRESSURE

In a mixture of non-reacting gases A, B, C etc., if each gas is considered to be an ideal gas, then applying

$$PV = nRT,$$

$$P_A = n_A \frac{RT}{V}, P_B = n_B \frac{RT}{V}, P_C = n_C \frac{RT}{V} \text{ and so on}$$

where P_A, P_B and P_C are partial pressures of A, B & C respectively.

By Dalton's law of partial pressure,

$$\text{Total pressure, } P = p_A + p_B + p_C + \ldots = \frac{RT}{V}(n_A + n_B + n_C + \ldots$$

$$\therefore \frac{p_A}{P} = \frac{n_A}{n_A + n_B + n_C + \ldots} = x_A \qquad \text{(mole of fraction of A)}$$

or $p_A = x_A \times P$

Similarly, $p_B = x_B \times P$ and so on. Thus.

Partial pressure of A = mole fraction of A × Total pressure

Illustration 10 :

250 mL of nitrogen maintained at 720 mm pressure and 380 mL of oxygen maintained at 650 mm pressure are put together in one litre flask. If the temeprature is kept constant, what will be the final pressure of the mixture ?

Step 1. To calculate the partial pressure of nitrogen

Given conditions	Final conditions
Volume V_1 = 250 mL	V_2 = 1000 mL
Pressure P_1 = 720 mm	P_2 = ? mm

Applying Boyle's Law since the temperature remains constant

$$1000 \times P_2 = 720 \times 250$$

or $P_2 = \frac{720 \times 250}{1000} = 180\,\text{mm}$

Thus, the partial pressure due to nitrogen (p_{N_2}) = 180 mm.

Step 2. To calculate the partial pressure of oxygen

Given conditions	Final conditions
Volume V_1 = 380 mL	V_2 = 1000 mL
Pressure P_1 = 650 mm	P_2 = ? mm

Applying Boyle's Law (since the temperature remains constant)

$$1000 \times P_2 = 380 \times 650$$

or $$P_2 = \frac{380 \times 650}{1000} = 247 \text{ mm}$$

Thus, the partial pressure due to oxygen (P_{O_2}) = 247 mm.

Step 3. To calculate the final pressure of the gaseous mixture.

If P is the final pressure of the gaseous mixture, then according to Dalton's Law of Partial Pressures,

$P = P_{N_2} + P_{O_2} = 180 + 247 = 427$ mm

Types of gases : Gases are mainly classified in two classes.

(i) Ideal gas (ii) Real gases

Ideal gases :

Those gases which obey gas laws at all temperatures and pressure or volume.

Real gases :

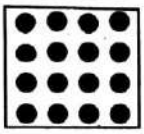
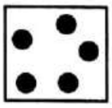
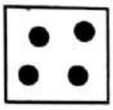
Those gases which do not obey gas laws at all temperatures and pressures.

Infact ideal gas is only imaginary and the real gases behave as ideal gases at high temperature and low pressure.

Comparison of Ideal and Real gases

	Ideal Gas		**Real Gas**
(a)	Obeys ideal gas equation PV = RT	(a)	Obeys vander Waal's equation
(b)	No force of interaction between the molecules.	(b)	Intermolecular forces exists.
(c)	Obeys Boyle's and Charle's law for all pressures and temperatures	(c)	Do not obey Boyle's and Charle's law
(d)	Internal energy depends on temperature only.	(d)	Internal energy depends on temperature as well as volume.

Comparison of solids, liquids and gases

Solids	Liquids	Gas
		
Particles are very closely packed thus rigid in nature	Particles are loosely packed thus can flow	Particles are very loosely packed and expand to large volume
Voids are extremely small therefore incompressible	Voids are relatively larger thus slightly compressible	Voids are very larger thus highly compressible
Particle motion is restricted to vibratory motion	Particle motion is very slow	Particle motion is very rapid and also random
Inter-particle force is very large thus very dense	Inter-particle forces are intermediate resulting in low density	Inter-particle forces are negligible. Thus imparting very low density

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PLASMA : Plasmas are a lot like gases, but the atoms are different because they are made up of free electrons and ions of the element. You don't find plasmas too often when you walk around. They aren't things that happen regularly on Earth. If you have ever heard of the Northern Lights or ball lightning, you might know that those are types of plasmas. It takes a very special environment to keep plasmas going. They are different and unique from the other states of matter.

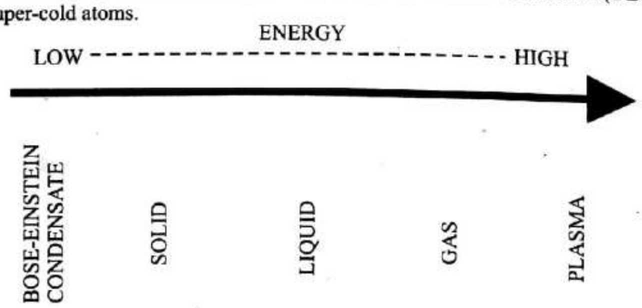
You won't find plasmas just anywhere. However, there may be some in front of you. Think about a fluorescent light bulb. They are not like regular light bulbs. Inside the long tube is a gas. Electricity flows through the tube when the light is turned on. The electricity acts as that special energy and charges up the gas. This charging and exciting of the atoms creates glowing plasma inside the bulb.

Another example of plasma is a neon sign. Just like a fluorescent light, neon signs are glass tubes filled with gas. When the light is turned on, the electricity flows through the tube. The electricity charges the gas, possibly neon, and creates plasma inside of the tube. The plasma glows a special color depending on what kind of gas is present inside the plasma.

You also see plasma when you look at stars. Stars are big balls of gases at really high temperature. The high temperatures charge up the atoms and create plasma. Fluorescent lights are cold compared to really hot stars. They are still both forms of plasma, even with different physical characteristics.

BOSE-EINSTEIN CONDENSATES : Condensation happens when several gas molecules come together and form a liquid. It all happens because of a loss of energy. Gases are really excited atoms. When they lose energy, they slow down and begin to collect. They can collect into one drop. Water condenses on the lid of your pot when you boil water. It cools on the metal and becomes a liquid again. You would then have a condensate.

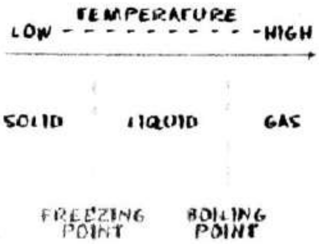
In 1995, two scientists, Cornell and Weiman, finally created this new state of matter. Two other scientists, Satyendra Bose and Albert Einstein, had predicted it in the 1920. They didn't have the equipment and facilities to make it happen in the 20s. Now, we do. If plasmas are super hot and super excited atoms, the atoms in a Bose-Einstein condensate (BEC) are total opposites. They are super-unexcited and super-cold atoms.



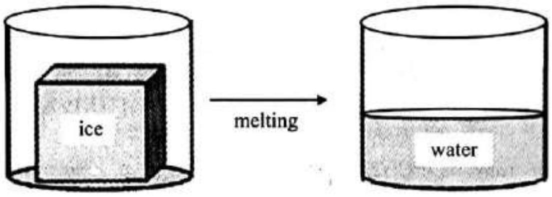
INTERCONVERSION OF MATTER INTO DIFFERENT STATE :

The phenomenon of change of matter from one state to another state and back to original state, by altering the condition of temperature and pressure, is called interconversion of matter. All matter can move from one state to another. It may require very low temperatures or very lower or high pressures, but it can be done. Phase changes happen when certain points are reached. when a liquid turns in to solid. Scientists use parameter called a freezing point to measure when that liquid turns into a solid.

There are physical effects that can change the freezing point. Pressure is one of those effects. When the pressure surrounding a substance goes up, the freezing point also goes up. That means it's easier to freeze the substance at higher pressures. When it gets colder, most solids shrink in size. There are a few which expand but most shrink.



If you have a solid (cube of ice) and want to make it liquid water. You need some energy. Atoms in a liquid state have more energy than the atoms in a solid state. The easiest energy around is probably heat. There is a particular temperature for every solid substance called the melting point. When a solid reaches the temperature of its melting point it melts and get converted in to a liquid. For water the temperature has to be a little over zero degrees Celsius.

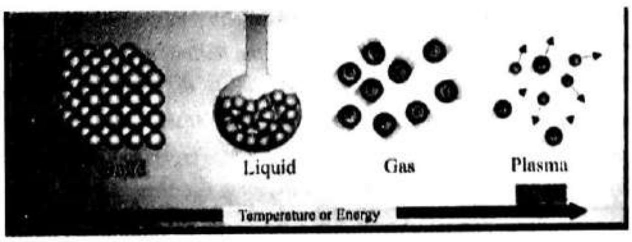


Melting point of a solid also depends upon the surrounding pressure. More will be the pressure more lower will be the melting point. Thus solid melts easily at higher pressure.

The reverse is true if you have a gas. You need to lose some energy from very excited gas atoms. The easy answer is to lower the surrounding temperature. When the temperature drops, energy will be sucked out of gas atoms. When the temperature of the condensation point is achieved it become a liquid. If you have the steam of a boiling pot of water and it hit the wall, the wall would be so cool that steam would quickly become a liquid.

Condensation point of gas also depends upon the surrounding pressure. More will be the pressure more closer will be molecules and thus greater will be the intermolecular forces of attraction. Thus more will be the surrounding pressure more easily gas gets condensed in to liquid.

A plasma can be made from a gas if a lot of energy is pushed inside. All of this extra energy makes the neutral atoms break apart into positively and negatively charged ions and free electrons. They wind up in a big gaseous ball.



The various state of matter can be interchanged into one another by altering the conditions of (1) Temperature (2) Pressure.

Altering the Temperature of Matter:

(a) Interconversion of solid into liquid & vice versa:

The solids can be converted into liquids by heating them. Similarly, liquids can be cooled to form solids.
For e.g. : Ice at 0°C changes into water at 0°C, when heat energy is supplied to it.
The water at 0°C changes into ice at 0°C on freezing.

(i) Melting or fusion :

The process due to which a solid changes into liquid state by absorbing heat energy is called melting or fusion. The constant temperature at which a solid changes into liquid state at atmospheric pressure by absorbing heat energy is called melting point.

(ii) Freezing or solidification :

The process due to which a liquid changes into solid state by giving heat energy is called freezing or solidification. The constant temperature at which liquid changes into a solid state by giving out heat energy is called freezing point.

Explanation : On increasing the temperature of solids, the kinetic energy (K.E.) of particles increases. Due to increase in K.E., the particles start vibrating with greater speed. The energy supplied by heat overcomes the force of attraction between the particles. Then particles leave their fixed positions & start moving freely and thus solid melts.

Latent Heat of Fusion : The amount of heat energy that is required to change 1 kg of solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion. Latent heat of fusion of ice = 3.34×10^5 J/kg.

The numerical value of freezing point and melting point is same

Melting point of ice is 0°C (273.16 K)
Freezing point of water is 0°C
0°C=273.16 K

Particles of water at 0°C (273 K) have more energy as compared to particles in ice at the same temperature.

✓CHECK POINT **Why during melting of solid temperature remains constant?**

Check Your Answer

When melting point of solid is reached. Energy supplied further in the form of heat is utilised in phase transition from solid to liquid till solid gets converted in to liquid.

(b) Interconversion of liquid into gaseous state & vice versa:

Liquids can be converted into gases by heating them. Similarly, gases can be converted into liquids by cooling them.

(i) Boiling or vaporisation:

The process due to which a liquid changes into gaseous state by absorbing heat energy is called boiling.
Boiling point: The constant temperature at which a liquid rapidly changes into gaseous state by absorbing heat energy at atmospheric pressure is called boiling point.

For water, the vapour pressure reaches the standard sea level atmospheric pressure of 760 mmHg at 100°C. Since the vapour pressure increases with temperature, it follows that for pressure greater than 760 mmHg (e.g., in a pressure cooker), the boiling point is above 100°C and for pressure less than 760 mmHg (e.g., at altitudes above sea level), the boiling point will be lower than 100°C. As long as a vessel of water is boiling at 760 mmHg, it will remain at 100°C until the phase change is complete. Rapidly boiling water is not at a higher temperature than slowly boiling water. The stability of the boiling point makes it a convenient calibration temperature for temperature scales.

(ii) Condensation or liquefaction :

The process due to which a gas changes into liquid state by giving out heat energy is called condensation.

Condensation Point: The constant temperature at which a gas changes into liquid state by giving out heat energy at atmospheric pressure.

Explanation : When heat is supplied to water, particles start moving faster. At a certain temperature, a point is reached when the particles have enough energy to break the forces of attraction between the particles. At this temperature the liquid starts changing into gas. Boiling is a bulk phenomena. Condensation is the opposite of evaporation. It takes place when water vapour in the air condenses from a gas, back into a liquid form, and leaves the atmosphere, returning to the surface of the Earth. You must have seen water droplets on glass containing ice cubes, it is due to condensation.

Latent heat of vaporisation : The amount of heat which is required to convert 1 kg of the liquid (at its boiling point) to vapour or gas without any change in temperature. Latent heat of vaporisation of water = 22.5×10^5 J/kg.

The numerical value of condensation point and boiling point is same.

Water changes into steam at 100°C

(273 + 100) = 373 K

Steam changes into water at 100°C

Particles in steam, that is water vapour at 373 K have more energy than water at the same temperature.

✔ CHECK POINT | **Why steam cause more severe burns than boiling water (100°C)?**

Check Your Answer

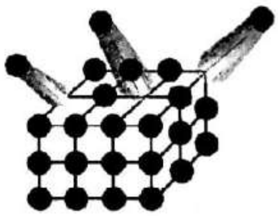
As steam have absorbed extra energy in the form of latent heat of vaporisation. Steam at 100°C will be more dangerous than water at 100°C.

(c) Direct Interconversion of solid into gaseous state & vice versa : Sublimation

Certain substances when heated, pass directly from the solid state to vapour state without being converted into liquid. The vapours when cooled give back the solid substance. This phenomenon is known as sublimation and the substance is called sublimate.

$$\text{Soild} \underset{\text{on cooling}}{\overset{\text{on heating}}{\rightleftharpoons}} \text{Vapours}$$

The examples of substances which can easily sublime are camphor, iodine, napthalene, ammonium chloride, etc. The force of attraction is not uniform in the molecules of all the solids. In some solids, the molecules are bonded together with stronger inter-moleculer forces and in the other, the molecules are bonded together with comparatively weak inter-molecular forces.



Sublimation depicted at submicroscopic level

The solids, having weak inter-molecular forces, when heated are directly converted into vapours (gaseous state) without being converted into liquids. Small amount of energy is sufficient to make the inter-molecular force of attraction negligible. This increases the inter molecular distance to a very great extent. Therefore, the solid is directly converted into vapours.

IDEA BOX

Take appropriate quantity of ammonium chloride in a china dish. Cover the dish with a perforated filter paper. Now place an inverted funnel over the dish. Plug the upper open end of the funnel with cotton. Now keep the entire apparatus as such for 3 days and after that check inverted funnel and record your observation. Now repeat the same after regular interval of 3 days for 15 days. Now repeat this experiment with camphor, iodine and naphthalene also. Record your observations and find out the role of perforated filter paper in this experiment. Also draw a conclusion on the basis of your experiment.

Do You Know!!

The process of sublimation is very helpful in separating a mixture of solids and also in the purification of the substances.

✔ CHECK POINT

$$\text{Solid} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{Gas}$$

Which phenomena is represented by above equation?

Check Your Answer

Sublimation

2. By Altering Pressure:

The difference in various states of matter is due to the difference in intermolecular spaces between their particles. So when a gas is compressed the intermolecular space between its particles get decreases & ultimately it will converted into liquid. So high pressure & low temperature can liquify gases.

For eg : Carbon dioxide (CO_2) is gas under normal conditions of temperature and pressure. It can be liquefied by compressing it to a pressure 70 times more than atmospheric pressure.

EVAPORATION :

Perhaps one of the most accepted facts of life is that wet things eventually become dry. The liquid water has changed to the gaseous state in a process known as *vaporization*. When this process occurs below the boiling point, it is known as *evaporation*. In order for a molecule of a liquid to escape to the vapour state, however, it must overcome the intermolecular forces attracting it by its neighbours in the liquid. Two conditions allow a molecule in a liquid to escape the liquid state to the gaseous state. First, it must be at or near the surface of the liquid. Second, it must have at least the minimum amount of kinetic energy to overcome the intermolecular forces.

✔ CHECK POINT **Why do we see water droplets on the outer surface of a glass containing Ice-cold water ?**

Check Your Answer

The water vapour present in air on coming in contact with cold glass of water, loses energy. So water vapour gets converted to liquid state, which we see as water droplets

Do You Know!!

Evaporation is important to life on Earth. The heat of the sun evaporates water from earth's surface. The evaporated water goes high into the air. Then it cools down, forms clouds, and falls from the sky as rain or snow.

Evaporation is important for people too. When we sweat, water on our skin evaporates. The evaporation makes the skin feel cooler.

Why Evaporation Occurs :

Molecules in the liquid state are constantly moving, but at different speeds. Faster moving molecules at the surface of a liquid break away from the attraction of the other molecules, and escape into the air. Furthermore, heating makes liquids evaporate faster because there are more fast moving molecules and, therefore, more molecules can escape.

✓CHECK POINT | Why should we wear cotton clothes in summer ?

Check Your Answer

During summer, we perspire more because of the mechanism of our body which keeps us cool. During evaporation, the particles at the surface of liquid gain energy from the surroundings or body surface. The heat energy equal to latent heat of vaporisation is absorbed from the body leaving the body cool. Cotton, being a good absorber of water helps in absorbing the sweat.

Factors Affecting Evaporation :

(i) Temperature (ii) Surface area (iii) Humidity (iv) Wind speed (v) Pressure

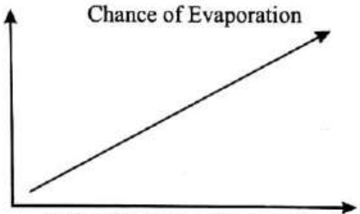
(i) Temperature:

With the increase in temperature the rate of evaporation increases.

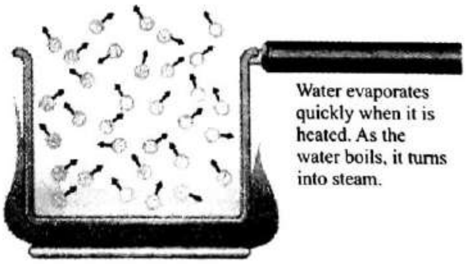
Rate of evaporation $\propto$ T.

Reason:

On increasing temperature more number of particles get enough K E. to go, into the vapour state.



An increase in heat makes things evaporate faster. For example, if a person put the pan of water on the stove and then turned on the heat, the water would soon begin to boil. The person might see steam rise off on top of the water. Steam is water turning into vapour.



(ii) Surface area :

Rate of evaporation $\propto$ surface area

Since evaporation is a surface phenomena. If the surface area is increased, the rate of evaporation increases. So, while putting clothes for drying up we spread them out.

✓CHECK POINT | Two vessels one is of cylindrical and another is of cuboidal shape have same volumes. Both vessels are filled with equal amount of water. In which case rate of evaporation will be more.

Check Your Answer

Evaporation will be more in case of cuboid vessel as it has greater surface area.

(iii) Humidity of air :

Rate of evaporation $\propto \frac{1}{\text{Humidity}}$

Humidity is the amount of water-vapour present in air.

When humidity of air is low, the rate of evaporation is high and water evaporates more readily.

When humidity of air is high, the rate of evaporation is low and water evaporate very slowly.

(iv) Wind speed :

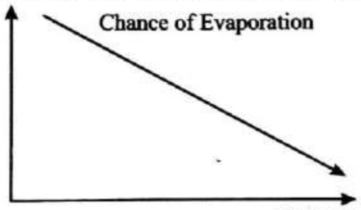
Rate of evaporation $\propto$ wind speed.

With the increase in wind speed, the particles of water-vapour move away with the wind.

So the amount of water-vapour decreases in the surrounding.

(v) Pressure :

The rate of evaporation can also increase with a decrease in the gas pressure around a liquid. Molecules like to move from areas of higher pressure to lower pressure. The molecules are basically sucked into the surrounding area to evenout the pressure. Once the vapour pressure of the area increases to a specific level, the rate of evaporation will slow down.



Some Common Student's Misconceptions About Evaporation :

(a) When liquid water evaporates, it changes from liquid to air.

(b) When liquid water evaporates, water molecules change into air molecules.

(c) When liquid water evaporates, it disappears and is gone.

(d) When liquid water evaporates, it goes to clouds or forms clouds (but not necessarily stays in the air).

Cooling Caused by Evaporation

The process of evaporation is always accompanied by a coolling effect. For example, when a liquid evaporates from the skin, a cooling sensation results. The reason for this that only the most energetic molecules of liquid are lost by evaporation, so that the average energy of the remaining molecules decreases. The surface temperature, which is a measure of this average energy also decreases. Many refrigeration processes are based on this principle.

The cooling effect of evaporating water is important to health maintenance in warm climates. Perspiration covers our bodies with a layer of water when it is warm. The evaporation of this water cools our bodies and us along with it. The cool feeling after a hot shower is not just a feeling but a reality. Evaporation cools the liquid but heats the air. If water is allowed to evaporate under a vacuum, the evaporation process occurs faster. Infact, the water cools enough to freeze.

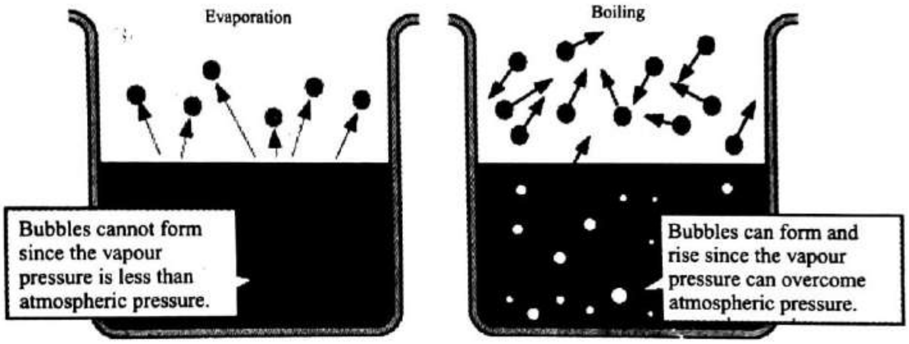
KNOWLEDG NHANCER

EVAPORATIVE COOLERS :
Also called air, swamp, or desert coolers are cooling devices which use simple evaporation of water in air. Evaporative cooling is especially well suited for climates where the air is hot and humidity is low. Residential evaporative coolers use direct evaporation and can be described as an enclosed metal or plastic box with vented sides containing a centrifugal fan or 'blower', electric motor, and a water pump to wet the evaporative cooling pads. The units can be mounted on the roof, or exterior walls or windows of buildings. To cool, the fan draws ambient air through vents on the unit's sides and through the damp pads. Heat in the air evaporates water from the pads which are constantly re-dampened to continue the cooling process. Thus cooled, moist air is then delivered to the building via a vent in the roof or wall.

Difference between Boiling and Evaporation :

(1) Boiling takes place only at a particular temperature for a liquid. Whereas evaporation occurs at all temperatures.

(2) Boiling is Bulk phenomena i.e., the bubble formation occurs even below the surface. Whereas evaporation is surface phenomena, i.e., bubble formation occurs only on the surface of liquid.



IDEA BOX

Take two plastic containers and fill them with equal amount of water. Now tightly cap one of the containers and wrap the cap's diameter with plastic tape. Such that the container becomes air tight. Keep the other container as such open. Now place both the containers together at side of your room. After 2–3 days check level of water in both containers. Record your observations and on the basis of that draw a conclusion.

EXERCISE 1

FIB Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. Matter is made up of small ....
2. The forces of attraction between the particles are .... in solids, ... in liquids and .... in gases.
3. .... is the change of gaseous state directly to solid state without going through liquid state, and vice-versa.
4. Evaporation causes ....
5. Latent heat of fusion is the amount of heat energy required to change 1 kg of solid into liquid at its ....
6. Solid, liquid and gas are called the three .... of matter.
7. The smell of perfume gradually spreads across a room due to ....
8. Rapid evaporation depends on the .... area exposed to atmosphere.
9. As the temperature of a system increases, the pressure of the gases....................
10. As the volume of a specific amount of gas decreases, it's pressure..................
11. As the temperature of a gas decreases, its volume...........
12. Gas molecules at higher temperatures have more .... than at cooler temperatures.
13. Usually the total charge of a plasma is ....
14. The pressure inside of a sealed tube if you raise the temperature go...............
15. Forces of attraction in liquids are ___ than in solids.
16. Liquids that move quickly downhill are described as having.....................

T/F True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Boiling is a bulk phenomenon.
2. Evaporation is a surface phenomenon.
3. The rate of evaporation depends only on the surface area exposed to the atmosphere.
4. Latent heat of vaporisation is the heat energy required to change 1 kg of a liquid to gas at atmospheric pressure at its melting point.
5. Water at room temperature is a liquid.
6. Atoms in a liquid are farther apart than the atoms in a gas.
7. The molecules in a gas are in constant motion.
8. Gases present in air have the same pressure throughout the entire atmosphere.
9. All materials move from solid to liquid to gas as the temperature increases.
10. Because electrons have been stripped away from atoms in plasma, plasmas have a negative charge.
11. It is just as easy to compress a liquid, as it is to compress a gas.
12. Evaporation and boiling are the same processes because molecules move from a liquid to gaseous state.
13. If we pour liquid nitrogen (N_2) into a glass, it will change its state to a solid.
14. You may find plasma in a star.
15. A system that changes from a solid state to a liquid state gains energy.
16. Plasmas are all made of the same ions. They have different colours due to different amounts of electricity.

MTC Match the Column

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in Column I have to be matched with statements (p, q, r, s) in Column II.*

1. Column II gives how rate of evaporation changes for factors given in column I match them correctly.

Column I	Column II
(A) Increase in surface area	(p) Increases
(B) Decrease in temperature	(q) Decreases
(C) Decrease in humidity	(r) Unchange
(D) Increase in wind speed	(s) May increase or decrease

2. Column II give properties for matter mention in column I match them correctly.

Column I	Column II
(A) Liquid	(p) Definite shape
(B) Solid	(q) Definite volume
(C) Plasma	(r) Super low energy
(D) Bose-Einstein condensate	(s) Super energetic

VSAQ Very Short Answer Questions

DIRECTIONS : *Give answer in one word or one sentence.*

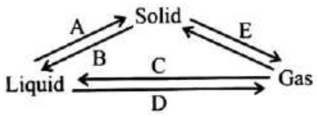
1. Name the three states of matter. Give one example of each.
2. What are the two ways in which the physical state of matter can be changed ?

3. Explain how gases can be liquified ?
4. What is sublimation ? Give examples.
5. Define latent heat of fusion.
6. Define latent heat of vaporization.
7. What produces more severe burns, boiling water or steam?
8. How can the boiling point of a liquid be raised, without adding any impurity ?
9. In how many forms did the earlier sceintists classify matter ?
10. Why does a summer rainstorm lower the temperature ?
11. A beaker of a liquid with a vapour pressure of 350 torr at 25°C is set alongside a beaker of water (Vapour pressure of 23.76 torr) and both are allowed to evaporate. In which liquid does the temperature change at a faster rate ? Why
12. At a given temperature, one liquid has a vapour pressure of 240 torr and another measures 420 torr. Which liquid probably has the lower boiling point ? Which probably has the lower heat of vaporization ?
13. A drop of detiol got evenly distributed in water. How ?
14. Liquid nitrogen is used as a commercial refrigerant to flash freeze foods. Nitrogen boils at –196°C. What is this temperature on the Kelvin temperature scale ?
15. What property or properties of gases can you point to support the assumption that most of the volume in a gas is empty space?
16. What is unit cell?
17. What is the effect on surface tension of temperature.
18. Surface tension is same for different liquids. Explain

SAQ Short Answer Questions

DIRECTIONS : *Give answer in 2-3 sentences.*

1. What is condensation ? How is the condensation of a gas carried out ?
2. Why do solids not diffuse ?
3. The following diagram shows the three states of matter and how they can be interchanged.
   Name the changes A to E.



4. Convert the following Kelvin temperatures to degrees Celsius.
   (i) 175 K (ii) 295 K
   (iii) 300 K (iv) 225 K
5. Explain the diffusion of copper sulphate into water.
6. A constant pressure tank of gas at 1.01 Atm has propane in it at 15°C when it is at 255 cubic meters. What is its volume at 48°C?
7. What is the mass of 15 liters of chlorine gas at STP?
8. How many litres of hydrogen at 0°C and 1400 mmHg are produced if 15g of magnesium reacts with sulfuric acid?
9. A 250 Kg tank of liquid butane (C_4H_{10}) burns to produce carbon dioxide at 120°C. What volume of carbon dioxide is produced at 1 Atm?
10. How many liters of product at 950 mmHg and 0°C is produced by the burning of three liters of acetylene (C_2H_2) at 5 atm and 20°C?
11. A fixed quantity of gas at 23°C exhibits pressure of 748 torr and occupies a volume of 10.3 L. (a) Use Boyle's law to calculate the volume the gas will occupy at 23°C if the pressure is increased to 1.88 atm. (b) Use Charles's law to calculate the volume the gas will occupy if the temperature is increased to 165°C while the pressure is held constant.
12. (a) Write the ideal-gas equat ion, and give the units used for each term in the equation when
    $R = 0.0821$ L-atm/mol-K.
    (b) What is an ideal gas ?
13. A certain volume of a gas is under a pressure of 900 mm of Hg. When the pressure is increased by 300 mm, the gas occupies 2700 ml. If this change occurs at a constant temperature, calculate the initial volume of the gas.
14. Which state of matter is compressible ? Why ?
15. Why do the gases exert more pressure on the walls of the container than the solids ?
16. The process in which a solid is converted directly into a gas is called sublimation. Iodine is an element that sublimes. A sample of solid iodine in a stoppered flask was allowed to stand undisturbed for several days. Crystals of solid iodine grew on the sides of the flask. Explain at the molecular level what happened?
17. At a pressure of 2 atmosphere a fixed mass of hydrogen occupies a volume of 8 litres. What pressure must be maintained if the volume is to be increased to 10 litres, temperature remaining constant?
18. A given mass of a gas occupies 960 ml at 27°C. What volume will it occupy if the temperature is raised to 177°C, pressure remaining constant?
19. Give three examples of crystalline and amorphous solids.
20. Why is motor oil more viscous than water ? Does motor oil have a greater surface tension than water.
21. Describe why a drop of food coloring in a glass of water slowly becomes evenly distributed without the need for stirring?
22. Liquid mix more slowly than gases. Why ?

Foundation Chemistry for Class IX Part A for IIT JEE Foundation by K K Anand Chennai SmartEdu

LAQ Long Answer Questions

DIRECTIONS : *Give answer in four to five sentences.*

1. Explain why ?
   (i) A gas fill a vessel completely.
   (ii) Camphor disappears without leaving any residue.
   (iii) The temperature does not rise during the process of melting and boiling, though heat energy is constantly supplied.
   (iv) Water stored in an earthen vessel becomes cool.
   (v) An iron almirah is a solid at room temperature.
2. Which phenomenon occurs during the following changes?
   (i) Size of napthalene balls decrease.
   (ii) Wax melts in the sun.
   (iii) Drying of wet clothes.
   (iv) Formation of clouds.
   (v) Density of liquids is more than gases.
3. Calculate each of the following quantities for an ideal gas
   (a) the volume of the gas, in liters, if 2.46 mol has a pressure of 1.28 atm at a temperature of – 6°C;
   (b) the absolute temperature of the gas at which 4.79×10^{-2} mol occupies 135 mL at 720 torr;
   (c) the pressure, in atmospheres, if 5.52×10^{-2} mol occupies 413 mL at 88°C;
   (d) the quantity of gas, in moles, if 88.4 L at 54°C has a pressure of 9.84 kPa.
4. Vessel A contains CO (g) at 0°C and 1 atm. Vessel B contains SO_2 (g) at 20°C and 0.5 atm. The two vessels have the same volume. (a) Which vessel contains more molecules? (b) Which contains more mass ? (c) In which vessel is the average kinetic energy of molecules higher ?
5. Define :
   (i) Melting point
   (ii) Boiling point
   (iii) Vapourisation
   (iv) Freezing
   (v) Brownian motion
6. Differentiate between amorphous and crystalline solids.

EXERCISE 2

MCQ Multiple Choice Questions

DIRECTIONS : *This section contains 53 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. The quantity of matter present in an object is called its
   (a) weight (b) gram
   (c) mass (d) density
2. At higher altitudes
   (a) boiling point of a liquid increases
   (b) boiling point of a liquid decreases
   (c) no change in boiling point
   (d) melting point of solid increases
3. The boiling point of alcohol is 78°C. What is this temperature in Kelvin scale
   (a) 373 K (b) 351 K
   (c) 375 K (d) 78 K
4. In which phenomena water changes into water vapour below its B.P. ?
   (a) Evaporation (b) Condensation
   (c) Boiling (d) No such phenomena exist
5. The boiling point of water on celcius and Kelvin scale respectively is :
   (a) 373, 273 (b) 0, 273
   (c) 273, 373 (d) 100, 373
6. The liquid which has the highest rate of evaporation is
   (a) petrol (b) nail-polish remover
   (c) water (d) alcohol
7. When we put some crystals of potassium permanganate in a beaker containing water, we observe that after sometime whole water has turned pink. This is due to
   (a) boiling
   (b) melting of potassium permanganate crystals
   (c) sublimation of crystals
   (d) diffusion
8. The state of matter which consists of super energetic particles in the form of ionized gases is called
   (a) gaseous state
   (b) liquid state
   (c) Bose-Einstein condensate
   (d) plasma state
9. The force that binds the particles of matter together is known as
   (a) intermolecular space (b) bond
   (c) intermolecular force (d) nuclear force
10. The change of a liquid into vapour is called
    (a) vapourization (b) solidification
    (c) sublimation (d) None of these
11. Which of the following describes the liquid phase ?
    (a) It has a definite shape and a definite volume
    (b) It has a definite shape but not a definite volume
    (c) It has a definite volume but not a definite shape
    (d) It has neither a definite shape nor a definite volume
12. When a teaspoon of solid sugar is dissolved in a glass of liquid water, what phase or phases are present after mixing
    (a) liquid only (b) still solid and liquid
    (c) solid only (d) None of these
13. Volume of a gas at a particular temperature and on atmospheric pressure is 200 ml. Keeping the temperature constant if pressure is increased to 5 atmosphere, then volume of the gas will be
    (a) 100 ml. (b) 40 ml.
    (c) 200 ml. (d) 205 ml.
14. Which of the following statements best explains why a closed balloon filled with helium gas rises in air ?
    (a) Helium is an monatomic gas, whereas nearly all the molecules that make up air, such as nitrogen and oxygen, are diatomic.
    (b) The average speed of helium atoms is higher than the average speeds of air molecules, and the higher speed of collisions with the balloon walls propels the balloon upward.
    (c) Because the helium atoms are of lower mass than the average air molecules, the helium gas is less dense than air. The balloon thus weighs less than the air displaced by its volume.
    (d) Because helium has a lower molar mass than the average air molecule, the helium atoms are in faster motion. This means that the temperature of the helium is higher than the air temperature. Hot gases tend to rise.
15. Equal volumes of all gases under similar conditions of temperature and pressure contain equal numbers of molecules. This statement was made by
    (a) Gay-Lussac (b) Avogadro
    (c) Berzilius (d) John Dalton
16. Boyle's law states that the
    (a) pressure of a gas is directly proportional to the temperature at constant volume
    (b) pressure of a gas is inversely proportional the volume at constant temperature
    (c) volume is directly proportional to the temperature at constant pressure
    (d) None of the above
17. All gases will occupy zero volume when the temperature is reduced to
    (a) 273°C (b) 273°A
    (c) –273°C (d) 0°C

18. Non-reacting gases have a tendency to mix with each other. This phenomenon is known as
    (a) chemical reaction (b) diffusion
    (c) effusion (d) explosion
19. A gas which obeys the gas laws is known as
    (a) an ideal gas (b) a heavier gas
    (c) a lighter gas (d) a real gas
20. A gas can be compressed to a fraction of its volume. The same volume of a gas can be spread all over a room. The reason for this is that
    (a) the volume occupied by molecules of a gas is negligible as compared to the total volume of the gas.
    (b) gases consists of molecules which are in a state of random motion
    (c) gases consist of molecules having very large inter-molecular space which can be reduced or increased under ordinary conditions
    (d) None of these
21. What is the term used to describe the phase change of a liquid to a gas?
    (a) Boiling (b) Condensation
    (c) Melting (d) None of the above
22. What term is used to describe the phase change of a solid to a liquid?
    (a) Freezing (b) Melting
    (c) Boiling (d) None of the above
23. What is the term used to describe the phase change as a liquid becomes a solid?
    (a) Evaporation (b) Condensation
    (c) Freezing (d) None of the above
24. Which has the least energetic molecules?
    (a) Solids (b) Liquids
    (c) Gases (d) Plasmas
25. In which phase of matter would you expect compound (alcohol exists) at room temperature?
    (a) Solid (b) Liquid
    (c) Gas (d) Plasma
26. Which of these choices will not change the state of matter?
    (a) Temperature (b) Crushing a crystal
    (c) Pressure (d) Heat
27. If you leave water in a glass and some molecules turn into a gas, it is called...
    (a) Egasoration (b) Evaporation
    (c) Extinction (d) Solidification
28. As of the 1990s, scientists have proved the existence of how many states of matter?
    (a) Two (b) Three
    (c) Four (d) Five
29. Out of the following which is the densest state of matter?
    (a) Solids (b) Liquids
    (c) Gases (d) Plasmas
30. Densities of two gases are in the ratio 1 : 2 and their temperatures are in the ratio 2 : 1, then the ratio of their respective pressures is
    (a) 1 : 1 (b) 1 : 2
    (c) 2 : 1 (d) 4 : 1
31. Which of the following expression at constant pressure represents Charle's law?
    (a) $V \propto \frac{1}{T}$ (b) $V \propto \frac{1}{T^2}$
    (c) $V \propto T$ (d) $V \propto d$
32. For an ideal gas number of moles per litre in terms of its pressure P, gas constant R and temperature T is
    (a) PT/R (b) PRT
    (c) P/RT (d) RT/P
33. Rate of diffusion of a gas is
    (a) directly proportional to its density
    (b) directly proportional to its molecular mass
    (c) inversely proportional to the square root of its density
    (d) inversely proportional to the square root of its molecular mass
34. According to Graham's lawt at a given temperature, the ratio of the rates of diffusion r_A/r_B of gases A and B is given by
    (a) $(P_A/P_B)(M_A/M_B)^{1/2}$ (b) $(M_A/M_B)(P_A/P_B)^{1/2}$
    (c) $(P_B/M_B)(P_A/M_A)^{1/2}$ (d) $(M_A/M_B)(P_B/P_A)^{1/2}$
35. A bottle of ammonia and a bottle of dry hydrogen chloride connected through a long tube are opened simultaneously at both ends, the white ammonium chloride ring first formed will be
    (a) at the centre of the tube
    (b) near the hydrogen chloride bottle
    (c) near the ammonia bottle
    (d) throughout the length of the tube
36. Select the one that is not a matter.
    (a) Feeling of hot (b) Smoke
    (c) Humidity (d) Water
37. Which is incorrect statement?
    (a) Matter is continuous in nature.
    (b) Of the three state of matter, the one that is most compact is solid state.
    (c) In solid state interparticles space (i.e., empty space) is minimum.
    (d) The density of solid is generally more than that of a liquid.
38. Select the one that when used would be considered as best condition for liquification of a gas.
    (a) Increasing the temperature.
    (b) Decreasing the pressure.
    (c) Increasing the pressure and decreasing the temperature.
    (d) Decreasing the pressure and increasing the temperature.
39. Select the correct order of evaporation for water, alcohol, petrol and kerosene oil
    (a) water > alcohol > kerosene oil > petrol
    (b) alcohol > petrol > water > kerosene oil
    (c) petrol > alcohol > water > kerosene oil
    (d) petrol > alcohol > kerosene oil > water
40. Which one is a sublime substance?
    (a) Table salt (b) Sugar
    (c) Iodine (d) Potassium Iodide

41. S.I. unit of temperature is
(a) Celcius (b) Fahrenheit
(c) Kelvin (d) None of these

42. 10 K is equal to
(a) 283°C (b) –263°C
(c) 263°C (d) –283°C

43. The process of change of liquid state into gaseous state at constant temperature is known as
(a) boiling (b) melting
(c) fusion (d) evaporation

44. Dry ice is
(a) ice having no water of crystallisation
(b) ice that has been dried
(c) solid carbon dioxide
(d) None of these

45. Which one is a surface phenomenon?
(a) Evaporation (b) Boiling
(c) Both (a) and (b) (d) None of these

46. Rate of diffusion depends upon
(a) temperature .
(b) surface area
(c) both temperature and surface area
(d) None of these

47. Which of the following processes is known as fusion?
(a) Change of liquid to solid
(b) Change of solid to liquid
(c) Change of liquid to vapour
(d) Change of gaseous state to solid state

48. The evaporation of a liquid can best be carried out in a
(a) flask (b) china dish
(c) test tube (d) beaker

49. The one, in which interparticle forces are strongest, is
(a) sodium chloride (b) hydrogen
(c) ether (d) carbon dioxide

50. The melting point temperature of the solid state of a substance is 40°C. The freezing point temperature of the liquid state of the same substance will be
(a) 35°C (b) 40°C
(c) 45°C (d) can't predict.

51. Which one will help to accelerate the process of evaporation of a liquid kept in an open china dish?
(a) Keeping dish in open
(b) Blowing air into the liquid
(c) Keeping the dish under a running fan
(d) All the above

52. When a gas is compressed keeping temperature constant, it results in
(a) increase in speed of gaseous molecules
(b) increase in collision among gaseous molecules
(c) decrease in speed of gaseous molecules
(d) decrease in collision among gaseous molecules.

53. Pressure of air at sea level is
(a) one atmosphere (b) 76 cm of Hg
(c) 760 mm of Hg (d) All are correct.

MTOC More than One Correct

DIRECTIONS : *This section contains 15 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Which of the following substance(s) can sublime ?
(a) Camphor
(b) Solid carbon dioxide
(c) Ammonium chloride
(d) Sodium bicarbonate

2. The correct statement(s) amongst the following is/are
(a) gases diffuse at different rates
(b) diffusion also takes place in liquids
(c) diffusion of liquid and a gas is known as intimate mixing
(d) some liquids diffuses at rate equal to gases

3. Which of the following statement(s) about evaporation is/are correct?
(a) It is a bulk phenomena
(b) It causes cooling
(c) Results into increase in temperature
(d) It is a surface phenomena

4. Which of the following is/are value(s) of gas constant R ?
(a) 0.0821 L atm $k^{-1}mol^{-1}$
(b) 8.21 L torr $k^{-1}mol^{-1}$
(c) 82.1 atm mL $k^{-1}mol^{-1}$
(d) 8.314 J $mol^{-1}k^{-1}$

5. Which of the following properties of liquid increases with increase of temperature?
(a) Vapour pressure (b) Viscosity
(c) Surface tension (d) Evaporation

6. Which of the following properties is different for solids liquids and gases?
(a) Movement of molecules
(b) Particle size of the substance
(c) Mass of the substance
(d) Density

7. Gases can be liquified either by lowering the temperature, applying pressure. This shows that
(a) molecules of a gas repel each other
(b) there exists a kind of intermolecular attraction between molecules of a gas
(c) molecules of a gas are in a state of random motion
(d) intermolecular forces between gas molecules increases when distance between molecules decreases.

8. Which of these statement(s) is are/true?
(a) Gases have high density.
(b) Gases can be compressed more than solids.
(c) Gases have very specific shapes.
(d) Gases undergoes diffussion fastest

9. Which of these choices is defined as "Standard Pressure?"
(a) 14.7 psi (b) 1 atm
(c) 760 torr (d) 1 pascal

10. All liquids have different
    (a) density (b) viscosity
    (c) solubility (d) rate of evaporation
11. Which of the following statement(s) is/are applicable for amorphous solids?
    (a) Are more flexible at higher temperatures.
    (b) Include glasses.
    (c) Do not have specific melting points.
    (d) Have sharp melting points
12. Which of the following statement(s) about solids is/are incorrect ?
    (a) Expand largely when the temperature rises.
    (b) Change shape easily.
    (c) Have a low density.
    (d) Generally solids have high density
13. Which of these choices is / are example(s) of a plasma?
    (a) Aurora Borealis
    (b) Fluorescent Light Bulb
    (c) Neon Sign
    (d) Incandescent Light Bulb
14. Which of the following statement(s) is /are true for gases?
    (a) Gases do not have a definite shape and volume
    (b) Volume of the gas is almost equal to the volume of the container confining the gas
    (c) Confined gas exerts uniform pressure on the walls of its container in all directions
    (d) Mass of the gas cannot be determined by weighing a container in which it is enclosed
15. At constant temperature, in a given mass of an ideal gas
    (a) the ratio of volume and temperature always remains constant
    (b) volume always remains constant
    (c) pressure always remains constant
    (d) the product of pressure and volume always remains constant

FIP Fill in the Passage

DIRECTIONS : *Complete the following passage(s) with an appropriate word/term to be filled in the blank spaces.*

1. In the liquid state, ...(1).............. causes water to form spherical drops. ....(2)....... is a property relating to the rate of flow. When evaporation of a liquid occurs, the remaining liquid becomes.......(3)......... . The........... (4)............ is the pressure exerted by the vapour of a liquid at a given ....(5)......... The vaporization of a solid is known as ....(6)........ The normal boiling point is the temperature at which the............(7)............ is equal to 760 torr.
2. The process in which solid changes into liquid is called ....(1)......... The process due to which a liquid changes into solid is called ....(2).......... The amount of heat energy required to change 1 kg of solid into liquid at 1 atm is known as ....(3)......... The process in which liquid changes in to gas is called ....(4)............ The amount of heat required to convert 1kg of liquid to vapour or gas without any change in temperature is known as ....(5).............. .

PBQ Passage Based Questions

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

Chlorine is widely used to purify municipal water supplies and to treat swimming pool waters suppose that the volume of a particular sample of Cl_2 gas is 9.22 L at 1124 torr and 24°C.

1. How many grams of Cl_2 are in the sample?
   (a) 39.7 g (b) 37.9 g
   (c) 40.2 g (d) 39.5 g
2. What volume will the Cl_2 occupy at STP?
   (a) 13.5 L (b) 8.5 L
   (c) 12.5 L (d) 8.43 L
3. At what temperature will the volume be 15.00 L if the pressure is 8.76×10^2 torr?
   (a) 400 K (b) 384.5 K
   (c) 373 K (d) 377 K

A&R Assertion and Reason

DIRECTIONS : *Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** Ideal gas equation is valid at low pressure and high temperature.
   Reason : Molecular interactions are negligible under this condition.
2. **Assertion :** It is easier to cook food at hill.
   Reason : The boiling point of water increases at hill.
3. **Assertion :** During evaporation of liquid the temperature of the liquid remains unaffected.
   Reason : Kinetic energy of the molecules is directly proportional to absolute temperature.
4. **Assertion :** At room temperature, the evaporation of a liquid takes place at constant rate.
   Reason : During evaporation of a liquid, the temperature of the liquid remains unaffected.

MMQ Multiple Matching Questions

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

Column I	Column II
(A) Boyle's law	(p) Temperature
(B) Charle's law	(q) Pressure
(C) Gay-Lussac law	(r) Volume
(D) Ideal gas equation	(s) Number of moles of a gas

2.

Column I	Column II
(A) Diffusion	(p) Solids
(B) Condensation	(q) Liquids
(C) Definite volume	(r) Gases
(D) Compressibility	(s) Plasma

HOTS Hots Subjective Questions

DIRECTIONS : *Answer the following questions.*

1. When a jar of coffee is opened, people in all parts of the room soon notice the smell. Explain why this happens?
2. If water is boiling and the flame supplying the heat is turned up, does the water become hotter ? What happens?
3. Why we close the bottle of nail polish remover immediately after using it ?
4. Why does a desert cooler cools better on hot dry day ?
5. Which diffuses faster, the bad smell from a cat-pan due to ammonia or an expensive French perfume with an average molecular weight of 170 g/mol ? How much faster does the faster one diffuse?
6. Ethyl chloride boils at 13°C. When it is sprayed on the skin, it freezes a small part of the skin and thus serves as a local anaesthetic. Explain how it cools the skin?
7. Why is ice at 273 K more effective in cooling than water at the same temperature ?
8. A graduated cylinder was filled with water to the 15.0 mL mark and weighed on a balance. Its mass was 27.35g. An object made of silver was placed in the cylinder and completely submerged in the water. The water level rise to 18.3 mL. when reweighed, the cylinder, water, and silver object had a total mass of 62.00 g. Calculate the density of silver.
9. What volume in millilitres does a sample of nitrogen with a mass of 0.245g occupy at 21°C and 750 torr ?
10. The label on a cylinder of a noble gas become unreadeble, a student allowed some of the gas to flow into a 300 mL gas bulb until the pressure was 685 torr. The sample now weighed 1.45 g, its temperature was 27.0° C. What is the molecular mass of this gas?
11. What change or changes in the state of a gas bring about each of the following effects? (a) The number of impacts per unit time on a given container wall increases. (b) The average energy of impact of molecules with the wall of the container decreases. (c) The average distance between gas molecules increases. (d) The average speed of molecules in the gas mixture is increased.
12. 400 ml of a gas at 227°C is to be reduced to a volume of 300 ml. By what degrees Celsius, must the temperature be altered, keeping pressure constant.
13. 200 ml of a gas at 27°C and 1140 mm pressure is transferred to a vessel of 450 ml capacity. What temperature is to be applied, if the pressure applied is 1 atmosphere?
14. What are super cooled liquids?
15. How water below the surface of earth rises to plants through the roots?
16. What is implied by the word "equilibrium" in equilibrium vapour pressure ?
17. Why do the doctors advice to put strips of wet cloth on the forehead of a person having high temperature ?
18. When we smell the odour of a rose, our olfactory nerves are sensing molecules of the scent. Explain how smelling a rose demonstrates that molecules are always moving?
19. The volume of a given mass of gas, at 150°C is 400 ml. At what temperature, will it occupy a volume of 600 ml at the same pressure?
20. A gas occupies 500 ml at 40°C and 800 mm pressure. What volume will it occupy at 353°C and 600 mm pressure?

SOLUTIONS

EXERCISE – I

FILL IN THE BLANKS

1.	particles		
2.	maximum, intermediate, minimum		
3.	Sublimation	4.	cooling
5.	melting point	6.	states
7.	diffusion	8.	surface
9.	increases	10.	increases
11.	decreases	12.	kinetic energy
13.	zero	14.	up
15.	weaker	16.	low viscosity

TRUE/FALSE

1.	True	2.	True	3.	False
4.	False	5.	True	6.	False
7.	True	8.	False	9.	True
10.	False	11.	False	12.	False
13.	False	14.	True	15.	True
16.	False				

MATCH THE COLUMN

1. (A) $\rightarrow$ (p); (B) $\rightarrow$ (q); (C) $\rightarrow$ (p); (D) $\rightarrow$(p)
2. (A) $\rightarrow$(q); (B) $\rightarrow$(p, q); (C) $\rightarrow$(s); (D) $\rightarrow$(r);

VERY SHORT ANSWER QUESTIONS

1. Solids, liquids and gases are three states of matter and there examples are ice, water and steam respectively.
2. Melting and boiling are two ways in which the physical state of matter can be changed.
3. Gases can be liquefied by increasing pressure or by lowering temperature.
4. Sublimation is a phenomena of interconversion of solid into gases and vice-versa.

$$\text{solid} \rightleftharpoons \text{gases}$$

e.g., solid CO_2 gets directly converted into gaseous form.

5. Latent heat of fusion : The amount of heat energy that is required to change 1 kg of solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion.
6. Latent heat of vaporisation : The amount of heat which is required to convert 1 kg of the liquid (at its boiling point) to vapour or gas without any change in temperature.
7. Steam produces more severe burn as it is in a gaseous phase thus have absorbed extra energy in the form of latent heat of vaporisation.
8. By increasing pressure on liquid.
9. They classified the matter in four forms: air, earth, fire and water.
10. Water evaporates quickly on a hot day and thus lowers the air temperature.
11. The liquid other than water. The higher the vapour pressure, faster the liquid evaporates more quickly it cools and lower will be its temperature.
12. The liquid with the higher vapour pressure (420 torr) has the lower boiling point. It also probably has the lower heat of vaporization.
13. This is because there is enough space between the particles of water and dettol particles gets into the spaces between the particles of other matter (water).
14. $K = {}^\circ C + 273 = -196 + 273 = 77\ K$
15. The fact that gases are readily compressible supports the assumption that most of the volume of a gas sample is empty space.
16. It is the smallest portion of the crystal lattice which defines completely the repeating pattern in the crystal in all directions.
17. Surface tension decreases with rise in temperature.
18. No surface tension is different for different liquids. As surface tension depends upon intermolecular forces which vary from liquid to liquid.

SHORT ANSWER QUESTIONS

1. The process due to which a gas changes into liquid state by giving out heat energy is called condensation. When a gas is compressed it loses its heat energy there by consequently decreasing intermolecular distance between molecules and increasing intermolecular forces of attraction between molecules. Thus, resulting into liquefaction of gas.
2. This is because the forces of attraction between the particles of a solids are very strong and there is very little space for the particles to move around.
3. A–freezing, B–melting, C–condensation D–evaporation, E–sublimation
4. (i) $-98°C$ (ii) $22°C$ (iii) $27°C$ (iv) $-48°C$
5. Copper sulphate crystals are blue in colour. When we put some crystals of copper sulphate at the bottom of the beaker containing water, the water slowly turns blue. This is because the particles of copper sulphate mix with the particles of water. This mixing of particles will continue till the whole solution turns blue. This phenomenon is called diffusion.
6. According to Charle's law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad ...(i)$$

Here V_1 = 255 cubic meters

T_1 = 288 K

V_2 = volume at 48°C

T_2 = 321 K

By putting these values in equation (1), we get

$$\frac{V_1}{T_1}=\frac{V_2}{T_2}$$

$$\frac{255}{288}=\frac{V_2}{321}$$

$$V_2=\frac{255\times 321}{288}$$

V_2 = 284.2 cubic meters

7. 47.5 g
8. Given pressure = 1400 mm of Hg
1 atm = 760 mm of Hg

$$1\text{mm of Hg}=\frac{1}{760}\text{atm}$$

$$1400\text{ mm of Hg}=\frac{1400}{760}\text{ atm}=1.842\text{ atm}$$

T = 273K

$$\text{No. of moles of magnesium}=\frac{15}{24.305}$$

n = 0.617

R (gas constant) = 0.0821 L atm $mol^{-1}K^{-1}$
From ideal gas equation

PV = nRT

$$V=\frac{0.617\times 0.0821\times 273}{1.842}$$

V = 7.50

9. 6.56 L
10. 33.5 L
11. Initially
T = 296 K, P = 748 torr, V = 10.3 L

$$P=\frac{748}{760}=0.984\text{ atm}$$

(a) According to Boyle's law

$$P_1V_1=P_2V_2$$

$$0.984\times 10.3=1.88\times V_2$$

$$V_2=\frac{0.984\times 10.3}{1.88}=5.39\text{ litres}$$

(b) According to Charle's law here T_2 = 165°C = 438K

$$\frac{V}{T}=\text{constant}$$

$$\frac{V_1}{T_1}=\frac{V_2}{T_2}=\frac{10.3}{296}=\frac{V_2}{438}$$

$$V_2=\frac{10.3\times 438}{296}$$

V_2 = 15.24 litres

12. (a) $PV = nRT$; P in atmospheres, V in liters, n in moles, T in kelvins.
(b) An ideal gas exhibits pressure, volume, and temperature relationships described by the equation $PV = nRT$.

13. P_1 = 900 mm of Hg, P_2 = 1200 mm of Hg
V_1 = ?, V_2 = 2700 ml
Applying Boyle's Law

$$P_1V_1=P_2V_2$$

Substituting the values

$$900\times V_1=1200\times 2700$$

$$V_1=\frac{1200\times 2700}{900}=3600\text{ ml}$$

Initial volume = 3600 ml

14. The gaseous state is compressible because the distance between the molecules are greater and on applying external pressure, the gas molecule come closer to each other and occupies less space than before. Thus gas gets compressed.
15. In gases, the particles move randomly at high speed and they collide with each other and with walls of the container. Due to this collision with walls of the container, the gases exert more pressure than solids.
16. Iodine molecules sublime from the crystals at the bottom of the flask into the gas phase, where their presence imparts a pale violet color to the gas. Some of these molecules then condense on the surface (sides) of the flask, forming crystals.
17. P_1 = 1520 mm of Hg, P_2 = ?
V_1 = 8 lt, V_2 = 10 lt
Applying Boyle's Law, $P_1V_1=P_2V_2$
Substituting the values

$$2\times 8=P_2\times 10$$

$$P_2=\frac{2\times 8}{10}=1216\text{ mm of Hg}$$

The pressure that must be maintained = 1216 mm of Hg

18. V_1 = 960 ml, V_2 =?
T_1 = (27°C + 273) = 300 K T_2 = 177°C = (273 + 177) K = 450 K

Applying Charle's law $\frac{V_1}{T_1}=\frac{V_2}{T_2}$

Hence, $V_2=\frac{V_1\times T_2}{T_1}$

On substituting the values

$$V_2=\frac{960\times 450}{300}=1440\text{ ml.}$$

Hence the new volume will be 1440 ml.

19. Crystalline solids are NaCl, CaF_2, ZnS, etc., whereas amorphous solids are rubber, plastic, glass, etc.
20. In case of motor oil internal resistance between the layer of liquids is more in comparison to water. Motor oil also has a higher surface tension.
21. Both the liquid molecules and food coloring molecules are in motion. Through constant motion and collisions the food colouring molecules eventually become dispersed.

22. Since gas molecules are far apart, therefore intermolecular forces of attraction between a particular gas molecules are less in comparision to liquids. Thus gas molecules of one type mix more easily with gas molecules of another type in comparison to liquids.

LONG ANSWER QUESTIONS

1. (i) This is because intermolecular forces of attraction between gas molecules is almost negligible. Thus gases occupy the volume of container in which they filled in.
   (ii) This is because camphor is a sublime substances. Thus it gets converted into gaseous form directly from solid state without first being converted into liquid as a result of sublimation.
   (iii) This is because during melting and boiling the heat energy supplied is utilised in a phase transition like solid to liquid in case of melting and liquid to gas in case of boiling. Therefore, temperature remains constant.
   (iv) As the earthen pot is made up of mud and having many pores in it. These pores serves as air cavities. The water evaporates through the air cavities present in earthen pot which results in cooling of remaining water. This is somewhat similar to the process of sweating in our body which keeps our body cool during summers.
   (v) Iron atoms have very less interatomic spaces between them and are thus firmly packed. That's why iron is rigid solid at room temperature and have high melting and boiling point.
2. (i) Napthalene is a sublime substance it gets converted into gaseous form directly without being first converted into liquid state. Thus the size of napthalene balls decreases automatically due to sublimation.
   (ii) Wax is a solid it absorbs heat energy from sun and starts melting.
   (iii) Wet clothes absorb heat energy from sun and water molecules evaporates off to atmosphere.
   (iv) Water vapours formed from ocean and other water bodies of earth when reaches up to atmosphere there they got cooled up and release there energy and undergoes condensation to form clouds.
   (v) In comparison to gases, in liquids the molecules are close to each other. Therefore, density of liquids is higher than that of gaseous state.
3. (a) $n = 2.46$ mol $P = 1.28$ atm $T = 267$ K
   From ideal gas equation
   $$PV = nRT$$
   $$V = \frac{nRT}{P}$$
   $$V = \frac{2.46\text{mol} \times 0.0821\text{L atm mol}^{-1}\text{K}^{-1} \times 267\text{K}}{1.28 \text{ atm}}$$
   $V = 42.1$ litres

   (b) $n = 4.79 \times 10^{-2}$ mol $V = 135 \text{ mL} = 135 \times 10^{-3}\text{L}$
   $$P = 720 \text{ torr} = \frac{PV}{nR} \text{ atm} = 0.947 \text{ atm}$$
   From ideal gas equation
   $$T = \frac{PV}{nR} = \frac{0.947 \text{ atm} \times 135 \times 10^{-3}\text{L}}{4.79 \times 10^{-2}\text{ mol} \times 0.0821 \text{L atm mol}^{-1}\text{K}^{-1}}$$
   $$T = \frac{127.845 \times 10^{-1}}{0.3932}\text{K}$$
   $T = 32.51$ K

   (c) $n = 5.52 \times 10^{-2}$ mol $V = 413 \text{ mL} = 413 \times 10^{-3}$ L
   $T = 88°C = 88 + 273$ K
   $T = 361$ K
   From ideal gas law
   $$PV = nRT$$
   $$P = \frac{nRT}{V}$$
   $$P = \frac{5.52 \times 10^{-2} \text{ mol} \times 0.0821 \text{ L atm mol}^{-1}\text{K}^{-1} \times 361\text{K}}{413 \times 10^{-3}\text{L}}$$
   $$P = 3.96 \text{ atm}$$

   (d) $V = 88.4$ L $T = 27^3 + 54 = 327$ K
   $P = 9.84 \text{ Kpa} = 9.84 \times 10^3$ *pa*
   $$1 \text{ pa} = \frac{1}{101,325} \text{ atm}$$
   $$9.84 \times 10^3 \text{ pa} = \frac{9.84 \times 10^3}{101,325}\text{atm}$$
   $9.84 \times 10^3 \text{ pa} = 0.097$ atm
   From ideal gas law
   $$n = \frac{PV}{RT}$$
   $$= \frac{0.097\text{atm} \times 88.4\text{L}}{0.0821 \text{ L atm mol}^{-1}\text{K}^{-1} \times 327\text{K}}$$
   $$= \frac{8.574}{26.84} \text{mol} = 0.319 \text{ mol}$$
4. (a) From ideal gas equation
   $$pv = nRT$$
   $$n = \frac{PV}{RT}$$
   n_{CO} = number of moles of carbon monoxide
   n_{SO_2} = number of moles of sulphur dioxide
   $$n_{CO} = \frac{1 \text{ atm} \times V}{R \times 273\text{K}} \quad ...(1)$$
   $$n_{SO_2} = \frac{0.5 \text{ atm} \times V}{R \times 293\text{K}} ...(2)$$

Now, by dividing equation (1) by (2), we get,

$$\frac{n_{CO}}{n_{SO_2}} = \frac{1\text{ atm} \times V}{R \times 273K} \times \frac{R \times 293K}{0.5\text{ atm} \times V}$$

$$\frac{n_{CO}}{n_{SO_2}} = \frac{293}{0.5}$$

$$\frac{n_{CO}}{n_{SO_2}} = 586$$

Thus, number of moles of CO in vessel A is more means vessel A has more molecules.

(b) As we know density is given by

$$\text{Density }(\rho) = \frac{\text{Mass (M)}}{\text{Volume (V)}}$$

As here two vessels have the same volume therefore

Density $\propto$ Mass

The density of CO is 1.25g/L and the density of SO_2 is 1.33 g/L. Thus vessel B has more mass.

(c) Average kinetic energy of gas molecules is directly proportional to temperature. Thus the average kinetic energy of molecules in vessel B is higher.

5. (i) The constant temperature at which a solid changes into liquid state at atmospheric pressure by absorbing heat energy is called melting point.

(ii) The constant temperature at which a liquid rapidly changes into gaseous state by absorbing heat energy at atmospheric pressure is called boiling point.

(iii) The process due to which a liquid changes into gaseous state by absorbing heat energy is called vapourisation.

(iv) The process due to which liquid changes into solid state by giving heat energy is called freezing or solidification.

(v) The zig-zag movement of small solid particles suspended in a liquid or gas is called Brownian motion.

6. Difference between amorphous and crystalline solids are

	Properties	Crystalline solids	Amorphous solids
1	Crystal geometry	These have a definite crystal shape due to orderly arrangement of atoms, molecules or ions in three dimensional network	These do not have a definite geometrical shape due to haphazard order of constituent particles
2	M.P.	These show sharp m.p.	These do not have sharp m.p.
3	Physical state	These are hard and rigid solids	These are comparatively soft and not very rigid
4	Symmetry	Crystalline solids have (a) plane of symmetry (b) centre of symmetry (c) axis of symmetry	Amorphous solids do not have any symmetry
5	Crystal system	Crystalline solids have a definite crystal system e.g., cubic, tetragonal, hexagonal, etc.	These do not have any crystal system i.e. these do not have a regular repeating units
6	Anisotropic or Isotropic nature	Crystalline solids show of the physical properties different in different directions of the crystal e.g., refractive index and electrical conductivity. So these are termed as anisotropic	Their physical properties are same in all directions. Thus these are termed as isotropic
7	Examples	Crystals of NaCl, CsBr, CaF_2 and Zns	Rubber, plastic, glass, *etc.*

EXERCISE – 2

MULTIPLE CHOICE QUESTIONS

1. (c) The mass of an object is a fundamental property of the object, a numerical measure of inertia, a fundamental measure of the amount of matter in the object.
2. (b) At higher altitudes atmospheric pressure decrease. Therefore at lower temperature vapour pressure becomes equal to atmospheric pressure. Thus boiling point of a liquid decreases.
3. (b) K = 273 + t°C
   K = 237 + 78 = 351 K
4. (a) Boiling point of water is 100°C whereas evaporation of water into water vapours occurs at room temperature.
5. (d) Boiling point of water = 100°C = 100 + 273 = 373K
6. (a) As intermolecular forces are least in case of petrol. Thus, it has highest rate of evaporation.
7. (d) This is due to diffusion of particles of potassium permanganate into intermolecular spaces between particles of water.
8. (d)
9. (c)
10. (a) During vapourization energy is supplied to liquid in the form of heat. Liquid reaches its boiling point and get converted into gas (vapours).
11. (c)
12. (a) Sugar molecules occupy the intermolecular spaces present in water molecules. Thus after dissolution only liquid is left.

13. (b) $P_1 = 1$ atm, $V_1 = 200$ml
$P_2 = 5$ atm $V_2 =$
According to Boyle's law
$P_1V_1 = P_2V_2$
$$V_2 = \frac{P_1V_1}{P_2} = \frac{1 \times 200\text{ml}}{5} = 40 \text{ ml}$$
14. (c) 15. (b)
16. (b) Boyle's law
$$P \propto \frac{1}{V}$$
$$P = \frac{K}{V}$$
$$PV = K$$
17. (d)
18. (c) Effusion is the process in which individual molecules flow through a hole without collisions between molecules.
19. (a) An ideal gas is one which obeys gas laws under all conditions of temperature, pressure and volume.
20. (c) 21. (a) 22. (b) 23. (c)
24. (a) As order of energy for different states of matter is following Bose-Einstein < Solids < Liqiuds < Gases < plasmas condensate.
25. (b) Alcohol because of presence of intermediate magnitude of inter molecular forces is liquid at room temperature.
26. (b) Crystal is a solid and even on crushing it you will get smaller crystals (solid).
27. (b)
28. (d) After 1990s five states of matter are known solid, liquid, gas, plasma and Bose Einstein condensate.
29. (a)
30. (a) $\frac{d_1}{d_2} = \frac{1}{2}, \frac{T_1}{T_2} = \frac{2}{1}$ $\qquad \because \frac{P_1}{P_2} = \frac{V_2}{V_1} \times \frac{T_1}{T_2} = \frac{T_1.d_1}{T_2.d_2}$
$$\frac{P_1}{P_2} = \frac{2}{1} \times \frac{1}{2} = \frac{1}{1}$$
31. (c) According to Charle's law $V \propto T$ or $\frac{V}{T} = k$.
32. (c) $PV = nRT$ $\qquad \therefore \frac{n}{V} = \frac{P}{RT}$
33. (d) According to Graham's law of diffusion,
$$D \propto \frac{1}{\sqrt{\rho}} \text{ or } \rho = \frac{M}{V} \quad (M = \text{molar mass})$$
34. (c) $\frac{r_A}{r_B} = \sqrt{\frac{d_B}{d_A}}$, $PV = r.RT \Rightarrow PV = \frac{m}{M}RT$
$$\Rightarrow P = \frac{d}{M}RT \Rightarrow d = \frac{PM}{RT}$$
$$\Rightarrow \frac{r_A}{r_B} = \sqrt{\frac{P_BM_B}{P_AM_A}}$$
35. (b) NH_4Cl ring will first formed near the HCl bottle because rate of diffusion of NH_3 is more than that of HCl because
$M_{NH_3} : M_{HCl} = 17 : 36.5$.
So NH_3 will reach first to the HCl bottle and will react there with HCl to form NH_4Cl ring.
36. (a) 37. (a) 38. (c) 39. (d)
40. (c) 41. (c) 42. (b) 43. (a)
44. (c) 45. (a) 46. (c) 47. (b)
48. (b) 49. (a) 50. (b) 51. (d)
52. (d) 53. (d)

MORE THAN ONE CORRECT

1. (a,b,c) Camphor, solid CO_2 and ammonium chloride all are sublimate and get directly converted into gases or vice-versa.
2. (a,b,c) As rate of diffusion of a gas depends upon its molar mass and each gas have different molar mass. Mix one liquid of any colour with water entire mixture after some becomes cloured means liquid to show phenomena of diffusion. Moreover no liquid diffuse as fast as gases.
3. (b,d) During evaporation molecules having greater kinetic energy leaves liquid surface there by causing cooling. Moreover only the molecules present on surface escapes thus it is a surface phenomena.
4. (a,c,d)
5. (a,d) More will be temperature more number of molecules possess enough kinetic energy to escape liquid surface thereby increasing vapour pressure. It also increase rate of evaporation.
6. (a,d) 7. (b,d)
8. (b,d) Gases have very low intermolecular force between their molecules thus they can be compressed and undergoes rapid diffusion.
9. (a,b,c)
10. (a,b,c,d)
Different liquids have different density, viscosity, solubility and rate of evaporation.
11. (a,b,c) Amorphous solids like glass and plastic do not have a sharp melting point.
12. (a,b,c)
13. (a,b,c) Plasma is a superenergetic state of matter consisting superexited atoms.
14. (a,b,c) The mass of gas can be determined by weighing the container, filled with gas and again weighing this container after removing the gas. The difference between the two weights gives the mass of the gas.
15. (a,d) According to Boyle's law, $V \propto \frac{1}{P}$
$$PV = \text{constant}$$
According to Charle's law at constant pressure
$$\frac{V}{T} = \text{constant}$$

FILL IN THE PASSAGE

I. 1. surface tension 2. viscosity
3. cooler 4. vapour pressure
5. temperature 6. sublimation
7. vapour pressure

II. 1. Melting or fusion 2. Freezing or solidification
3. Latent heat of fusion 4. Boiling or vaporisation
5. Latent heat of vaporisation

PASSAGE BASED QUESTIONS

$V = 9.22\text{ L} \quad P = 1124\text{ torr} = \frac{1124}{760}\text{ atm} = 1.47\text{ atm}$

$T = 24°C = 24 + 273 = 297\text{ K}$

From ideal gas equation

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$= \frac{1.47\text{ atm} \times 9.22\text{ L}}{0.0821\text{ L atm mol}^{-1}\text{K}^{-1} \times 297\text{K}} = 0.56\text{ mol}$$

1. (a) No. of moles of $Cl_2 = \frac{\text{Given gram of } Cl_2 \text{ in sample}}{\text{Molecular mass of } Cl_2}$

$$0.56 = \frac{\text{Given grams of } Cl_2 \text{ in sample}}{70.906}$$

Given grams of Cl_2 in sample = 39.7 g

2. (c) At STP $P_2 = 1$ atm

$T_2 = 273$ K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1.47\text{ atm} \times 9.22\text{L}}{297\text{K}} = \frac{1\text{ atm} \times V_2}{273\text{K}}$$

$$V_2 = \frac{1.47\text{ atm} \times 9.22\text{L} \times 273\text{K}}{297\text{K}}$$

$$V_2 = 12.458\text{ L} = 12.5\text{ L}$$

3. (d) $V_2 = 15$ L $\qquad P_2 = 876$ torr

$$\frac{1124\text{ torr} \times 9.22\text{L}}{297\text{K}} = \frac{876\text{ torr} \times 15\text{L}}{T_2}$$

$$T_2 = \frac{876\text{ torr} \times 15\text{L} \times 297\text{K}}{1124\text{ torr} \times 9.22\text{L}}$$

$$T_2 = \frac{3902580}{10363.28}\text{K}$$

$$T_2 = 376.577\text{ K}$$

$$T_2 = 377\text{ K}$$

ASSERTION & REASON

1. (a) With the increase in temperature when pressure is low the distance between molecules increases and intermolecular forces becomes almost negligible. Thus under those conditions a gas behaves like ideal gas.
2. (c) The higher the altitude, the lower the atmospheric pressure. Lower pressure in turn causes water to evaporate more quickly, and water boils at a lower temperature.
3. (d) During evaporation molecules at surface possess more kinetic energy and escapes to atmosphere. Therefore, resulting liquid undergoes cooling.
4. (c) Duration evaporation of a liquid, the temperature of the liquid falls.

MULTIPLE MATCHING QUESTIONS

1. A-(q,r); B-(p, r); C - (p, q); D - (p, q, r, s)
2. A-(p,q,r); B-(q, r); C - (p, q); D - (r)

HOTS SUBJECTIVE QUESTIONS

1. This is due to diffusion. Some particles with high kinetic energy leave the coffee jar and spread out through the air in the room in a haphazard and random way. That's why we notice the smell of coffee in a room.
2. The water does not become hotter, but it will boil faster.
3. Nail polish remover contains acetone which has a high rate of evaporation. To stop the evaporation of acetone, we have to close the bottle immediately after using it.
4. Cooling by a desert cooler is caused by the evaporation of water. A desert cooler cools better on a hot and dry day because the higher temperature increases the rate of evaporation of water and dryness of air (less humidity in air) also increases the rate of evaporation. Evaporation removes all the particles of high kinetic energy and the particles left behind have low kinetic energy and this causes cooling.
5. As the molar mass of ammonia is only 17 g/mol which is less than molar mass of expensive French perfume (170g/mol)

   According to Graham's law of difussion rate of diffussion

   $$\propto \sqrt{\frac{1}{\text{Molar mass of gas}}}$$

   Molar mass of perfume is 10 times more than NH_3. Thus bad smell of cat-pan diffuses.

   10 times faster than French perfume.
6. Ethyl chloride is a highly volatile and inflammable gas. It condenses to liquid at 13°C, and is kept in sealed tubes under pressure. On striking the warm skin, it vaporizes with such a rapidity that it freezes the tissues. This makes it a local anaesthesia of a moments duration, during which a small cut, as of an abscess or infected finger may be made without pain.

7. Cooling takes place when we removes heat from the system. At 273 K, the ice will take away the latent heat from the medium and convert itself into water. Thus, in case of ice at 273 K there will be a change in physical state whereas in case of water at 273 K, there will be no change in state. Hence, in case of water, lesser energy will be taken away from the medium.

8. Mass of silver = 62.00 g – 27.35 g = 34.65 g
Volume of silver = 18.3 mL – 15 mL = 3.3 mL
Density of silver = (mass of silver) / (volume of silver) = (34.65g) / (3.3 mL) = 11 g/mL

9. We will use the ideal gas law. First we need to know the number of moles of nitrogen :
No of moles of N_2

$$= (0.245\text{g } N_2)\left(\frac{1 \text{ mol } N_2}{28.02 \text{ g } N_2}\right) = 8.74\times10^{-3} \text{mol } N_2$$

$$V = \frac{nRT}{P} = \frac{(8.74\times10^{-3}\text{mol})(0.0821 \text{ L atm/mol K})(294 \text{ K})}{(750 \text{ torr})\left(\frac{1 \text{ atm}}{760 \text{ torr}}\right)}$$

$$= 0.214 \text{ L} = 214 \text{ mL}$$

10. Since, $PV = nRT$, then $n = PV/RT$

$$n = \frac{PV}{RT} = \frac{(685 \text{ torr})\left(\frac{1 \text{ atm}}{760 \text{ torr}}\right)(0.300\text{L})}{\left(0.0821 \frac{\text{L atm}}{\text{mol K}}\right)(300.2 \text{ K})}$$

$$\text{molar mass} = \frac{1.45\text{g}}{0.0110\text{mol}} = 132 \text{ g mol}^{-1}$$

11. (a) Increase in temperature at constant volume or decrease in volume or increase in pressure (b) decrease in temperature (c) increase in volume, decrease in pressure (d) increase in temperature

12. $V_1 = 400$ ml, $V_2 = 300$ ml
$T_1 = (227°C + 273) = 500$ K $T_2 = ?$

Applying Charle's law , $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Hence, $T_2 = \frac{T_1 \times V_2}{V_1}$

Substituting the values, $T_2 = \frac{500\times300}{400}$ or $T_2 = 375$ K

T_2 in degree Celsius = 375 – 273 = 102°C
Alteration of temperature = 227°C – 102°C = 125°C
The temperature should be reduced by 125°C.

13. $P_1 = 1140$ mm, $P_2 = 760$ mm, $V_1 = 200$ ml,
$V_2 = 450$ ml
$T_1 = 27°C + 273 = 300$ K, $T_2 = ?$

Applying gas equation, $\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$

Hence, $T_2 = \frac{P_2 V_2 T_1}{P_1 V_1} = \frac{760\times450\times300}{1140\times200} = 450$ K

Temperature to be applied = 450 K – 273K = 177°K.

14. Amorphous solids in which constituent particles are arranged in haphazard manner. They resemble liquids as these flow very slowly at room temperature and thus termed as super cooled liquids.

15. It is due to capillary action. The rise of liquid in a capillary is due to the inward pull of surface tension acting on the surface which pushes the liquid into the capillary tube.

16. Equilibrium refers to a state where opposing forces are balanced in the case of a liquid in equilibrium with its vapour, it means that a molecule escaping to the vapour is replaced by one condensing to the liquid.

17. We put strips of wet cloth on the forehead of a person having high temperature. This is because when the water evaporates, it takes away the necessary heat from the body of the patient and thus lowers the body temperature.

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

19. $V_1 = 400$ ml $V_2 = 600$ ml
$T_1 = 15°C + 273 = 288$ K, $T_2 = ?$

Applying Charles' law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Hence, $T_2 = \frac{T_1 \times V_2}{V_1}$

Substituting the values

$$T_2 = \frac{288\times600}{400}$$

$$T_2 = 432 \text{ K}$$

T_2 in degree Celsius = 432 – 273 = 159°C
The new temperature = 159°C.

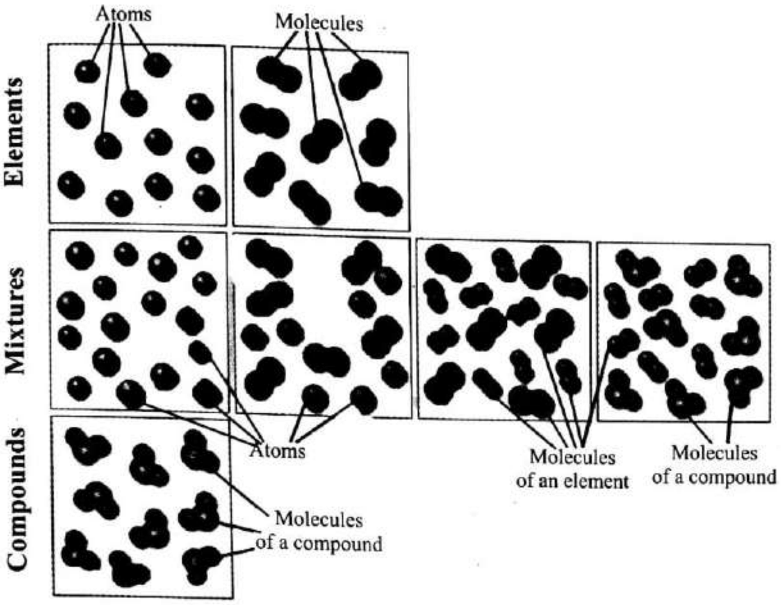
20. $P_1 = 800$ mm of Hg, $P_2 = 600$ mm of Hg
$V_1 = 500$ ml , $V_2 = ?$
$T_1 = 40°C + 273 = 313$ K, $T_2 = 353°C + 273 = 626$ K

Applying gas equation , $\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$

Hence, $V_2 = \frac{P_1 V_1 T_2}{T_1 P_2}$

$$V_2 = \frac{800\times500\times626}{313\times600} = 1333.33 \text{ ml}$$

New volume = 1333.33 ml.



2
CHAPTER

Element, Mixture and Compounds

INTRODUCTION

All matter can be broadly divided into two major groups "Pure" and "Impure". The term 'purity' has quite a different meaning in chemistry than in our day-to-day life. Normally when we refer to pure water, pure milk, etc., what is implied is that the water, milk etc., are free from harmful substances such as bacteria, fungi, viruses, etc. 'Purity' in chemistry is entirely of a different nature. When we say a substance is pure, it means that the substance is made of only one type of constituent particles.

All matter can be classified into two categories: pure substances and mixtures. A pure substance consists of a single element or compound. Iron is formed only of iron (Fe) atoms; table salt is formed only by sodium chloride (NaCl) molecules. A mixture, however, is made up of different compounds or elements. When salt is added to water to make saltwater, it becomes a mixture. The salt and water molecules do not combine to form new molecules, but only "mix" together while still retaining their identities. Air is also a mixture, containing just the right amounts of nitrogen, oxygen, and other gases for life on Earth.

Very little of our surroundings can actually be classified as "pure". Most of what we see is a mixture of the pure substances known as elements and compounds. Sometimes pure substance mix uniformly with no boundaries between components, but sometimes the pure substances form more obvious mixtures with boundaries. Even when the presence of a mixture is not obvious, however, it has properties that are different than the pure component substance. Physical properties distinguish between a mixture and a pure substance.

According to the chemical classification of matter there are two main categories:
(i) *Pure substances* **(ii)** *Mixtures*

PURE SUBSTANCE :

Lavoisier, a French chemist on the basis of quantitative studies classified pure substances into elements and compounds. He showed that when we heat mercuric oxide it changes into mercury and oxygen.

$$\text{Mercuric oxide} \longrightarrow \text{Mercury} + \text{Oxygen}$$

Mercuric oxide is a compound because it decomposes into simpler substances, whereas mercury and oxygen cannot be further decomposed into anything simpler as they are elements.

A pure substance has a constant composition. Water, for example, is always 88.81% oxygen by weight. Pure substances also have constant chemical and physical properties. Water freezes at exactly 0°C and boils at exactly 100°C at atmospheric pressure. The composition and properties of a pure substance are the same regardless of where it is found. When pure, the salt found in a salt shaker on the dining room table has the same composition as the salt dug from mines deep beneath the earth or the salt obtained by evaporating seawater. No matter where salt comes from, it always contains 1.54 times as much chlorine by weight as sodium. Since it always has the same composition, salt has the same chemical and physical properties.

✔ CHECK POINT **Two samples of ammonia are collected one from manufacturing plant and other from urine deposits of animals. Both samples have same composition of nitrogen and hydrogen? if yes then give reason.**

Check Your Answer

Yes, both samples will have same amount of nitrogen and hydrogen as both samples are pure substance, not mixture.

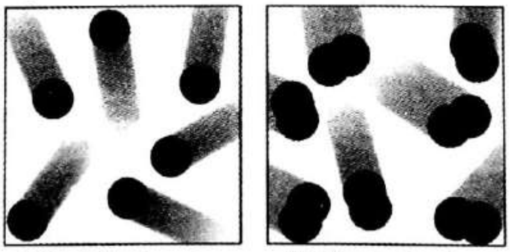
Do You Know!!

A solution of salt in water or sugar solution being homogeneous appears to consist of one type of particles. But it is made up of more than one kind of particles. Hence, it is not a pure substance. ***It is a mixture. A material is said to be homogeneous if it has uniform composition and identical properties throughout.***

ELEMENT :

An element is defined as a pure substance that contains only one kind of particles. These particles may be atoms or molecules. Elements are made up of particles/atoms of only one kind. However, in nuclear reactions, elements having high atomic mass can be split into lighter elements.

Carbon, sulphur, iron, lead, gold, mercury, hydrogen, oxygen and nitrogen are some examples of familiar elements. Iron, gold, copper etc. contain single atoms as constituent particles held together, whereas in some other cases, the constituent particles are molecules which contain two or more atoms combined together. For example, hydrogen, oxygen, nitrogen etc. consist of molecules, comprising of two atoms combined together.



(a) Atoms of an element (b) Molecules of an element

Figure : Elements might consist of individual atoms, as in (a), or molecules, as in (b).

Do You Know!!

Most of the elements are solids, while eleven of them are gases and only two are liquids. Of the two liquids, mercury, is a metal and bromine is a non-metal. However, two other metals can also exist in the liquid state at around 30°C. These two metals are gallium and caesium (gallium melting point = 29.9°C and caesium melting point = 28.6°C).

Classification of Elements :

On the basis of variation in their properties elements can be broadly classified as **metals, non-metals** and **metalloids.**

Element

- **Metals** (e.g., sodium, potassium, gold, silver)
- **Non-metals** (e.g., hydrogen, oxygen, carbon, nitrogen)
- **Metalloids** (e.g., germanium arsenic, antimony)

METALS :

Metals are one of the most important elements that we use in our every day lives, but what we need to understand why it is important. Physical properties of metals which are as follows.

Physical State- Metals are solids at room temperature with the exception of mercury and gallium, which are liquids at room temperature.

Lustre- Metals have the quality of reflecting light from its surface and can be polished e.g., gold, silver and copper.

Malleability- Metals have the ability to withstand hammering and can be made into thin sheets known as foils.

Ductility- Metals can be drawn into wires. 100 gm of silver can be drawn into a thin wire about 200 meters long.

Hardness- All metals are hard except sodium and potassium, which are soft and can be cut with a knife.

Valency- Metals have 1 to 3 electrons in the outermost shell of their atoms.

Conduction- Metals are good conductors because they have free electrons. Silver and copper are the two best conductors of heat and electricity. Lead is the poorest conductor of heat. Bismuth, mercury and iron are also poor conductors.

Density- Metals have high density and are very heavy.

Iridium and osmium have the highest densities whereas lithium has the lowest density.

Melting and Boiling Point-Metals have high melting and boiling point.

Tungsten has the highest melting point whereas sodium and potassium have low melting points.

Electropositive Character-Metals are elements that have a tendency to lose electrons and form cations. They normally do not accept electrons.

$$Na \longrightarrow Na^{+} + e^{-}$$
$$Mg \longrightarrow Mg^{2+} + 2e^{-}$$
$$Al \longrightarrow Al^{3+} + 3e^{-}$$

✓CHECK POINT | **Choose one word or phrase from each pair that describes what most metals are like.**

(a) soft/hard (b) weak/strong (c) shiny/dull (d) tough/brittle (e) heavy or dense/light

(f) conduct heat/do not conduct heat (g) conduct electricity/do not conduct electricity (h) liquid/solid

Check Your Answer

(a) hard (b) strong (c) shiny (d) tough (e) dense (f) conduct heat (g) conduct electricity (h) solid

Foundation Chemistry for Class IX Part A for IIT JEE Foundation by K K Anand Chennai SmartEdu

KNOWLEDG NHANCER

"Base metals and Noble metals"

In chemistry the term base metal is used informally to refer to a metal that oxidizes or corrodes relatively easily, and reacts variably with dilute hydrochloric acid (HCl) to form hydrogen. Examples include iron, nickel, and zinc. Copper is considered a base metal as it oxidizes relatively easily, although it does not react with HCl. It is commonly used in opposition to noble metal.

"Noble metals are metals that are resistant to corrosion or oxidation, unlike most base metals. They tend to be precious metals, often due to perceived rarity. Examples include tantalum, gold, platinum, silver and rhodium."

NON-METALS :

Nonmetals are generally poor conductors of heat and electricity. Solid non-metals are generally brittle, with little or no metallic luster. Most non-metals have the ability to gain electrons easily. Non-metals display a wide range of chemical properties and reactivities.

Physical Properties of Non-metals

Physical state-Most of the non-metals exist in two of the three states of matter at room temperature: gases (oxygen) and solids (carbon). These have no metallic lustre, and do not reflect light.

Nature- Non-metals are very brittle, and cannot be rolled into wires or pounded into sheets.

Conduction- They are poor conductors of heat and electricity.

Reactivity-They generally form acidic or neutral oxides with oxygen.

Comparison Between Metals and Non-Metals :

Property	Metals	Non-metals
State of matter	These are usually solid, except mercury, which is a liquid at room temperature. Note: Gallium and Caesium melt below 30°C. So, if room temperature is around 30°C, they may also be in liquid state.	These exist in all the three states. Bromine is the only liquid.
Density	They usually have high density, except sodium, potassium, calcium, etc.	Their densities are usually low.
Melting point	They usually have a high melting point except mercury, cesium, gallium, tin, lead.	Their melting points are low.
Boiling point	Their boiling points are usually high.	Their boiling points are low.
Hardness	They are usually hard, except mercury, sodium, calcium, potassium, lead, etc.	They are usually not hard except diamond, which is the hardest substance known.
Malleability	They can be beaten into thin sheets.	They are generally brittle.
Ductility	They can be drawn into thin wires, except sodium, potassium, calcium, etc.	They cannot be drawn into thin wires.
Conduction of heat	They are good conductors of heat.	They are poor conductors of heat.
Conduction of electricity	They are good conductors of electricity.	They are non-conductors, except for carbon in the form of graphite and the gas carbon.
Lustre	Newly cut metals have high lustre. Some get tarnished immediately.	Usually not lustrous, except iodine and diamond which is the most lustrous of all the substances.
Alloy formation	They form alloys. However carbon, phosphorus, sulphur, etc., can be present in some alloys.	Generally, they do not form alloys.
Tenacity	These usually have high tensile strength except sodium, potassium, calcium, lead, etc.	These have low tensile strength.
Brittleness	They are hard but not brittle, except zinc at room temperature.	They are generally brittle.

IDEA BOX

Make arrangements as shown in figure below

Now here A is made up of aluminium. Record your observation that whether the bulb will light up or not?. Now place bar made up of iron, copper and silver one by one at place of A. On the basis of your observations predict order of electrical conductivity of iron, copper, silver and aluminium. Can you suggest few non-metals if they are placed at position of A bulb will light up.

METALLOIDS :

The properties of the metalloids are between those of the metals and non-metals, so the metalloids exhibit characteristics of both classes. Silicon, for example, possesses a metallic luster, yet it is an inefficient conductor and is brittle. The boiling points, melting points, and densities of the metalloids vary widely. The intermediate conductivity of metalloids means they tend to make good semi-conductors.

Metalloids are those chemical elements that exhibit properties of both metals and nonmetals. They behave as non-metals physically and chemically and show electrical conductivity like metals. However, they are not good conductors of eleсtricity like metals and are known as semiconductors. Let us go into the details of metalloids properties in the following paragraphs.

All chemical elements are placed together according to their physical and chemical properties in the periodic table. Elements are divided as metals and non-metals and few elements that are neither metals or non-metals. Metalloids characteristics include ability to form amphoteric oxides and ability to behave as semiconductors and semi-metals. The metalloids are placed between metals and non-metals in the periodic table. You can read more on metalloids characteristics.

There are seven metalloids in the periodic table that are placed in Group 13, 14, 15, 16 and 17. They form a zig zag step line in the periodic table. They are separated from the metals and non-metals by a line called the 'amphoteric line'. Metalloids in the periodic table include Boron (B), Silicon (Si), Germanium (Ge), Arsenic (Ar), Antimony (Sb), Tellurium (Te), Polonium (Po).

Illustration 1

An element M has the electronic configuration 2, 3. On the basis of electronic configuration, answer the following:

(i) Does this element form acidic, basic or amphoteric oxide?

(ii) Is this element a good conductor of electricity?

SOLUTION:

(i) Given element is Boron which being metalloid forms amphoteric oxide

(ii) Yes, it does conduct electricity but not as good as in case of metals

Foundation Chemistry for Class IX Part A for IIT JEE Foundation by K K Anand Chennai SmartEdu

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What are Metalloids Properties?

Metalloid is a term that is derived from the Greek word *metallon* that means 'metal' and *edios* that means 'sort of'. Many metalloids have multiple of oxidation states or valences. They react like non-metals ith metals and when act like metals when reacting with non-metals.

Metalloids Physical Properties

Metalloids can be shiny like metals or dull like non-metals. They are ductile in nature and can be drawn in shapes of pipes. They are conductors of heat and electricity, but not as good as metals. Metalloids like boron, germanium, arsenic are used as dopants in glasses in semiconductor chips. Metalloids are usually brittle in nature and behave as electrical insulators at room temperature.

Metalloids Chemical Properties

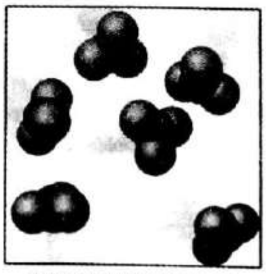
Metalloids tend to have an intermediate property between metals and non-metals. They may look like metals, in case of arsenic and antimony that are crystalline solids. However, in chemical reactions, they may behave either as metals or non-metals. The metalloids usually form amphoteric oxides as metals form majorly basic oxides and non-metals generally form acidic oxides. Some metalloids like boron, silicon and germanium behave as semiconductors. Their chemical reactivity depends on the substance they react with. Like boron acts as a metal when reacting with fluorine and behave as non-metals when reacting with sodium. Many metalloids have different allotropes. For a given metalloid, one of its allotrope may react as a metal and the other allotrope may behave as a non-metal.

Some allotropes have more prominent metal, non-metal or metalloid behaviour. Carbon in its diamond allotrope acts like a true non-metal. But graphite allotrope has limited ability to conduct electricity. Allotropes of tin, phosphorous and bismuth exhibit borderline behavior. However, in a standard periodic table layout, you will observe that some metalloids that are placed on the upper right side of the diagonal line through the p-block display increasing non-metallic behaviour. Those elements that are placed to the lower left of the line are more metallic in character. This diagonal line is called the 'stair-step' or 'staircase'. In short, non-metals are placed to the right end up and poor metals are placed to the left side below.

COMPOUND :

It is a pure substance that can be decomposed into simpler substances by some suitable chemical technique. A compound is formed by combination of two or more elements in a definite proportion.

Example, water is a compound of hydrogen and oxygen elements present in the ratio of 1: 8.



Molecules of a compound

Properties of Compounds

1. A compound cannot be separated into its constituents by mechanical or physical means.
   Example, if we bring a magnet near a sample of iron sulphide, the iron present in the iron sulphide cannot be separated.
2. Properties of a compound differ entirely from those of its constituent elements.
   Example, water is made up of hydrogen and oxygen. However, the properties of hydrogen and oxygen (both gases) are different from water (liquid). Hydrogen is combustible, oxygen is a supporter of combustion whereas water (made up of both hydrogen and oxygen) puts out a flame.

The sodium chloride NaCl is very different from the elemental sodium and the elemental chlorine used in its formation. Elemental sodium, (Na) consists of nothing but sodium atoms, which form a soft, silvery metal that can cut easily with a knife. Its melting point is 97.5°C and it reacts violently with water. Elemental chlorine, Cl_2 consists of chlorine molecules. This material, a yellow green gas at room temperature is very toxic, and it was used as a chemical warfare agent during World War I. Its boiling point is – 34°C. The compound NaCl is a translucent, brittle, colorless crystal having a melting point of 800°C. It does not react with water as sodium does and not toxic to humans which chlorine is, but it is an essential component of all living organism.

✔ CHECK POINT **Are the physical and chemical properties of a compound necessarily similar to those of the elements from which it was composed?**

Check Your Answer

No, it is not necessary that physical and chemical properties of compounds are similar to those of the elements of which they composed.

3. Energy changes are involved in the formation of a compound. For example, iron and sulphur reacts only when heat is supplied.

Do You Know!!

1. *A candle burns to form carbon dioxide and water vapour and liberates heat and light energy. [Exothermic reaction]*
2. *During the process of photosynthesis, carbon dioxide and water combine to form glucose by absorbing light energy. [Endothermic]*

4. The constituent elements in a compound are in a fixed proportion by weight. In water, hydrogen and oxygen are present in a fixed ratio of 1:8 by weight.
5. A compound is a homogenous substance. That is it is same throughout in properties and composition. A compound has a fixed melting point and boiling point. For example, ice melts at 0°C.

Do You Know!!

Non-stoichiometric compounds : *Molecules (constituting units of compounds) have definite atomic composition and are referred as stoichiometric compounds. e.g.,* CH_4, H_2O, NH_3 *etc.*

Certain materials in which atomic composition is variable are called non-stoichiometric compounds. e.g., the composition of cuprous sulphide may vary from $Cu_{1.7}S$ *to* Cu_2S.

Non-stoichiometry is common feature of sulphides and oxides of transition metals.

IDEA BOX

Make a project report by considering acid rain. Mention the name of elements involved and harmful compounds formed by them. Also explain in detail about the harm of the compounds formed and how their properties are different from constituent elements. You can consult science magazines, science journals, internet and can discuss with your teacher.

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Types of Compounds. All the compounds may be divided into the following two categories:

(1) Organic compounds

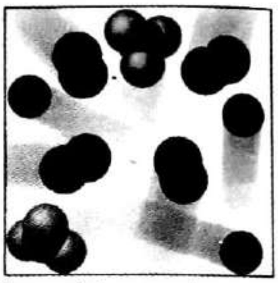
(2) Inorganic compounds

Organic compounds are the compounds containing carbon and a few other elements like hydrogen, oxygen, nitrogen, sulphur, halogens etc. These were originally obtained only from animals and plants.

Inorganic compounds are the compounds containing any two or more elements out of more than 114 elements known so far. These are usually obtained from minerals and rocks.

MIXTURE :

Mixtures are absolutely everywhere you look. Mixtures are the form for most things in nature. Rocks, air, or the ocean, they are just about anything you find. They are substances held together by physical forces, not chemical. That statement means the individual molecules stay near each other, but their fundamental chemical structure does not change as they do not undergoes chemical combination. When you see distilled water, it's a pure substance. That fact means that there are just water molecules in the liquid. A mixture would be water with other things dissolved inside, may be salt. Each of the substances dissolved in water keeps the original chemical properties. So, if you have some dissolved salt, you can boil off the water and still have those dissolved substances left over. Because it takes very high temperatures to boil salt, the salt is left in the container.



Mixture of elements and compound

There are an infinite number of mixtures. Anything you can combine is a mixture. Think of everything you eat. Just think about how many cakes there are. Each of those cakes is made up of a different mixture of ingredients. Even the wood in your pencil is considered a chemical mixture.

The substances that make up a mixture can be separated by physical means because they have different physical properties (such as different melting points) and are not chemically bonded. A mixture can be separated into its parts in a variety of ways, including decantation (letting the sand in a mixture of water and sand settle, and then draining off the water), filtering, and evaporation. You can use a kitchen funnel and coffee filter for filtration, and either use sunlight or low heat for evaporation.

Try out these methods on a salt water and a sand and water mixture to see how they work and compare the results. Evaporation will work for both salt water and sand and water solutions, but filtration will not work for salt water.

Illustration 2

Iron fillings and sulphur are mixed in a watch glass and then heated. Is there any change occurs after heating?

SOLUTION:

Yes, initially before heating we have mixture of iron fillings and sulphur. Mixture retains properties of its components from which iron fillings can be separated by using barmagnet after heating iron and sulphur combines to form iron (II) sulphide.

$$\underset{\text{Iron}}{Fe} + \underset{\text{Sulphur}}{S} \longrightarrow \underset{\text{Iron(II) Sulphide}}{FeS}$$

As iron (II) sulphide is a compound from it iron fillings can not be seperated out.

Differences between Mixtures and Compounds

Mixture	Compounds
A mixture can be separated into its constituents by physical processes (filtration, evaporation, sublimation, distillation)	A compound cannot be separated into its constituents by physical processes. It can be separated by chemical means
A mixture shows the properties of its constituents	A compound has a new set of properties different from its constituents
Composition of a mixture varies and the constituents are present in any proportion by weight. It does not have definite formula	The composition of a compound is fixed and the constituents are present in fixed proportions by weight. It has a definite formula
The constituents do not react chemically, thus no energy changes take place. A mixture does not have a fixed melting point or boiling point Examples: air, sand and salt	Chemical reactions take place and energy changes in the form of heat and light are involved. A compound has a fixed melting point and boiling point Examples: H_2O (water), FeS (iron sulphide)

Types of Mixtures : Depending upon the nature of the components that forms the mixture we can have different types of mixtures.

(i) **Homogeneous mixture :** It is a mixture that has the same composition throughout. e.g., a solution of sugar in water. Such a mixture has two or more components. The composition of such a mixture is variable (e.g., different quantities of sugar are added to the same quantity of water).
Some other examples of homogeneous mixture are common salt in water, copper sulphate solution, etc.

(ii) **Heterogeneous mixture :** In such a mixture the particles of each component of the mixture remain separate and can be observed as individual grains under a microscope. e.g., mixture of grains and sand. This type of mixtures contain physically distinct parts and have a non-uniform composition. Some other examples of heterogeneous mixture are a mixture of sodium chloride and iron fillings, a mixture of salt and sulphur, a mixture of oil and water.

✓ CHECK POINT **Sample A is a mixture of Iron and Sulphur and sample B is a black mass obtained by heating the mixture of sample A. When is observed for homogenity?**

Check Your Answer

A is heterogeneous B is homogeneous

Classification of Homogeneous Mixtures : Homogeneous mixtures can be further classified as follows:

(i) **Solid-solid mixture:** Examples of such a mixture are brass, bronze, etc.
A homogeneous mixture of two or more metals (or non-metals) is called an **alloy.** Brass and Bronze are alloys. Alloys find a wide range of applications in construction and various other types of industries.

(ii) **Solid-liquid mixture:** Examples of such a mixture are
(a) aqueous solution of salt or sugar
(b) solution of iodine (I_2) in carbon tetra chloride (CCl_4).

(iii) **Liquid-liquid mixture:** Examples of this type of mixture are
(a) rectified spirit (a mixture of gasoline and alcohol)
(b) a mixture of toluene and benzene.

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Many of the metallic products that we use in our daily lives are actually alloys. An alloy is a homogeneous mixture of metallic elements with one solid phase. Although an alloy is considered as a solid solution, it is made by mixing the metals in the molten state and then allowing the liquid solution to cool and resolidify.

The main idea with alloys is that they are better at something than any of the metals would be alone. Metallurgists sometimes add chromium (Cr) and nickel (Ni) to steel. While steel is already an alloy of iron and small amount of carbon that is also very strong one, the addition of small amounts of the other metals help steel resist rusting. Depending on what element is added, you could create Stainless Steel or Galvanized Steel. It's always about improving specific qualities of the original metal.

Amalgams are a special type of alloy, amalgams are alloys that combine mercury and other metals. The most obvious place you may have seen amalgams is in old dental work. The fillings in the mouths of your grand parents may have been amalgams. Mercury is a liquid at room temperature. That physical trait was used when they made fillings. Let's say you have an amalgam of mercury (Hg) and silver (Ag). When it is created, it is very soft. As time passes, the mercury leaves the amalgam and the silver remains. The silver that is left is very hard.
Never, ever, play with mercury (Hg) it is very poisonous. You shouldn't even touch it because it will seep into your skin. Dentists don't usually use amalgams with mercury anymore because it may have slowly poisoned people and gotten them sick.
Pure gold (24 K) is a comparatively soft element and is easily deformed. It is made stronger by mixing with other elements. For example, 18 K gold is 75% (by mass) gold with the rest silver or copper. Stainless steel is a mixture of three elements: 80% iron, 12% chromium, and 8% nickel. The percent composition of these alloys can be used to convert between the mass of the alloy and the mass of the component.

Classification of Heterogenous Mixture :

(i) **Solid-gas mixture:** For example, Hydrogen gas adsorbed on palladium.

(ii) **Solid-solid mixture:** For example

(a) gun powder

(b) mixture of sulphur and iron filling

(iii) **Solid-liquid mixture:** *Example* **:** Suspension of sulphur in water.

(iv) **Liquid-liquid mixture:** *Example* **:** Benzene in water (i.e. immiscible liquids).

✓ CHECK POINT | Classify the following substances into elements, compounds and mixtures:

(i) Milk (ii) 22-carat gold (iii) Iodized table salt (iv) Diamond (v) Smoke (vi) Steel (vii) Brass (viii) Dry ice (ix) Mercury (*x*) Air (*xi*) Aerated drinks (xii) Glucose (xiii) Petrol/Diesel/Kerosene oil (xiv) Steam (xv) Cloud.

Check Your Answer

Elements — (iv), (ix)

Compounds — (viii), (xii), (xiv), (xv)

Mixtures — (i), (ii), (iii), (v), (vi), (vii), (x), (xi), (xiii).

POINTS OF DIFFERENCE BETWEEN HOMOGENEOUS AND HETEROGENEOUS MIXTURES :

These are listed in table below :

Homogeneous mixtures	Heterogeneous mixtures
(i) Such mixture have same composition throughout	(i) Such a mixture has different composition in different parts.
(ii) The components of such a mixture cannot bc seen even under a microscope.	*(ii) The components of such a mixture can be seen even with naked eyes.*

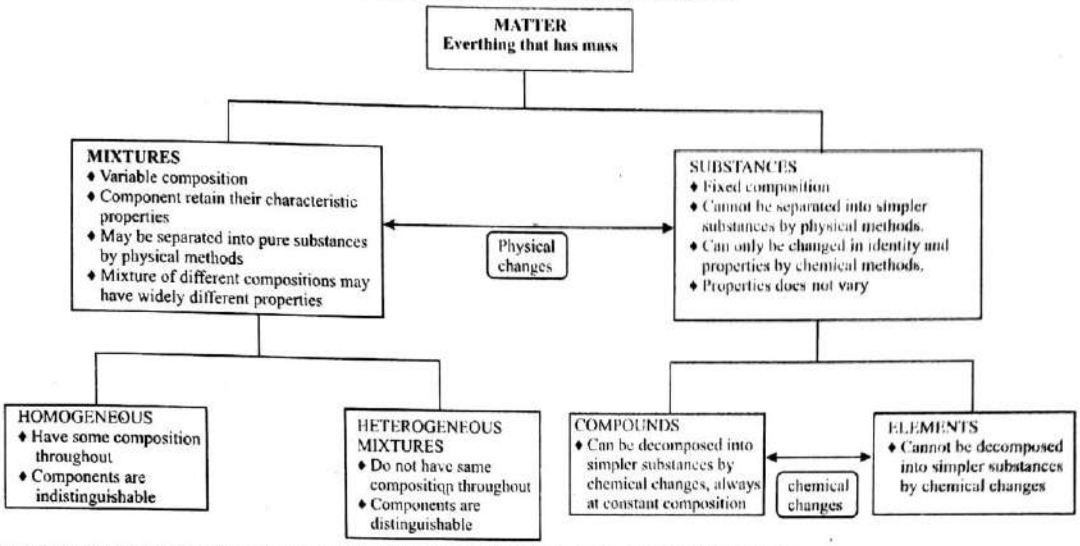
IDEA BOX

Carefully study the mixture of sulphur powder and iron fillings on the basis of (i) appearence (ii) behaviour towards magnet (iii) behaviour towards CS_2 and (iv) effect of heat. On the basis of your observation fill the following table with ✓ or × marks.

appearance		behaviour towards magnet		behaviour towards CS_2		effect of heat	
Homogeneous	Heterogenous	attracted	no attraction	one part dissolved	nothing dissolved	Mixture glow	no effect
______	______	______	______	______	______	______	______

Precautionary measure : Perform this experiment in your school chemistry laboratory in presence of your teacher or lab technician.

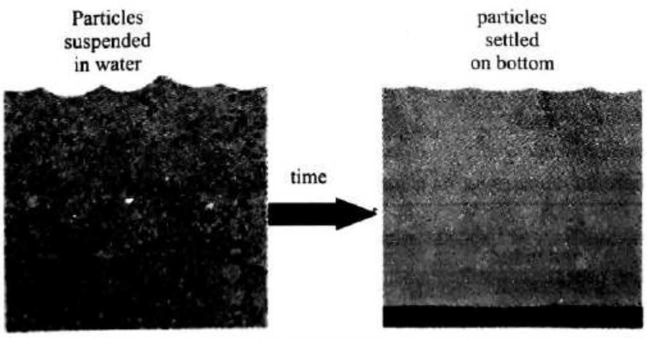
One scheme for classification of matter



METHODS OF SEPARATION OF THE CONSTITUENTS OF MIXTURES

We have already learnt that most of the natural substances are not chemically pure. Different methods of separation are used to get individual components from the mixtures. Heterogeneous mixture can be separated into their respective components by simple physical methods like hand picking, sieving, filtration that we use in our daily life. Sometimes special techniques are used for separation of components of a mixture. Some of these techniques are discussed in details. The constituents of any mixture can be separated by taking advantage of the difference in their physical properties. We have studied that every component retains its own characteristic properties even in the mixtures. Thus, based upon the particular property (e.g., melting point, boiling point, solubility, etc,) in which the constituents of the mixture differ, it can be separated into its constituents. Various techniques employed for the separation of mixtures are discussed below:

1. **Decantation or Sedimentation:** This separation technique is applicable for a mixture containing one liquid and the other solid component. The solid component should be heavier and insoluble in liquid. Sedimentation is the process by which insoluble heavy particles in a liquid, are allowed to settle down. This is a simple process that most people employ at home. For e.g., suppose you are making some tea. You have boiled the water, and added the tea leaves into the water. Then you realise that you cannot find the strainer. You may look for a clean piece of cloth but do not succeed. What would you do? Keep the tea with the leaves, aside for some time. The tea leaves will settle down. This settling down of the particles in lower part of the container is called sedimentation. Another example of sedimentation is the settling of mud particles in water (Fig.).



Sedimentation

Decantation is the process by which, a clear liquid obtained after sedimentation, is transferred into another container, without disturbing the settled particles. After the tea leaves have settled down, the clear tea (liquor) from the top, can be poured into a cup. This transfer of the clear tea, is called decantation (Fig.).

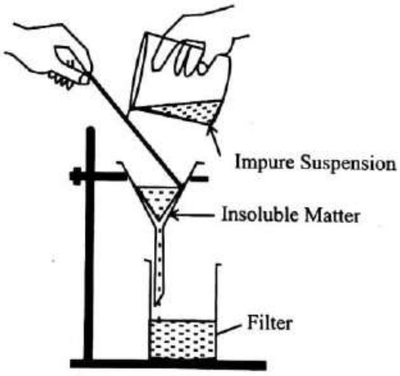
Decantation

2. **Filteration:** This technique is used when a mixture contains two components, of which only one is soluble in a particular solvent. For separation the mixture is shaken with the solvent and then filtered as shown in figure. The soluble component passes through the filter paper as **filtrate** and the insoluble solid component is retained on the filter paper called **residue.** The soluble component is recovered from filtrate either by evaporating off or distilling off the solvent. For example, the separation of mixture containing.

   (i) Salt (water soluble) and sand (water insoluble) using water as solvent.

   (ii) Sulphur (Soluble in CS_2) and glass powder (insoluble in CS_2) using CS_2 as solvent.

   (iii) Sugar (Soluble in water) and wood dust (insoluble in water) using water as solvent.



Separation by filtration

Filtration : *The process of separating a mixture containing an insoluble solid component in the liquid component, by passing it through a porous medium is called filtration.*

Example :

1. *Sawdust + water*	:	*Sawdust forms the residue*
2. *Chalk + water*	:	*Chalk forms the residue*
3. *Charcoal + water*	:	*Charcoal forms the residue*

Illustration 3

When do we use fluted filter paper or hot water funnel for filtration?

SOLUTION:

To avoid crystallization during filtration, fluted filter paper is used when the volume of the solution to be filtered is small and hot water funnel when the volume is large.

3. **Evaporation:** This technique is applied to separate a non-volatile soluble salt from its mixture in volatile liquid. On heating, the volatile liquid evaporates leaving behind the soluble salt. Many of you might be aware, that for preparing salt, seawater is taken in large pans and water is allowed to evaporate, by the heat of the sun. In the laboratory, salt can be obtained in a similar way, from an aqueous salt solution as under:

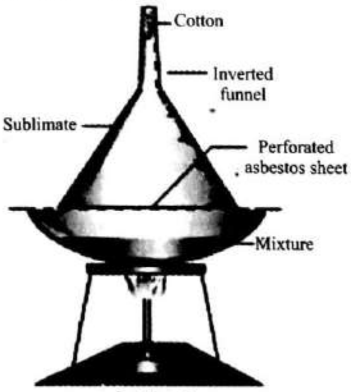
Take the solution of salt and water in evaporating dish. Heat the dish carefully till the entire water in the dish gets evaporated. The white crust that remains as residue after evaporation, is salt (Fig.).

Evaporation

Similarly, sulphur can be separated from a solution of sulphur and carbon disulphide. Keep the solution in a flat dish at room temperature, for some time. The carbon disulphide, being volatile, completely evaporates, leaving behind yellow crystals of sulphur.

4. **Sublimation:** This process is used to separate a mixture containing two components, one of which can form a sublimate i.e., direct change of solid to vapour state on heating, while the other do not.

The apparatus, shown in figure, involve a China dish containing mixture covered with perforated filter paper. An inverted funnel whose stem is plugged with cotton is placed on the China dish. The content of the dish is heated gently over sand bath causing the volatile substance to vapourise. These vapours are converted back to solid on cooling on the inner wall of the inverted funnel. The non-volatile substance is left behind in the dish.



Sublimation

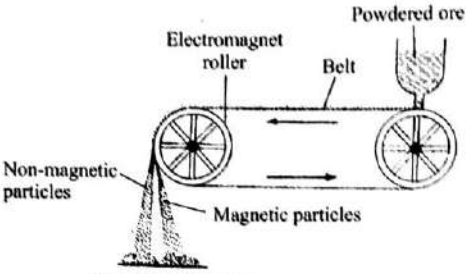
The sublimates of some mixtures that can be separated by sublimation are given in the table below.

Some mixtures that can be separated by sublimation

Mixture	Sublimate
Iodine and sand	Iodine
Ammonium chloride and sodium chloride	Ammonium chloride
Naphthalene and sand	Naphthalene
Camphor and glass powder	Camphor

5. **Gravity separation:** This technique is used for the separation of a mixture having components differing in densities. The powdered mixture is treated with a stream of running water when the lighter components are washed away leaving the heavier ones e.g., separation of gold particles from rocky substances.

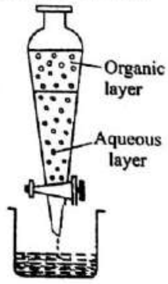
6. **Magnetic separation:** This method is applied to separate a mixture containing one magnetic component and the other non- magnetic components. The powdered mixture is allowed to fall on a belt of magnetic separator as shown in figure. When the mixture passes over the rollers, non-magnetic substance falls vertically down whereas the magnetic substance falls a little away. e.g.,
   (i) Separation of iron from sand
   (ii) Iron fillings from sulphur.



Magnetic Separation.

This method is used when one of the components of the mixture is magnetic in nature.

7. **Separating funnel:** This method is applicable to recover one of the components from aqueous solution of the mixture by extracting the mixture with a suitable solvent. The solvent should be immiscible with water but should dissolve one of the components of the mixture.
   The aqueous solution of the mixture is taken in a separating funnel as shown in figure. It is mixed with a small quantity of organic solvent and its contents are shaken well and then the funnel is allowed to stand for sometime. On standing, organic liquid forms a separate layer from aqueous layer. The two layers are collected separately by opening the stop cork. The extraction is further repeated with more quantity of organic solvent. Greater the number of extractions, more will be the amount of substance extracted. For example
   (i) Extraction of nicotine from aqueous solution of tea leaves using ether.
   (ii) Extraction of benzoic acid from aqueous solution using benzene.



The separating funnel is used when two immiscible liquids, having different densities, are to be seperated.

✓ CHECK POINT | Suggest a method to purify:
(i) Camphor containing traces of common salt.
(ii) Kerosene oil containing water.

Check Your Answer

(i) *Sublimation. Camphor sublimes while common salt remains as residue in the china dish.*

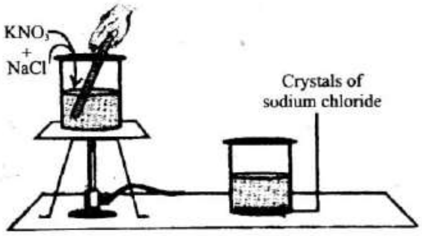
(ii) Solvent extraction using a separating funnel. The lower water layer is run off when kerosene oil is obtained. It is dried over anhydrous $CaCl_2$ and then distilled to give pure kerosene oil.

8. Crystallisation or Recrystallisation: Crystals are the purest form of a substance having definite geometrical shapes. The process by which an impure compound is converted into its crystals is known as crystallisation.

This is one of the most commonly used techniques for purification of solid organic compounds. It is based on the difference in the solubilities of the compund and the impurities in a suitable solvent. The impure compound is dissolved in a suitable solvent in which it is sparingly soluble at room temperature but appreciably soluble at higher temperature. The solution is concentrated to get nearly a saturated solution. When saturated solution is cooled, crystals of pure substance will separate out which are removed by filtration. The filtrate, i.e., mother liquor contains the impurities along with small quantity of the compound.

9. Fractional crystallisation: This method of separation is used when two solid components of the mixture have different solubilities in the same solvent. The procedure involves the dissolution of mixture in small quantity of hot suitable solvent. When the concentrated solution is allowed to cool, the less soluble component separates out leaving the more soluble component in the mother liquor. For example, separation of *o*-nitro acetanilide and *p*-nitro acetanilide by crystallization with ethanol.

1. In a solution containing potassium nitrate and sodium chloride, sodium chloride is less soluble and crystallizes out first.
2. In a solution containing potassium chloride and sodium nitrate, potassium chloride is less soluble and crystallizes out first.



✓ CHECK POINT | **A mixture contains two components A and B. The solubilities of A and B in water near their boiling point are 10 grams per 100 ml and 2g per 100 ml respectively. How will you separate A and B from this mixture?**

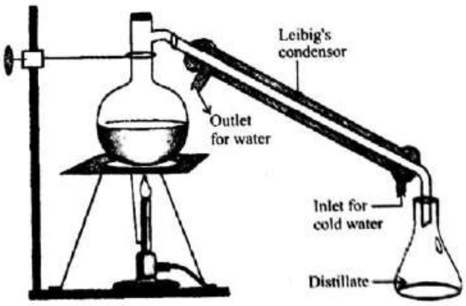
Check Your Answer

Fractional crystallization. When the saturated hot solution of this mixture is allowed to cool, the less soluble component B crystallizes out first leaving the more soluble component A in the mother liquor.

10. Distillation: This technique is commonly applied for the separation of a mixture of liquid components having a large difference in boiling point. The lower boiling point component vapourises first and its vapours are condensed by using water condenser and collected as shown in figure 1.5. The higher boiling residue is left behind in the distillation flask. e.g.,

(i) Separation of benzene (B.P. 353 K) and toluene (B.P. 384 K)

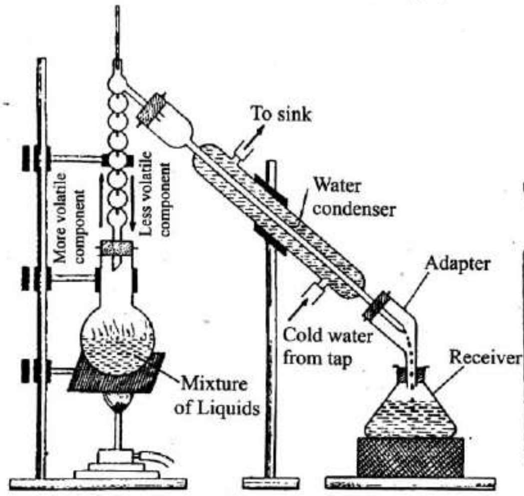
(ii) Separation of chloro benzene and bromobenzene.



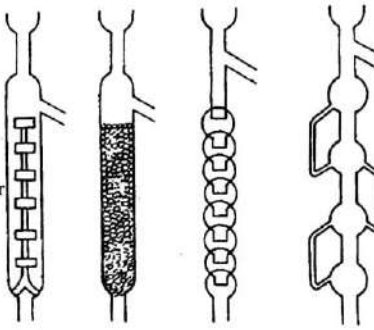
Do You Know!!

- *This process allows separation and recovery of both components of a solid-liquid mixture by the use of a distillation apparatus.*
- *Iodine is the soluble solid which is recovered as residue, while alcohol is the liquid component that is recovered as the distillate from mixture of iodine and alcohol.*

11. Fractional distillation : This method of distillation is applied for the separation of the mixture in which the components have a small difference in boiling points. In this method, the distillation flask is fitted with a large fractionating column having a large number of bulbs to increase the surface area as shown in figures (a) and (b). Cold water is circulated in the outer jacket of the condenser. On heating the flask, liquid vapourises and the vapours rise up the column. The vapours of less volatile component condense back in the flask while the vapours of only more volatile component escape from the top of fractionating column, condensed and collected in a receiver. For example,



(a). Fractional distillation.



(b). Shapes of fractionating columns.

(i) Separation of fractions like gasoline, kerosene, diesel, lubricating oil, etc, from crude petroleum.
(ii) Separation of a mixture of methanol (B.P. 338 K) and acetone (B.P. 329 K).

Do You Know!!

Fractional distillation method is used when b.p's of the two liquids of the mixture are very close to one another i.e. differ by 10 K.

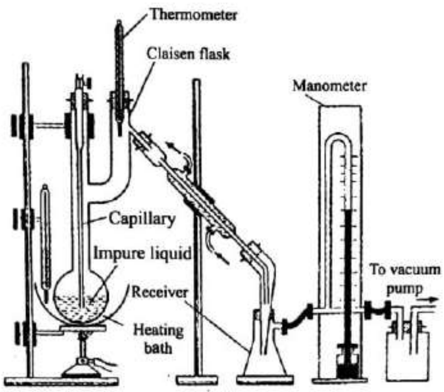
✓ CHECK POINT **Suggest methods for the separation of the following mixtures.**

(i) Mixture of liquid A (b.p. 365 K) and liquid B (b.p. 354 K).
(ii) Mixture of liquid C (b.p. 353 K) and liquid D (b.p. 413 K).

Check Your Answer

(i) Fractional distillation because the boiling points of the two liquids differ by just 11K.
(ii) Simple distillation since the boiling points of the two liquids are widely apart.

12. Vacuum distillation or distillation under reduced pressure: This technique of distillation is applied to liquids which decompose on heating to their boiling point. We know that the boiling point of a liquid varies with atmospheric pressure *i.e.*, at reduced pressure the boiling point of liquid is also reduced and thus liquid distils at low temperature. The apparatus involves a vacuum pump connected with receiver as shown in figure to carryout distillation under reduced pressure. For example, glycerol is distilled at reduced pressure as it decomposes on heating to its boiling point.

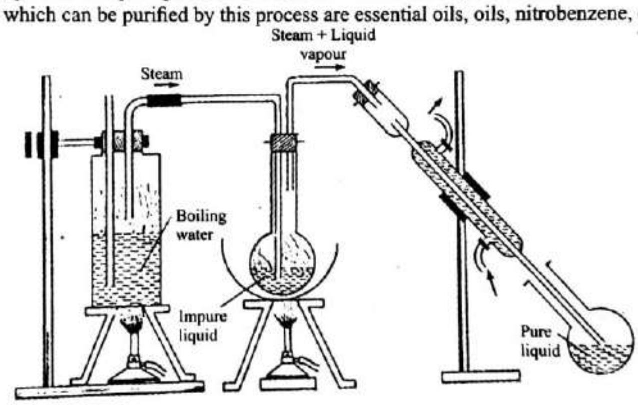


Distillation under reduced pressure.

Do You Know!!

With the commonly used water suction pumps in the laboratory, a pressure of 10– 20 mm Hg can be obtained. Under these conditions, the boiling points are reduced by about 100 degrees.

13. Steam distillation: This is a convenient method for the separation and purification of organic compounds (solid or liquid) from non-volatile organic or inorganic impurities. This method is applicable to only those compounds which are *volatile in* steam, insoluble in water, possess a vapour pressure of about 10 – 15 mm of Hg at 373 K and contain non-volatile **impurities.** Some of the compounds which can be purified by this process are essential oils, oils, nitrobenzene, chlorobenzene, **etc.**



Steam distillation apparatus.

The principle of steam distillation is based on Dalton's law of partial pressures. In steam distillation, a mixture of water and an organic liquid is heated by steam as shown in figure. The mixture boils when the combined vapour pressure of water (p_1) and that of the organic liquid (p_2) is equal to the atmospheric pressure (P) i.e.

$$P = p_1 + p_2$$

Evidently, the boiling temperature of the mixture would be lower than the boiling temperature of pure organic liquid and decomposition of organic compound is avoided.

The apparatus involves a steam generator connected to distillation flask. When steam passes through the impure organic compound the mixture starts boiling when the combined vapour pressure becomes equal to atmospheric pressure. At this temperature the vapours of the volatile liquid mixed with steam rise up and condense in condenser. The distillate contains the desired substance and water which can be easily separated with the help of a separating funnel to recover organic substance.

Illustration 4

How will you separate a mixture of *o*-nitrophenol and *p*-nitrophenol?

SOLUTION:

Steam distillation. *o*-nitrophenol being volatile distils over along with water while *p*-nitrophenol being non-volatile **remains in the flask.**

KNOWLEDG NHANCER

CHROMATOGRAPHY :

Chromatography is based on the difference in adsorption of different substances on the surface of a solid medium. The technique of separating the components of a mixture in which separation is achieved by the differential movement of individual components through a stationary phase under the influence of a mobile phase. It is a modern technique used for the separation of a mixture of substances. The name chromatography means colour writing, since in its original applications by Michael Tswett in 1906 it involved separation of mixtures containing coloured substances which when separated, formed distinct coloured rings. These zones or rings are named chromatograms. These days, chromatography is applied to coloured as well as colourless substances for analysis.

How it works :

The principle on which paper chromatography works is very simple. The pulp in the filter paper used for chromatography, is composed of thin threads acting as capillaries. When this paper is suspended in a beaker of water, touching the water surface, water ascends through these capillaries. Different soluble dyes move upwards at different speeds and to different levels, by capillary action. In research and industry a special kind of filter paper is used for chromatography. In the laboratory, a fine quality of ordinary filter paper can also be used.

In other type of Chromatography , the adsorbent medium used is generally magnesium oxide, alumina or filter paper. The solvent generally used for dissolving a mixture of two or more constituents is water or alcohol.

The different constituents of a mixture get absorbed differently on the same adsorbent material, because they have different rates of movement. The rate of movement of each absorbed material depends upon :

(i) The relative solubility of the constituent of mixture in a given solvent.

(ii) The relative affinity of the constituents of mixture for the adsorbent medium.

The stationary phase can be either a *solid* or tightly bound *liquid* on a solid support while the mobile phase can be either a *liquid* or a *gas*. Depending upon the nature of the stationary and the mobile phases, the different types of chromatographic techniques commonly used are

(1) Paper chromatography (2) Column chromatography (3) Thin layer chromatography (4) Gas chromatography

✓ CHECK POINT | **A liquid (1.0 g) has three components. Which technique will you employ to separate them?**

Check Your Answer

Column chromatography.

IDEA BOX

Take a rectangular strip of chromatography paper. Draw a line with a pencil at about three centimetres height from the base of this paper. Place a drop of black ink on the pencil line. Suspend this chromatography paper in a wide and tall glass cylinder. Gradually, pour water into the cylinder till the lower end of chromatographic paper slightly dips in the water. Cover the cylinder with a glass lid to prevent any evaporation and leave the apparatus undisturbed for an hour. Now record your observations and on the basis of your observation draw a conclusion.

PHYSICAL AND CHEMICAL CHANGES :

To understand the difference between a pure substance and a mixture, let us understand the difference between a physical and a chemical change. As with the properties of a substance, the changes that substances undergo can be classified as either physical or chemical. During physical changes a substance changes its physical appearance, but not its composition. The evaporation of water is a physical change. When water evaporates , it changes from the liquid state to the gas state, but it is still composed of water molecules. All changes of state (for example, from liquid to gas or from liquid to solid) are physical changes.

Example 1 : Mixing iron powder and sulfur powder at room temperature is a physical process. The mixture can be separated into their original constituent without any behavioral change. This can be achieved by using a magnet and the iron will be attracted towards the magnet, leaving the sulfur behind.

Example 2 : When sugar is dissolved in water, it seems to disappear completely, and not even a very powerful microscope can show us the molecules of sugar in water. However, the solution obtained is evenly sweet. By evaporating the water, the sugar can be recovered in a crystalline form.

Characteristics of Physical Changes :

(i) It is a temporary change.
(ii) No new substances are formed.
(iii) No change in mass takes place.
(iv) Can be reversed by reversing the conditions.
(v) Change in physical state, size and appearance.

Some Examples Involving Physical Changes :

Physical changes	Observation	Change on physical property
1. Switching of an electric bulb.	The bulb glows and gives out heat and light energy.	The physical appearance of the bulb changes.
2. Rubbing a permanent magnet on a steel rod.	The steel rod gets magnetised. If it is brought near iron nails, they get attracted.	The steel rod acquires the property of attracting pieces of iron.
3. Action of heat on iodine	The brownish grey crystals of iodine change to form violet vapours. On cooling the vapours condenses to for form crystals.	Change in state and colour.
4. Dissolving of common salt in water.	The white crystalline salt disappears in water. However, the water tastes exactly like common salt. Moreover, common salt can be recovered by evaporation.	Change of state.

Some Other Common Examples of Physical Changes :

(i) *Formation of dew*
(ii) *Evaporation of water*
(iii) *Crystallisation of sugar from its solution.*
(iv) *Ringing of an electric bell*
(v) *Breaking of a glass pane*
(vi) *Making of ice cream.*
(vii) *A rock rolling down a hill.*
(viii) *Bending of a glass tube by heating*
(ix) *Melting of wax.*
(x) *Sublimation of camphor*

Chemical Change :

A chemical change is one in which the identity of the original substance is changed and a new substance or new substances are formed. In a chemical change the properties of the substance before and after the change are entirely different. *e.g. souring of milk, burning of paper, buring of candle, etc.*

Look at the picture of the burning candle. The wax of a candle burns into ash and smoke.
The original materials are changing into something different.

Characteristics of a Chemical Change :

(i) A chemical change is permanent change and cannot be reversed to give back the original substance.
(ii) One or more new substances (called products) are formed.
(iii) Change in mass of a substance takes place.
(iv) The composition of the product is different from that of the starting substance.
(v) A chemical change is always accompanied by the change in energy.

✎ Illustration 5

Out of burning of candle and melting of ice which represents pure physical change?

SOLUTION:

Melting of Ice represents pure physical change as it involves change of state only. In case of burning candle hydrocarbons present in wax is converted into new products on combustion along with simultaneous melting of wax.

Some Examples Involving Chemical Changes :

Chemical change	Observation	Chemical equation
1. Burning of magnesium in air	When a magnesium ribbon is heated in a flame of Bunsen burner, it catches fire and burns with dazzling white flame to form white ash.	Magnesium + Oxygen ⟶ Magnesium oxide
2. Rusting of iron	When iron (silver grey) is left exposed to moist air for a few days, reddish brown powdery mass (rust) is found on its surface.	(from air) ⟶ Iron + Oxygen + Water vapours ⟶ Rust
3. Burning of LPG.	When LPG (liquefied petroleum gas) is burnt, it burns with a pale blue flame and liberates colourless gas carbon dioxide along with steam.	Butane (LPG) + Oxygen ⟶ Carbon dioxide + Water

Some Other Common Examples of Chemical Changes :

(i) *Burning of wood or charcoal* (ii) *Burning of candle*
(iii) *Decomposition of water into hydrogen and oxygen.*
(iv) *Formation of water from hydrogen and oxygen*
(v) *Digestion of food* (vi) *Formation of biogas (Gobar gas)*
(vii) *Curdling of milk* (viii) *Burning of petrol or diesel*
(ix) *Cigarette smoking* (x) *Drying of paint*
(xi) *Rusting of iron* (xii) *Ripening of fruit*
(xii) *Blood clotting* (xiv) *Fading of the colour of a dyed cloth*

Comparison Between Physical and Chemical Changes :

Physical change	Chemical change
(i) It is a temporary change and can be reversed by change of conditions	(a) It is a permanent change and is an irreversible change.
(ii) No new substance is formed and the composition of the substance remains unaltered.	(b) The composition of the substance changes resulting in the formation of one or more new substances.
(iii) No energy changes occur	(c) It is generally accompanied by energy changes.

✓ CHECK POINT **Classify the following as physical and chemical changes.**

(i) Conversion of milk into curd
(ii) Burning of magnesium ribbon in air
(iii) Rusting of iron nails
(iv) Dissolving salt in water
(v) Burning of coal
(vi) Electrolysis of sodium chloride solution by passing current
(vii) Crystallisation of copper sulphate.

Check Your Answer

(i) Chemical change (ii) Chemical change (iii) Chemical change (iv) Physical change (v) Chemical change (vi) Chemical change (vii) Physical change.

IDEA BOX

As you have studied about physical and chemical changes once again go through the concept of physical and chemical changes thoroughly. Now call your friends at your home and also remind them that they should also go through the concept of physical and chemical changes thoroughly. Now play a quiz with your friends in which you become host and make your all friends participants. Given your friends an example and they have to make right guess that whether given example is of physical or chemical change. For right guess 10 points will be awarded and 5 points will be deducted for wrong answer. Let's see who wins.

Do You Know!!

Changes where physical as well as chemical changes are involved :

(i) *Burning of a candle (wax)*

(ii) *Sublimation of ammonium chloride*

(iii) *Action of heat on zinc hydroxide*

(iv) *Action of heat on sodium nitrate*

EXERCISE 1

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. Common salt is a ....
2. A mixture contains more than .... substance mixed in .... proportion.
3. Properties of a .... are different from its constituent elements, whereas a .... shows the properties of its constituting elements.
4. A solution is defined as a mixture that is............
5. We can remove salts from a solution by using the process of............
6. A pure substance has a fixed .... or ....at constant temperature.
7. An element is made up of only one kind of......
8. Miscible liquids are separated by .....
9. Immiscible liquids are separated by using a ....
10. Filtered tea is a ....mixture
11. Alloy is a ....
12. Sublimation of camphor is a .... change.
13. Most common chemical change we observe in our routine life is rusting of ....

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Water is homogeneous substance.
2. Element is always metal.
3. Substance is always homogeneous
4. In compound elements combine in definite proportion.
5. Iodine can be purified by sublimation.
6. Mixtures are always combinations of the same compounds that are at different states.
7. We can separate all mixtures by filtration.
8. All mixtures are defined as "heterogeneous.
9. Only specific compounds can be combined to form mixtures.
10. No pure elements are liquids at room temperature.
11. Mixtures are combinations of one or more compounds that can be separated with chemical processes.
12. Crystals can be made of mixtures.

Match the Column

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in Column I have to be matched with statements (p, q, r, s) in Column II.*

I. Match them correctly.

Column I	Column II
(A) Steel	(p) Mixture
(B) Air	(q) Compound
(C) Water	(r) Alloy
(D) Diamond	(s) Element

II. Column II gives method to separate phases mentioned in column I match them correctly.

Column I	Column II
(A) Miscible liquids	(p) Distillation
(B) Immiscible liquids	(q) Crystallisation
(C) Pure copper sulphate from an impure sample	(r) Sublimation
(D) Salt and ammonium chloride	(s) Seperating funnel

Very Short Answer Questions

DIRECTIONS : *Give answer in one word or one sentence.*

1. What difference in the property of two miscible liquids enables their separation by fractional distillation ?
2. Why is solution not heated to dryness to get crystals ?
3. Give one example each of homogeneous and heterogeneous mixture.
4. Name the apparatus by which mixture of oil and water can be separated.
5. How can we check whether the given solid substance is pure or not?
6. A hard substance produces a tinkling sound when beat. Is it metal or a non-metal?
7. Is brass a mixture or a compound?
8. What type of solution is an alloy?
   liquid solution or solid solution.
9. A mixture consisting of two miscible liquids 'A' and 'B' whose boiling points differ by 5°C can be separated by which process ?
10. Which separation, technique is employed to separate complex mixture of organic compounds like carbohydrates, amino acids, vitamins, hormones, etc?
11. In fractional crystallisation two organic compounds gets differentiated on the basis of which property.

12. Which method can be used to separate mixture of iron filings and common salt?
13. Give one example of solid-liquid homogeneous mixture.
14. What is a aquaregia?
15. Which method is used to separate two immiscible liquids?
16. Name two elements which are in liquid state at room temperature?

SAQ Short Answer Questions

DIRECTIONS : *Give answer in 2-3 sentences.*

1. Define element, compound and mixture.
2. What are pure substance? Give two examples of pure substances.
3. What are metals ? Given two examples of metals.
4. Which method can be used to separate a mixture of napthalene and common salt ?
5. Define homogeneous and heterogeneous mixtures.
6. Classify the following into elements, compounds and mixtures.
   (a) Sodium (b) Soil
   (c) Sugar solution (d) Silver
   (e) Calcium carbonate (f) Tin
7. Classify each of the following as a homogeneous or heterogeneous mixture.
   Sodawater, wood, air, soil, vinegar.
8. Classify the following elements as metal, nonmetal, or metalloid : aluminium, fluorine, gallium, phosphorus, krypton, tellurium, thorium, barium and strontium.
9. Given the names of the elements present in the following compounds :
   (a) Quicklime (b) Hydrogen bromide
   (c) Baking soda (d) Potassium sulphate
10. Can an element be distinguished from its compound by examination of its physical properties only ? Explain.
11. Explain why, water is a compound and not a mixture ?
12. How do the properties of a mixture differ from the properties of the components of the mixture?
13. In terms of physical properties, what is there about mixtures that makes it possible to separate out the components?
14. How would you separate the following mixture?
    (i) salt and water
    (ii) glass powder and iron filings
15. Which of the following mixtures are homogeneous ?
    (a) Wood (b) Tap water
    (c) Soil (d) Cloud
    (e) Smoke
16. Why are the metals good conductors of electricity ?
17. What are the advantages of chromatography as a method of separation of components of a mixture ?

LAQ Long Answer Questions

DIRECTIONS : *Give answer in four to five sentences.*

1. List five characteristics by which compounds can be distinguished from mixtures.
2. What is chromatography ? Explain by giving principle involved. State its important applications.
3. Identify the following as homogeneous or heterogeneous matter.
   (a) gasoline (b) dirt (c) smog
   (d) alcohol (e) iron nail (f) vinegar
   (g) aerosol spray (h) air (i) sea water
   (j) steel
4. Suggest a scheme for the separation of constituents of the following mixture:
   Sulphur + sand + sugar + iron filings
5. Which method of distillation is employed for the concentration of raw juice in sugar factories. Explain in detail.
6. Classify the following as physical change or chemical change.
   (i) Burning of magnesium ribbon in air
   (ii) Burning of sulphur in air
   (iii) Electrolysis of water
   (iv) Purification of copper sulphate from impure copper sulphate by crystallization.
   (v) Preparation of sugar solution
   (vi) Conversion of milk into curd
   (vii) Evaporation of alcohol
   (viii) Burning of coal
7. Complete the following table based on separation techniques. The first one example is done for you.

Mixture	Types of mixture	Separation technique	Principle
(i) Sulphur + carbon disulphide	....	....	....
(ii) Iron + sulphur	....	....	....
(iii) Pigments of flower	....	....	....
(iv) Petrol + water	....	....	....
(v) Sand + water	....	....	....

EXERCISE 2

MCQ Multiple Choice Questions

DIRECTIONS : *This section contains 32 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. Air is regarded as a mixture because
   (a) its pressure may very
   (b) its temperature may change
   (c) its volume changes under different conditions
   (d) its composition may vary
2. Which of the following is a compound ?
   (a) Stainless steel (b) Bronze
   (c) Graphite (d) Hydrogen sulphide
3. The process used to separate oil and water is
   (a) distillation (b) sublimation
   (c) separating funnel (d) chromatography
4. In which of the following the constituents are present in any ratio?
   (a) Mixture (b) Compound
   (c) Solution (d) Colloid
5. A mixture of common salt, sulphur, sand and iron filings is shaken with carbon disulphide and filtered through a filter paper. The filtrate is evaporated to dryness in a china dish. What will be left in the dish after evaporation?
   (a) Sand (b) Sulphur
   (c) Iron filings (d) Common salt
6. Two substances A and B when brought together form a substance C with the evolution of heat. The properties of C are entirely different from those of A and B. The substance C is
   (a) a compound (b) an element
   (c) a mixture (d) none of the above.
7. Camphor can be purified by
   (a) distillation (b) filtration
   (c) sedimentation (d) sublimation
8. Which one of the following will result in the formation of a mixture?
   (a) Crushing of a marble tile into small particles
   (b) Breaking of ice cubes into small pieces
   (c) Adding sodium metal to water
   (d) Adding milk in water
9. Purity of a solid substance can be checked by its
   (a) boiling point (b) melting point
   (c) solubility in water (d) solubility in alcohol
10. A mixture of ethanol and water can be separated by
    (a) filtration (b) decantation
    (c) fractional distillation (d) sublimation
11. Salt can be obtained from sea water by
    (a) filtration (b) decantation
    (c) evaporation (d) sublimation
12. A sample contains two substances and has uniform properties. The sample is
    (a) a compound
    (b) a heterogeneous mixture
    (c) an element
    (d) a homogeneous mixture
13. A mixture of $ZnCl_2$ and $PbCl_2$ can be separated by
    (a) distillation (b) crystallization
    (c) sublimation (d) adding acetic acid
14. A mixture of methyl alcohol and acetone can be separated by
    (a) distillation
    (b) fractional distillation
    (c) steam distillation
    (d) distillation under reduced pressure
15. Mixture of sand and sulphur may best be separated by
    (a) fractional crystallisation from aqueous solution
    (b) magnetic method
    (c) fractional distillation
    (d) dissolving in CS_2 and filtering
16. Which component of the mixture (Fe + S) reacts with dil. HCl and gives hydrogen gas?
    (a) Sulphur (b) Iron
    (c) Both (d) None
17. Which of the following is considered to be a pure substance?
    (a) Granite. (b) Sodium chloride.
    (c) Muddy water (d) Milk of magnesia
18. Physical properties of a mixture
    (a) vary with the amount of substance.
    (b) depend on the volume of the substance
    (c) depend on the organization of the substance
    (d) vary depending upon its components
19. Compounds
    (a) are the same as mixtures
    (b) can be separated by their physical properties
    (c) contain only type of element
    (d) are different kinds of atoms chemically combined with each other.
20. White gold is used in jewelry and contains two elements, gold and palladium. A jeweler has two different samples that are both identical in appearance and have a uniform composition throughout. What can be said about the samples?
    (a) They are homogeneous mixtures and be classified as metallic alloys.
    (b) The materials are heterogeneous mixtures and can be classified by their components

(c) The samples have variable compositions and are classified as metallic solutions.
(d) The samples are heterogeneous mixtures that can be separated using magnetic properties.

21. To prepare iron sulphide, by heating a mixture of iron filings and sulphur powder, we should use a
(a) Copper dish (b) Watch glass
(c) China dish (d) Petri dish

22. Which of the following is an example of a heterogeneous substance?
(a) Bottled water (b) Table salt
(c) Pieces of copper (d) Candle

23. Which of the following is an example of a homogeneous substance?
(a) Granite (b) Copper sulphate
(c) M & M candy (d) Muddy water

24. Which flow chart correctly describes a homogeneous material?
(a) Unknown — density — 3 layers
(b) Unknow — filtration — two substances
(c) Unknown — magnet — two substances
(d) Unknown — boiling — one temperature

25. A student was given a mixture of iron filings and sulphur in the ratio 1 : 2 by weight. He was then asked to heat the mixture over a flame and to observe the colour change. The student will observe that the mixture becomes:
(a) Black (b) Grey
(c) Yellow (d) Orange

26. Filtration can be used to separate
(a) solids from solids (b) liquids from solids
(c) liquids from liquids (d) liquids from gases

27. One common method used to separate dyes is
(a) filtraton (b) distillation
(c) chromatography (d) conductivity

28. Melting points can separate materials because
(a) substances melt at different temperatures
(b) molecules vibrate rapidly when heated
(c) heat causes molecules to disintegrate
(d) many substances fuse at the melting point

29. Distillation is a good separation technique for
(a) solids (b) liquids
(c) solid alloys (d) gases

30. Solubility is a good separation technique for
(a) pure metals (b) noble gases
(c) different salts (d) metallic alloys

31. Magnetism is most beneficial for separating
(a) gases and non-metallic liquids
(b) magnetic solids and solids such as sulfur
(c) non-metallic solids and solids such as sulfur
(d) non-magnetic solids from non-magnetic liquids

32. Before the heating when iron filings mixed with sulphur. Is this reaction will show chemical change:
(a) Yes
(b) No
(c) Initially physical then chemical change
(d) Initially chemical then physical change

MTOC More than One Correct

DIRECTIONS : *This section contains* **14** *multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Which of the following is/are true for mixtures?
(a) Mixtures can be homogeneous or heterogeneous.
(b) Components in a mixture are present in a fixed ratio.
(c) Properties of a mixture are the average of its components.
(d) Components of a mixture can be separated easily by simple physical methods.

2. A mixture of sulphur and iron filings is heated strongly to obtain a residue. Which of the following is/are characteristic property/properties of the residue ?
(a) It can be separated into sulphur and iron filings by physical methods.
(b) Its composition does not change from one part to another.
(c) Its properties are entirely different from those of sulphur and iron filings.
(d) Its appearance is different from those of sulphur and iron filings.

3. Which of the following is/are true for a compound?
(a) It is heterogeneous in nature.
(b) A compound contains different elements in a fixed ratio.
(c) Properties of a compound are entirely different from those of the elements present in it
(d) Constituents of a compound cannot be separated by simple physical methods.

4. Which of the following is an example(s) of alloy?
(a) Sugar (b) Brass
(c) Bronze (d) NO_2

5. Which of the following is/are compound(s) ?
(a) Sugar (b) Common salt
(c) Diamond (d) Plaster of paris

6. Which of the following is/are a mixture(s)?
(a) Solution (b) Alloy
(c) Amalgam (d) Ammonia

7. Which of these is/are a mixture?
(a) Oil and water (b) Sand and water
(c) Diet soda (d) Deionized water

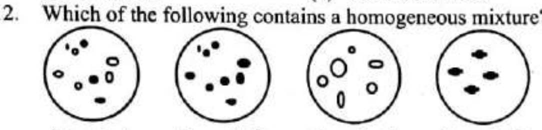
8. Which of the following statements is/are incorrect ?
(a) A pure substance must contain only one type of atom.
(b) A mixture containing two compounds must be heterogeneous.
(c) A heterogeneous mixture must contain at least three elements.
(d) A homogeneous mixture must be uniform.

9. Mixtures
   (a) can have the same composition throughout
   (b) have physical properties dependent on its components
   (c) have the same physical properties as compounds
   (d) can be separated into their components

10. Which of the following is an example of a heterogeneous substance?
    (a) Mixture of sand and rice grains
    (b) Sodium sulfate
    (c) Aspirin
    (d) Salad dressing

11. Which of the following is an example of a homogeneous substance?
    (a) Glass (b) Dirt
    (c) Flowers (d) Deionized water

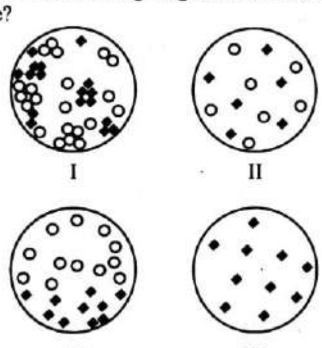
12. Which of the following contains a homogeneous mixture?



Sample A Sample B Sample C Sample D

    (a) Sample A (b) Sample B
    (c) Sample C (d) Sample D

13. Which of the following diagrams shows a heterogeneous mixture?



I II III IV

    (a) Diagram I (b) Diagram II
    (c) Diagram III (d) Diagram IV

14. Which of the following shows the correct example of a heterogeneous material?
    (a) Mixtue — same composition throughout — solution
    (b) Mixture — magnet — two separate substances
    (c) Mixture — filtration — two substances
    (d) Air — wind — one solution of gases

FIP Fill in the Passage

DIRECTIONS : *Complete the following passage(s) with an appropriate word/term to be filled in the blank spaces.*

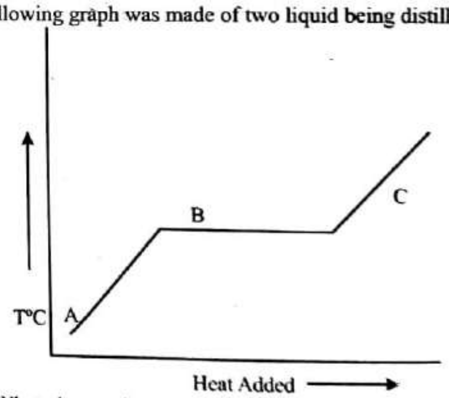
1. Pure substances can mix in either of two ways. If the mixture is composed of more than one phase, it is ....(1)....... If there are two liquid phases, the liquid on top has the ....(2)....... density. If pure substance is mixed in such a way that only one phase is formed, the mixture is ....(3)....... Mixtures that result in one liquid phase are usually referred to as ....(4).......These mixtures are distinguished from pure substances by their variable properties such as ....(5)....... and ....(6)....... points and density. Mixtures of metals that result in one solid phase are referred to as ....(7).......

II. On the basis upon the particular property (e.g., melting point, boiling point, solubility, etc, in which the constituents of ....(1)....... , differ, it can be separated into its constituents. Various techniques are employed for separation of mixtures. ....(2)....... is used when a mixture contains two components out of which only one is soluble. Evaporation is used to separate a non-volatile salt from its mixture in ....(3)....... liquid. Mixture containing one magnetic component is separated by........(4)....... Distillation method is applied for the separation of a mixture of liquid components having difference in ....(5)....... Similarly, there are other techniques also employed for separation of mixtures.

PBQ Passage Based Questions

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

The following graph was made of two liquid being distilled.



1. What observation can be made regarding point B?
   (a) The first liquid component is boiling
   (b) The second component has already boiled
   (c) The mixture is homogeneous
   (d) Energy is being removed from the liquid

2. What observation can be made regarding point C?
   (a) The second component has already boiled
   (b) The temperature of first component starts increasing
   (c) The temperature of second component starts increasing
   (d) None of the above

3. What is the minimum temperature difference required between boiling points of two liquids to be distilled?
   (a) 10 – 20 K (b) 10°C – 20°C
   (c) 5 – 15 K (d) 5°C – 15°C

A&R Assertion and Reason

DIRECTIONS : *Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** A mixture of He and O_2 is used for respiration for deep sea divers.
   Reason : He is soluble in blood.
2. **Assertion :** Moving phase is liquid and stationary phase is solid in paper chromatography.
   Reason : Paper chromatography is used for analysis of polar organic compounds.
3. **Assertion :** Refining of petroleum involves fractional distillation.
   Reason : Fractional distillation involves repeated evaporation and distillation.
4. **Assertion :** Oils are purified by steam distillation.
   Reason : The compounds which decompose at their boiling points can be purified by steam distillation.
5. **Assertion:** Germanium, arsenic and antimony are classified as metalloids.
   Reason : Germanium, arsenic and antimony possess some properties of metals and some properties of non-metals.
6. **Assertion :** Pure substances in which molecules are made up of only one kind of atoms are known as elements.
   Reason : Hydrogen, oxygen and nitrogen are elements.

MMQ Multiple Matching Questions

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

I.

Column-I	Column-II
(A) Iron fillings and common salt	(p) distillation
(B) Salt and water	(q) magnetic separation
(C) Benzene and toluene	(r) evaporation
(D) Rice grains and alcohol	(s) filteration

II.

Column-I	Column-II
(A) Steel	(p) Fe
(B) Copper amalgam	(q) Cr
(C) 18 k gold	(r) Hg
(D) Iron amalgam	(s) Cu

HOTS Hots Subjective Questions

DIRECTIONS : *Answer the following questions.*

1. How would you confirm that a colourless liquid given to you is pure water ?
2. From the following techniques :
   distillation, filtration, fractional distillation, chromatography, crystallisation, sublimation, evaporation, decantation, sedimentation.
   Select the method you will use to separate :
   (a) the constituents of the colouring matter of ink
   (b) hydrated $CuSO_4$ from its aqueous solution
   (c) sand and water
   (d) common salt from sea-water
   (e) petrol from crude oil
3. Which of the following materials fall in the category of a "pure substance?"
   (a) Ice (b) milk
   (c) Iron (d) Hydrochloric acid
   (e) Calcium oxide (f) Mercury
   (g) Brick (h) Wood
   (i) Air
4. Why does ice float on water ? Is ice water homogeneous or heterogeneous matter ? Pure or a mixture ?
5. Classify each of the following as a pure substance or a mixture; if a mixture, indicate whether it is homogeneous or heterogeneous: (a) rice pudding; (b) seawater; (c) magnesium; (d) gasoline.
6. Tell whether each of the following properties describes a heterogeneous mixture, a solution (homogeneous mixture), a compound, or an element.
   (a) a homogeneous liquid that, when boiled away, leaves a solid residue.
   (b) a cloudy liquid that after a time seems more cloudy toward the bottom.
   (c) a uniform red solid that has a definite, sharp melting point and cannot be decomposed into simpler substances.
   (d) a colorless liquid that boils at one unchanging temperature and can be decomposed into simpler substances.
   (e) a liquid that first boils at one temperature but as the heating continues, boils at slowly increasing temperatures.
7. A solid white substance A is heated strongly in the absence of air. It decomposes to form a new white substance B and a gas C. The gas has exactly the same properties as the product obtained when carbon is burned in an excess of oxygen. Based on these observations, can we determine whether solids A and B and the gas C are elements or compounds? Explain your conclusions for each substance.
8. How does a gas differ from a liquid with respect to ability to mix with other substances of the same phase to form homogeneous mixtures ?

9. Which of the following mixtures is homogeneous and why?
   Ethyl alcohol and water
   Or
   Oil and water
10. Sometimes we refer to alloys as substitutional solids. Why?
11. Discuss the function of fractionating column in fractional distillation.
12. When two substances A and B were made to combine, they formed a third substance C. The following observations were recorded for this :
    (i) During formation of C from combination of A and B a large amount of heat was evolved.
    (ii) The properties of C were different from those of A and B. Predict the nature of C.
13. Is fresh air free of dust particles and impurities of all other kind, a pure substance?
14. Why is a compound considered as pure substance but mixture is not considered as a pure substance?
15. Mixtures can be separated into their components by taking advantage of differences in the chemical properties of the components. Why might this separation method be less convenient than taking advantage of differences in the physical properties of the components?
16. Many dry cereals are fortified with iron, which is added to the cereal in the form of small iron particles. How might these particles be separated from the cereal?

SOLUTIONS

EXERCISE – I

FILL IN THE BLANKS

1. compound
2. one, any
3. compound, mixture
4. homogeneous
5. evaporation
6. M.P & B.P.
7. atoms.
8. fractional distillation
9. separating funnel
10. homogeneous
11. solid solution
12. physical
13. iron

TRUE/FALSE

1. True
2. False
3. False
4. True
5. True
6. False
7. False
8. False
9. False
10. False
11. False
12. True

MATCH THE FOLLOWING

I. $A \rightarrow (r)$; $B \rightarrow (p)$; $C \rightarrow (q)$; $D \rightarrow (s)$

II. $A \rightarrow (p)$; $B \rightarrow (s)$; $C \rightarrow (q)$; $D \rightarrow (r)$

VERY SHORT ANSWER QUESTIONS

1. The difference in boiling point of two miscible liquids enables their separation by fractional distillation.
2. Heating the solution to dryness will not remove the soluble impurities and crystals of very poor quality are not obtained.
3. Homogeneous mixture – aqueous solution of table salt. Heterogeneous mixture – milk.
4. Separating funnel.
5. By checking its melting point whether it agrees with the value given in tables or not. If it agrees then it is pure.
6. It is a metal. (Metals are hard and produce tinkling sound.)
7. It is mixture, because its composition is variable.
8. Alloy is a solid solution.
9. Fractional distillation.
10. Chromatography.
11. On the basis of difference in solubility.
12. The given mixture can be separated by magnetic method.
13. Solution of I_2 in CCl_4.
14. It is a mixture of 3 parts of HNO_3 and 1 part of HCl.
15. A separating funnel is used for this purpose.
16. Mercury, Bromine.

SHORT ANSWERS QUESTIONS

1. **Element :** It is defined as a substance that can not be further reduced to simpler substances.
   Compound : It is a pure substance that can be decomposed into simpler substances by some suitable chemical techinque. A compound is formed by combination of two or more elements in a definite proportion.
   Mixture: A mixture contains more than one substance, elements or compounds. A mixture depicts the properties of its constituting substances.
2. A pure substance is one which has constant composition. Lavoisier, a French chemist on the basis of quantitative studies classified pure substances into elements and compounds example of pure substance water, oxygen, nitrogen, etc.
3. Metals are those elements which are good conductor of electricity and heat. Metals are ductile and malleable. Two important metals are iron and aluminium.
4. Given mixture can be separated by sublimation. Napthalene being a sublime substance sublimes off on heating leaving common salt (with high melting point) behind.
5. (*i*) **Homogeneous mixture :** *It is a mixture that has the same composition throughout. e.g., a solution of sugar in water. Such a mixture has two or more components. The composition of such a mixture is variable (e.g., different quantities of sugar are added to the same quantity of water).*
   Some other examples of homogeneous mixture are common salt in water, copper sulphate solution, etc.
   (ii) **Heterogeneous mixture :** In such a mixture the particles of each component of the mixture remain separate and can be observed as individual grains under a microscope. e.g., mixture of grains and sand. This type of mixtures contain physically distinct parts and have a non-uniform composition. Some other examples of heterogeneous mixture are a mixture of sodium chloride and iron fillings, a mixture of salt and sulphur, a mixture of oil and water.
6. (a) element
   (b) mixture (heterogeneous mixture)
   (c) mixture (homogeneous mixture)
   (d) element
   (e) compound ($CaCO_3$)
   (f) element
7. (a) Soil is a heterogeneous mixture
   (b) Vinegar is a *solution*. It is a homogeneous mixture.
   (c) Air is a *solution*. It is a homogeneous mixture.
   (d) Wood is *not* a homogeneous mixture so it is *not* a solution.
   (e) Soda water is a homogeneous mixture so it is a solution.
   [A solution is a homogeneous mixture]

8. Metals :aluminium, thorium, barium, gallium and strontium.

   Nonmetals : fluorine, phosphorus and krypton

   Metalloids : tellurium

9. (a) Quicklime is calcium oxide, CaO. The elements present in it are : Calcium (Ca) and Oxygen (O).

   (b) Hydrogen bromide is HBr. The elements present in it are : Hydrogen (H) and Bromine (Br)

   (c) Baking soda is sodium hydrogen carbonate, $NaHCO_3$. The elements present in it are : Sodium (Na), Hydrogen (H), Carbon (C) and Oxygen (O).

   (d) Potassium sulphate is K_2SO_4. The elements present in it are : Potassium (K), Sulphur (S) and Oxygen (O)

10. Yes, because there occur a change in physical chracteristic of an element when it combines to form compound. For example sodium and chlorine are elements and sodium chloride is compound formed from elements sodium and chlorine they have difference in physical properties like appearence, melting point, solubility, etc.

11. Water is considered a compound because of the following reasons :

    (i) Water cannot be separated into its constituents, hydrogen and oxygen, by the physical methods such as filtration, evaporation, distillation, sublimation, magnet, etc.

    (ii) The properties of water are entirely different from those of its constituents, hydrogen and oxygen. For example, water is a liquid whereas hydrogen and oxygen are gases, water does not burn whereas hydrogen burns, water does not support combustion whereas oxygen supports combustion.

12. The chemical properties of the components of a mixture do not change within a mixture. The properties of the whole mixture vary greatly depending on the amount of each component and the specific property being investigated.

13. The components of a mixture are not chemically combined; therefore, the individual chemical and physical properties of the two components remain individual and unique, allowing for easy separation based on these properties.

14. (i) By distillation, salt remains as residue. In case of insoluble salt we can use filtration.

    (ii) By magnetic separation. Iron filings are attracted by magnet.

15. Cloud and tap water are homogeneous mixtures. Others are heterogeneous mixtures.

16. In metals we find that *mobile electrons* are present and it accounts for the high electrical conductivity of metals.

17. Main advantages of chromatography are :

    (i) Only a small quantity of sample is required.

    (ii) The constituents retain their individual characteristics during the process.

    (iii) The process can be used for separation of constituents even if they have very similar chemical properties.

LONG ANSWER QUESTIONS

1.

Mixture	Compounds
A mixture can be separated into its constituents by physical processes (filtration, evaporation, sublimation, distillation).	A compound cannot be separated into its constituents by physical processes. It can be separated by chemical means.
A mixture shows the properties of its constituents.	A compound has a new set of properties different from its constituents.
Composition of a mixture varies and the constituents are present in any proportion by weight. It does not have definite formula.	The composition of a compound is fixed and the constituents are present in fixed proportions by weight. It has a definite formula.
The constituents do not react chemically, thus no energy changes take place. A mixture does not have a fixed melting point or boiling point Examples: air, sand and salt.	Chemical reactions take place and energy changes in the form of heat and light are involved. A compound has a fixed melting point and boiling point Examples: H_2O (water), FeS (iron sulphide).

2. Chromatography is the collective term for a set of laboratory techniques for the separation of mixtures. The mixture is dissolved in a fluid called the "mobile phase", which carries it through a structure holding another material called the "stationary phase". The various constituents of the mixture travel at different speeds, causing them to separate. The separation is based on **differential partitioning between the mobile and stationary phases.**

Applications of chromatography

1. Toxicology is an area where chromatography is used Separating and identifying different drugs of abuse.
2. In sports medicine, any illegal drugs will be picked up using chromatographic techniques. (e.g. Gas chromatography)
3. Chromatography can identify a substance and show how it differs from others that may look alike on the surface. For instance, if you **perform chromatography**

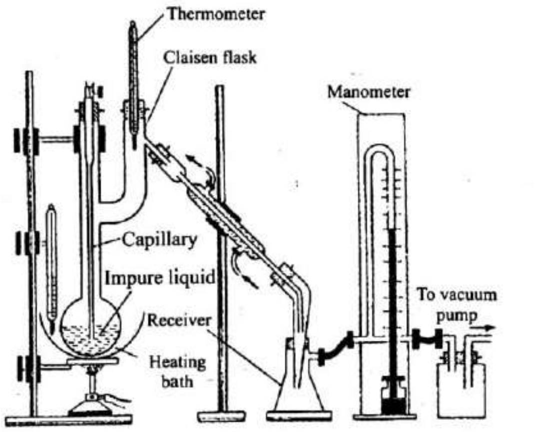
on black ink from different pens, you can determine which brand of ink matches an unknown sample.

4. Chromatography has evolved to be one of the most widely used chemical techniques to separate particles and contaminates in chemical plants. For example, in the chemical industries, pesticides and insecticides like DDT in the groundwater and PCBs (Polychlorinated biphenyls) are removed by the process of chromatography.

3. (a) homogeneous (b) heterogeneous
(c) heterogeneous (d) homogeneous
(e) homogeneous (f) homogeneous solution
(g) heterogeneous (h) homogeneous
(i) heterogeneous (j) homogeneous

4. A magnet is moved several times over the mixture containing sulphur, sand, sugar and iron filings. The iron filings are attracted by the magnet, they stick to the magnet and get separated.
The remaining mixture of sugar, sulphur and sand is stirred with water when sugar dissolves in it. On filtration sugar solution is obtained as a filtrate from which sugar can be recovered by evaporation. The residue contains sulphur and sand.
Sulphur and sand mixture is shaken with carbon disulphide when sulphur dissolves in it but sand remains undissolved. On filtration, sulphur is obtained as a filtrate from which solid sulphur can be recovered by evaporating carbon disulphide. Sand is left behind as a residue on the filter paper.

5. **Vacuum distillation or distillation under reduced pressure:** This technique of distillation is applied to liquids which decompose on heating to their boiling point. We know that the boiling point of a liquid varies with atmospheric pressure *i.e.*, at reduced pressure the boiling point of liquid is also reduced and thus liquid distils at low temperature. The apparatus involves a vacuum pump connected with receiver as shown in figure to carryout distillation under reduced pressure.



Distillation under reduced pressure.

6. (i) Chemical change (oxide of magnesium is formed)
(ii) Chemical change (oxide of sulphur formed)
(iii) Chemical change (hydrogen and oxygen are formed)
(iv) Physical change (no new substance formed)
(v) Physical change
(vi) Chemical change (a new substance is formed)
(vii) Physical change
(viii) Chemical change (carbon dioxide formed formation of new product indicated chemical change)

7. Complete the following table based on separation techniques. The first one example is done for you.

Mixture	Types of mixture	Separation technique	Principle
(i) Sulphur + carbon disulphide	Homogeneous	Evaporation	Difference in boiling point
(ii) Iron + sulphur	Heterogeneous	Magnetic Separation	Iron is magnetic in nature
(iii) Pigments of flower	Homogeneous	Chromatography	Difference in adsorption levels
(iv) Petrol + water	Heterogeneous	Separating funnel	Organic compounds get dissolved in organic solvents
(v) Sand + water	Heterogeneous	Filteration	Particles of larger size will left as residue on filter paper.

EXERCISE - 2

MULTIPLE CHOICE QUESTIONS

1. (d) Air is a mixture of different gases like N_2, O_2, CO_2 etc. Its general composition is N_2 = 78%, O_2 = 21% and traces of few other gases but there may be variation in its composition from place to place and at different height.
2. (d) Hydrogen sulphide (H_2S) is a compound of hydrogen and sulphur stainless steel and bronze are alloys whereas graphite is allotrophic form of element carbon.
3. (c) As oil being less denser than water it forms upper layer. Thus mixture of oil and water can be separated by using separating funnel.
4. (a)
5. (b) Sulphur will left behind. As in given mixture only sulphur gets dissolved in carbon disulphide.
6. (a)
7. (d) Camphor being a sublime substance can be purified by sublimation.
8. (d)
9. (b) Every pure solid has a fixed melting point.
10. (c) Mixture of ethanol and water can be separated by fractional distillation as they have different boiling points.
11. (c) Sea water is a solution of salt and water.During evaporation water gets evaporated off and salt left as a residue.
12. (d) Homogeneous mixture is a solution having uniform composition and properties throughout.
13. (b)
14. (b) Mixture of methyl alcohol and acetone can be separated by fractional distillation as there is only small difference between boiling points of methyl alcohol and acetone.
15. (d) Sulphur gets dissolved in CS_2 and separates out as a filterate. While sand gets collected on filter paper as residue.
16. (b)
17. (b) Sodium chloride being compound is a pure substance. Granite, muddy water and milk of magnesia all are mixtures.
18. (d) Physical properties of mixtures are same as of its components.
19. (d)
20. (a) As they have uniform composition throughout they are considered as homogeneous mixture. Both samples are mixture of two metals (gold and palladium) thus are alloys.
21. (c)
22. (d) Candle is a heterogeneous mixture of wax and threads. Copper is element while bottled water and table salt are compounds.
23. (b) It is a compound.
24. (d) Homogeneous liquid have a particular boiling point.
25. (a) 26. (b)
27. (c) Chromatography is based on the difference in adsorption of different substances on the surface of a solid medium. This method is frequently used to separate coloured mixture at commercial scale also in laboratories.
28. (a) Different pure solid substances melts at a different temperatures.
29. (b) Distillation is a separation techniques used for separation of miscible liquids having different boiling point.
30. (c) Different salts have different solubility in a particular solvent. Thus on this basis mixture of different salts can be separated.
31. (b) Magnetism is useful for separation of magnetic and non-magnetic substances.
32. (b)

MORE THAN ONE CORRECT

1. (a,c,d) Mixtures are not pure substances thus composition of its components vary in different proportion. Mixture exhibit properties of its components. Components of a mixture can be separated easily by physical method like filteration, magnetism, solubility, distillation, etc.
2. (b,c,d) When both element sulphur and iron are heated strongly the combine to form a compound iron (II) sulphide.

$$Fe(s) + S(s) \xrightarrow{\Delta} FeS(s)$$

Now compounds have uniform composition and properties, appearence different from constituent elements.

3. (b,c,d)
4. (b, c) Alloys are homogeneous mixture of metals. Brass is an alloy of copper and zinc whereas bronze is an alloy of copper and tin.
5. (a,b,d) Diamond is an allotrope of element carbon where as rest all are compounds.
6. (a,b,c) Ammonia is a compound whereas solution, alloy and amalgam are mixtures.
7. (a,b,c) Deionized water is a compound with fixed composition of its substituents whereas rest all are mixtures.
8. (a,b,c) A homogeneous mixture must have uniform composition and properties.
9. (b, d) Mixtures have same physical properties as of there components and can be separated into its components by various physical methods.

10. (a, d) Glass and deionized water have uniform composition throughout.
11. (a, d) Thus both are homogeneous in nature.
12. (b, c) As it is clear from given figure that sample B and C contains mixture with uniform composition.
13. (a,b,c) Diagram I, II and III represents heterogeneous mixture with non-uniform composition and properties.
14. (b, c)

FILL IN THE PASSAGE

I. (1) heterogeneous (2) lesser
(3) homogeneous (4) solutions,
(5) melting (6) boiling
(7) alloys

II. (1) mixture (2) Filteration
(3) volatile (4) magnetic separation
(5) boiling point

PASSAGE BASED QUESTIONS

1. (a) The constant temperature at point B indicates boiling point of first liquid out of two.
2. (c) When first component of mixture is boiled off the temperature of second component starts increasing.
3. (a)

ASSERTION & REASON

1. (c) Sea diver must be supplied air at a pressure equal to that of water surrounding the upper limit of oxygen pressure above which the oxygen becomes biochemically toxic. So, it is necessary to include something to dilute the oxygen in a diver's breathing gas by a non-toxic diluent N_2, He, etc.
2. (b)
3. (b) As different fractions of petroleum have very less difference in their boiling points. Thus refining of petroleum is done via fractional distillation.
4. (c) Essential oils and other oils are separated by method of steam distillation. The compounds which decompose at their boiling points are purified by vaccum distillation.
5. (a) They possess some properties of metals and some properties of non-metals.
6. (b) Hydrogen, oxygen and nitrogen are elements as they all are made up of similar kind of atoms only.

MULTIPLE MATCHING QUESTIONS

I. (A) (q, s); (B) →(p, r); (C) →(p); (D) →(s)

II. (A) (p, q); (B) →(r, s); (C) →(s); (D) →(p, r)

HOTS SUBJECTIVE QUESTIONS

1. To confirm whether the colourless liquid given is pure or not? We can proceed as follows:
   (i) Filter the given liquid using a very fine filter paper to see if it contains any suspended impurities. If any thing is left on filter paper the given liquid is impure. Otherwise it is pure.
   (ii) Evaporate a part of the given liquid in a china dish. If any residue is left it is impure and in case no residue is left it is pure.
   (iii) Determine the b.p. of the given liquid. If the b.p. is 100°C (373 K) it is pure water.
   [**Note:** B.P. of pure water is 373 K at 1atmospheric pressure]
2. (a) Chromatography. (b) Crystallisation
   (c) Decantation (d) Evaporation
   (e) Fractional distillation
3. (a) *Ice: Pure substance* (It is pure water in solid state) It is a component.
   (b) *Milk:* It is a heterogeneous mixture. Mixtures are *impure substance.*
   (c) *Iron*: *Pure substance* (It is an element)
   (d) *Hydrochloric acid:* It is an *impure substance*. It is a *homogeneous mixture*. It is a *solution of gas in a liquid.*
   (e) *Calcium oxide*: It is a *pure substance.* (It is a compound)
   (f) *Mercury*: It is a *pure substance*. (It is an element)
   (g) *Brick:* Heterogeneous mixture so *impure substance.*
   (h) *Wood:* Heterogeneous mixture so *impure substance.*
   (i) *Air:* It is homogeneous mixture so *impure substance.*
4. Ice is less dense than water. An ice water mixture is pure but heterogeneous in nature.
5. (a) Heterogeneous mixture
   (b) Homogeneous mixture
   (c) Pure substance
   (d) Homogeneous mixture.
6. (a) a solution (a solid dissolved in a liquid)
   (b) heterogeneous mixture (probably a solid suspended in a liquid such as dirty water)
   (c) element
   (d) compound
   (e) solution (two liquids)
7. C is a compound; it contains carbon and oxygen. A is a compound as it decomposes to give B which contains carbon and oxygen and C. B is not defined by the data given; it is probably a compound because few elements exist as white solids.
8. All mixtures of gases are homogeneous. In case of liquids similar liquid molecules form homogeneous mixtures, while very dissimilar molecules form heterogeneous mixtures

9. Ethyl alcohol and water mixture is considered as homogeneous mixture because in such a mixture there is no boundary of separation between two components (i.e., ethyl alcohol and water) and it exists in a single phase.

   In case of oil and water mixture we can see the boundary of separation between oil and water and there are two separate layers, one of water and other of oil is formed thus it is heterogeneous mixture.

10. Alloys contain two or more metals and have a variable composition so they are homogeneous mixtures. e.g., brass contains copper and zinc. Copper is a crystalline solid i.e. in copper atoms are closely packed to form a crystal lattice. When brass is formed some of these atoms of copper have been replaced by atoms of zinc (i.e., zinc atoms have substituted some copper atoms) and due to this brass is considered as *substitutional solid solution*.

11. The fractionating column obstructs the upward movement of vapours of the liquids and helps in absorptions of heat energy released by high boiling liquid to be taken up by low boiling liquid. Due to this the lower boiling liquid remains in vapour phase and the high boiling liquid condenses back to liquid phase and this condensed liquid falls back in the distillation flask. In this way fractionating column helps in the separation of two liquids.

12. C is a compound

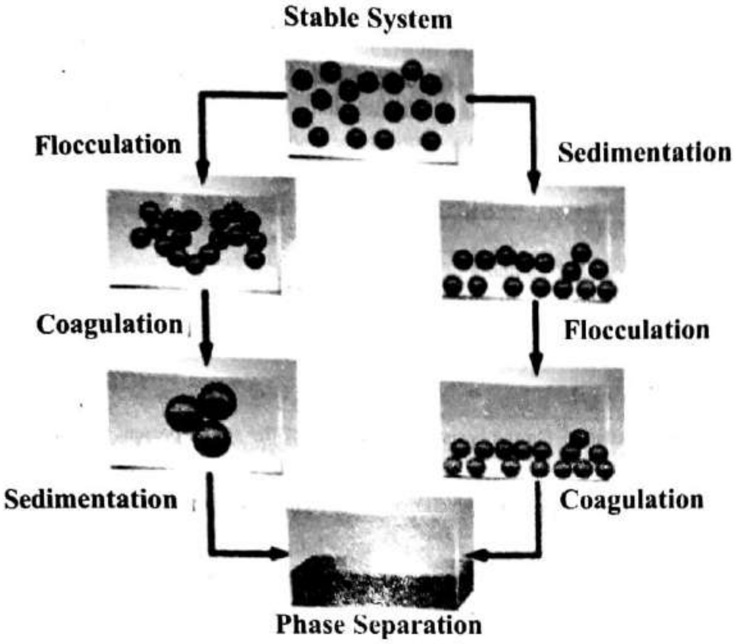
    Both the above observations are observed during formation of a compound.

13. No, only elements and compounds are pure substance. Air is a mixture and so not pure substance.

14. A compound is a single substance with a fixed composition and so it fulfills the condition required for a pure substance. The m.p. or b.p. of a compound is fixed. These conditions are not fulfilled by a mixture so it is not considered as a pure substance.

15. During chemical change substances may undergo decomposition or addition that is they themselves change. Therefore, separation of mixture by taking advantage of difference in their chemical properties is less convenient.

16. The particles of iron can be separated by magnet.



3
CHAPTER

Solutions

INTRODUCTION

Solutions are common in nature and are extremely important in all life processes, in all scientific areas, and in many industrial processes. The body fluids of all forms of life are solutions. Variations in their concentrations, especially those of blood and urine, give physicians valuable clues about a person's health. A solution is defined as a homogeneous mixture of substances in which no settling occurs. A solution consists of a solvent and one or more solutes, whose proportions vary from one solution to another. By contrast, a pure substance has fixed composition. The solvent is the medium in which the solutes are dissolved. The fundamental units of solutes are usually ions or molecules.

Solutions include many different combinations in which a solid, liquid, or gas acts as either solvent or solute. Usually the solvent is a liquid. For instance, sea water is an aqueous solution of many salts and some gases such as carbon dioxide and oxygen. Carbonated water is a saturated solution of carbon dioxide in water. Examples of solutions in which the solvent is not a liquid also are common. Air is a solution of gases with variable composition. Dental fillings are solid amalgams, or solutions of liquid mercury dissolved in solid metals. Alloys are solid solutions of solids dissolved in a metal.

It is usually obvious which of the components of a solution is the solvent and which is (are) the solute(s). The solvent is usually the most abundant species present. In a cup of instant coffee, the coffee and any added sugar are considered solutes, and the hot water is the solvent. If we mix 10 ml of alcohol with 90 ml of water, alcohol is the solute. If we mix 10 ml of water with 90 ml of alcohol, water is the solute. But which is the solute and which is the solvent in a solution of 50 ml of water and 50 ml of alcohol? In such cases, the terminology is arbitrary and, in fact, unimportant.

SOLUTION

Solution may be **defined as a homogeneous mixture of two or more pure substances, the relative ratio of which can be varied within certain limits**. Solution of two substances is the most common type of solution and is termed as **binary solution**. With three or four components it is referred as **ternary** or **quaternary** solution respectively. A solution, inspite of its homogeneous nature, retains the properties of its constituents. The two constituents of solution are

(i) Solvent (ii) Solute

Solvent is that component of the solution – –

(a) which is present in relatively large proportion in the solution

(b) whose physical state is the same as that of the resulting solution.

Solute is the component of solution which is present in relatively small proportion. For example, a solution of sugar in water (colourless solution) and a solution of copper sulphate in water (blue solution) have small quantities of sugar and copper sulphate respectively as solute dissolved in water as solvent.

Types of Solutions : Solutions can be categories in two ways.

(i) Depending on the amount of solute in solution: On the basis of the amount of the solute present in solution, solutions are classified as

(1) Dilute solution : The solution in which quantity of solute in a given mass of solvent is very small is called a dilute solution.

(2) Concentrated solution : The solution in which quantity of solute in a given mass of solvent is very large is called a concentrated solution.

(3) Saturated solution : If a solution contains dissolved solute equal to its solubility then it is called saturated solution.

(4) Unsaturated solution : A solution in which amount of solute dissolved is less than its solubility at that temperature and more solute can be dissolved in it is called unsaturated solution.

(5) Supersaturated solution : Sometimes it is also possible to dissolve more solute than its solubility. Such solutions are known as supersaturated solutions.

✔ CHECK POINT | A solution contains quantity of solute dissolved at temperature T. Now when more quantity of solute is added it remains undissolved, what kind of solution is that?

Check Your Answer

Saturated solution.

(ii) Depending on the Solute Particle Size in Solution– Based on the size of particles solutions are classified into three main catagories **1.** True solution **2.** Colloidal solution **3.** Suspension

1. True solutions : A solution in which the particles of the solute are broken down to such of fine state, that they cannot be seen under powerful microscope is called a true solution.

Characteristics of true solution :

(i) A true solution is always clear and transparent, i.e., light can easily pass through it without scattering.

(ii) The particles of solute break down to almost molecular size and their diameter is of the order of 1 nm (10^{-9} metre) or less.

(iii) A true solution can completely pass through filter paper as particle size of solute is far smaller than the size of pores of filter paper.

(iv) A true solution is homogeneous in nature.

(v) In a true solution, the particles of solute do not settle down, provided temperature is constant.

(vi) From a true solution, the solute can easily be recovered by evaporation or crystallisation.

Types of true solutions : Depending upon the physical states of the solute and the solvent, following combinations are possible for a true solution.

Solute	Solvent	Solution	Example
solid	solid	solid	certain alloys
liquid	solid	solid	Hg in Ag
gas	solid	solid	hydrogen gas in palladium metal
solid	liquid	liquid	sugar in water
liquid	liquid	liquid	petrol in kerosene
gas	liquid	liquid	soft drinks
solid	gas	gas	carbon in air (smoke)
liquid	gas	gas	fog
gas	gas	gas	air

Among the given solutions following combinations form the heterogeneous solutions therefore must not be considered as true solutions.

(i) solid - gas Example ; Storm
(ii) liquid - gas Example ; Aerosol
(iii) gas - solid Example ; Styrene foam
(iv) solid-solid Example ; Minerals

✓ CHECK POINT

(1) Suggest an alternate name for a homogeoneus mixture.

(2) Does a homogeneous mixture exhibit the characteristics of the constituents present?

Check Your Answer

(1) Homogeneous mixture are also called true solution.
(2) Yes, for example mixture of salt in water is also salty in taste as common salt.

In most of the cases water is taken as the solvent since it can dissolve a wide range of chemical compounds. Those solutions in which water is taken as the solvent are called aqueous solutions. Besides water other liquids can also be taken as solvents. Such solutions are called non-aqueous solutions.

Amongst the above described solutions, the most common and widely studied forms of solutions are

(a) Gas – liquid solutions
(b) Liquid – liquid solutions
(c) Solid – liquid solutions

(a) Gas-Liquid Solutions :

The gases are usually soluble in water as well in other solvents to a certain extent. The solubility of a gas in liquid depends on (i) *nature of the gas*, **(ii)** *the pressure applied*, **(iii)** *temperature* **and (iv)** *the nature of the liquid solvent.*

The solubility of a gas in liquid is defined as ***The mass of a gas dissolved in a given volume of a liquid at constant temperature is directly proportional to the pressure of the gas in equilibrium with the liquid.*** This is known as **Henry's law.**

So, if m be the mass of gas dissolved per unit volume of a solvent at pressure P then

$m \propto P$ at constant temperature

$m = K P$ where K is proportionality constant

In terms of mole fraction

$x = K_H P$

x — mole fraction of gas

p — partial pressure of gas over the solvent

KNOWLEDG NHANCER

Application of Henry's Law

(i) Bottler use the effect of pressure of solubility in producing carbonated beverages such as champagne, beer and soft drinks. These are bottled under a pressure slightly greater than one atmosphere. When the bottles are opened in air, the partial pressure of CO_2 above the solution decreases and CO_2 bubbles out from the solution.

(ii) The exchange of O_2/CO_2 at cellular level and in lungs is based on Henry's law.

(iii) In the breathing mixture for deep sea divers, N_2 is replaced by less soluble He, to minimize painful effects.

1. *Solubility of CO_2, HCl, NH_3 etc. in water can't be explained by using Henry's law, as they react with water*

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$
$$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$$
$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

2. *Solubility order of some gases in water is*

$$He < H_2 < N_2 < CO < O_2 < CO_2 < NH_3$$

3. *O_2 is less soluble in blood plasma than water but more soluble in blood (due to formation of oxyhemoglobin).*

Illustration 1 :

At 298 K and 1 atm pressure solubility of N_2 in water was found to be 6.8×10^{-4} mol/L. If partial pressure of N_2 is 0.78 atm, then what is the concentration of N_2 in water under atmospheric conditions?

SOLUTION:

We know $x = K_H \cdot P$

and given $x = 6.8 \times 10^{-4}$ mol/L; $P = 1$ atm

$\therefore$ $K_H = 6.8 \times 10^{-4}$ mol/L

Now at 0.78 atm pressure

$x = 6.8 \times 10^{-4} \times 0.78$ mol/L $= 5.3 \times 10^{-4}$ M

✔CHECK POINT **Which substance acts as solvent in aerated drinks?**

Check Your Answer

In case of aerated drinks like softdrinks and soda. Water acts as solvent and majorly CO_2 gas as a solute

(b) Liquid-Liquid Solutions :

When two liquids are mixed, three different types of situations may arise

(i) **The two components may be almost immiscible (Immiscible liquids) :** This situation arises when one of the liquids is polar while the other is of non-polar nature. For example, ether and water, carbon tetrachloride and water.

(ii) **The two components may be partially miscible :** In this case the intermolecular attraction of one liquid is greater than the intermolecular attraction of the other. However, by increasing the temperature the solubility can be increased e.g. aniline and water.

(iii) **The two components may be completely soluble (miscible liquids) :** If the two liquids are of the same nature or members of the same homologous series, then these are completely miscible e.g. alcohol and water (both being polar). Similarly, benzene and toluene are highly miscible (both being non-polar and members of the same homologous series). In other words we can state that **"like dissolves like"** i.e. chemically alike substances form completely miscible solutions.

✓CHECK POINT | **Given an example of a solution in which liquid acts as a solute as well as solvent.**

Check Your Answer

Solution of benzene in acetone is solution in which solute and solvent both are liquid.

IDEA BOX

Following is the list of some liquid-liquid solutions

- Gasoline and kerosene oil
- Ethanoic acid and water
- Oil and vinegar
- Formaldehyde and water
- Methoxybenzene and acetone
- Gasoline and water
- Water and triethylamine
- Silver and zinc in liquid

Categorize them into three separate categories of immiscible liquids, partially miscible liquids and miscible liquids. Also make a project report on topic of miscible and immiscible liquids. Project report should contain detailed explanation about one why some liquids are miscible while some are immiscible. Also suggest atleast method for separation of miscible and immiscible liquids. You can consult your teacher, science journals, internet, etc.

(c) Solid-Liquid Solutions :

In this type of solutions, the solid is referred as solute while the liquid is termed as solvent. To prepare this type of solution, relatively small amount of solute (usually inorganic ionic compounds) is dissolved in large quantity of water (solvent).

SOLUBILITY :

Solubility is the ability of the solvent (water) to dissolve the solute (sugar). The solubility of a solute is defined as the maximum amount that dissolves in a given amount of solvent at a specified temperature. When a specific amount of solvent contains the maximum amount of dissolved solute, the solution is said to be saturated. If less than the maximum amount is present, the solution is unsaturated. In certain unusual situations, an unstable condition may exist in which there is actually more solute present in solution than its solubility would indicated. Such a solution is said to be supersaturated. Supersaturated solutions often shed the excess solute if a tiny "seed" crystal of solute is added, or if the solution is shaken.

The solubilities of several compounds in water are listed in table.

Do You Know!!

Note that $PbSO_4$, $Mg(OH)_2$ and AgCl have very low solubilities and thus are considered insoluble.

$$\text{Solubility} = \frac{\text{Weight of solute in saturated solution}}{\text{Weight of solvent in saturated solution}} \times 100$$

Table : Solubilities of compounds (At 20°C)

Compound	Solubility (g solute/100g H_2O)
sucrose (table sugar)	205
HCl	63
NaCl	38
KNO_3	34
$PbSO_4$	0.04
$Mg(OH)_2$	0.01
AgCl	1.9×10^{-4}

Various Factors that Effect solubility are :

(i) Effect of temperature : Most solids and liquids are more soluble in water at higher temperatures. Unlike solids, gases become less soluble as the temperature increases. This can be witnessed by observing water being heated. As the temperature increases, the water tends to fizz somewhat as the dissolved gases are expelled.

✓ CHECK POINT **How high temperature in lakes could be a problem for aquatic life?**

Check Your Answer

High temperatures in lakes can be a danger for aquatic animals and may cause fish kills. The lower solubility of oxygen at the higher temperatures can lead to an oxygen-depleted lake.

(ii) Effect of pressure : Solubility also depends on pressure, When you increase the surrounding pressure, you can usually dissolve more gases in the liquid. Think about your soda can. They are able to keep the fizz inside because the contents of the can are under higher pressure.

(iii) Nature of solvent : Solvents with high value of dielectric constant can dissolve polar and ionic compounds to a larger extent than the solvents with low value of dielectric constants.

(iv) Nature of solute : Ionic compounds (or polar compound) are more soluble in water (i.e., a polar solvent). Non-polar compounds are more soluble in non-polar solvents like benzene.

(v) Size of solute particles : Smaller the size of the particles greater is the solubility. Example, it is easier to dissolve powdered sugar than granules of sugar.

(vi) Mechanical stirring : Mechanical stirring increases solubility. Example, sugar dissolves faster on stirring with a spoon.

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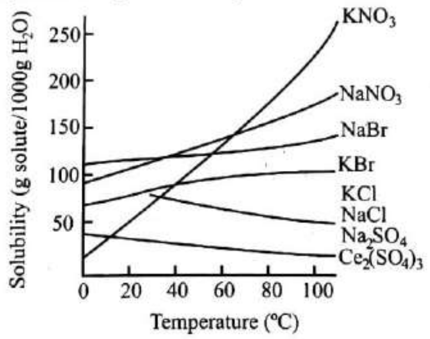
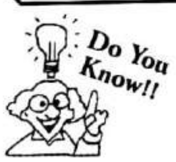
Solubility curves : The graphs which show the variation of solubility with temperature are called solubility curves. With the help of solubility curves solubility of any solute at a particular temperature can be find out.





1 Liter of water weigh approximately 1kg at 4°C. Thus the density of water at 4°C is 1 kg/L.

METHODS OF EXPRESSING CONCENTRATION OF SOLUTIONS

Following are the various ways of expressing concentration of solutions.

1. *Mass Percent*
2. *Volume percent*
3. *Normality*
4. *Molarity*
5. *Molality*
6. *Mole fraction*
7. *Mass fraction*
8. *Formality*
9. *Mole percent*

(1) Mass Percentage (% by weight).

The mass of the solute in gms per 100 g of the solution is termed as the mass percent.

Mathematically,

$$\%\text{ by weight} = \frac{\text{Weight of the solute}}{\text{Weight of the solution}} \times 100$$

For example, a 15% solution of urea in water (by mass) means that 15 g of urea is present in 100 g of solution. Similarly, a 10% solution of NaCl by weight means that 100 g of solution contains 10 g of NaCl.

Illustration 2

A syrup is prepared by dissolving 250g sucrose in 150 g of water. Calculate the mass per cent sucrose in the solution.

SOLUTION:

We know that

$$\text{Mass\%} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

However, Mass of solution = Mass of solute + Mass of solvent = 250 + 150 = 400 gm

$$\text{Mass\%} = \frac{250\text{g} \times 100}{400\text{g}} = 62.5\%$$

(2) Volume Percentage (% by volume).

It may be defined as the volume of solute in ml present in 100 ml of the solution.

$$\%\text{ by volume} = \frac{\text{Volume of the solute}}{\text{Volume of the solution}} \times 100$$

For example, a 20% solution of acetic acid (by volume) means 20 ml of acetic acid is present in 100 ml of solution.

(3) Normality (N) –

Normality of a solution may be defined as the number of gram equivalent of solute present per litre of the solution. It is denoted by N.

Mathematically,

$$N = \frac{\text{Gram equivalents of solute}}{\text{Volume of the solution in litres}}$$

$$N = \frac{\text{Weight of solute in gm}}{\text{Eq. wt. of solute} \times \text{volume of solution in litre}}$$

$$N = \frac{\text{Strength of solution in gm/litre}}{\text{Equivalent weight of solute}}$$

The unit of normality is **equivalent** lit^{-1}.

KNOWLEDGE ENHANCER

Gram equivalent mass of the solute can be determined by using the formula

$$\text{Gram equivalent mass} = \frac{\text{Molar mass}}{Z}$$

where Z is a whole number and represents

(i) the number of H^+ ions furnished by an acid molecule in solution i.e., basicity of an acid.

(ii) the number of OH^- ions furnished by a molecule of base in solution i.e., acidity of base.

(iii) the number of electrons involved in oxidation of a reducing agent or reduction of an oxidising agent.

Some common representations of the normality of solution are shown below.

N = Normal solution

$\frac{N}{2} = 0.5\text{ N}$ = Seminormal

$\frac{N}{5} = 0.2\text{ N}$ = Pentanormal

$\frac{N}{10} = 0.1\text{ N}$ = Decinormal

10 N = Decanormal

Illustration 3

Calculate the normality of NaOH solution containing 50.0 gm NaOH in 5.0 litre solution.

SOLUTION:

$$\text{Equivalent weight of NaOH} = \frac{\text{M.W. of NaOH}}{\text{Acidity of base}} = \frac{40}{1} = 40$$

$$\therefore \quad \text{No. of equivalents in 50.0 g NaOH} = \frac{50}{40} = 1.25$$

$$\text{Normality of NaOH solution} = \frac{\text{Equivalents of solute}}{\text{Volume of solution in litres}} = \frac{1.25}{5} = 0.25\text{N}$$

(4) Molarity (M) –

Molarity of a solution is defined as *the number of moles of the solute per litre of solution.* For example, a molar (1 M) solution of sugar means a solution containing 1 mole of sugar (i.e., 342 gm) per litre of the solution.

Thus mathematically,

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres}}$$

$$\text{or} \quad M = \frac{\text{Wt. of solute in gms}}{\text{Molecular wt. of solute} \times \text{Volume of solution in litres}}$$

Therefore, unit of molarity is **moles lit.$^{-1}$**. It is the most common way of representing the concentration of the solution.

Relationship between normality and molarity of a solution can be given by the undermentioned formula

Normality = Molarity $\times \dfrac{\text{Mol. wt.}}{\text{Eq. wt.}}$ *or × or maility = Molarily × Acidity of Base or Basicity of acid*

where acidity of base = No. of replaceable OH^- ion

and Basicity of Acid = No. of ***replaceable H+ ion.***

Molarity = Normality $\times \dfrac{\text{Eq. wt.}}{\text{Mol. wt.}}$

(5) Molality (m) :

Molality of a solution may be defined ***as the number of moles of the solute dissolved per 1000 g of the solvent.*** For example, a 0.2 molal (0.2 m) solution of glucose means a solution obtained by dissolving 0.2 gram mole of glucose in 1000 g (1 kg) of water.

Mathematically,

$$\text{Molality (m)} = \frac{\text{Moles of solute}}{\text{Mass of solvent in kilograms}}$$

$$\text{Molality (m)} = \frac{\text{No. of moles of solute}}{\text{Wt. of solvent in gms}} \times 1000$$

$$m = \frac{\text{Mass of solute in grams}}{\text{Molecular mass of solute}} \times \frac{1000}{\text{Wt. of solvent in gms}}$$

It is expressed in units of **moles kg^{-1}**.

The value of normality and molarity varies with temperature as the volume of solution containing equivalents or moles of the solute increases with rise in temperature. However, molality is temperature independent because here volume term is not involved.

Following is the relationship between molarity and molality derived from the formulae of molarity & molality.

$$\frac{\text{Molarity}}{\text{Molality}} = \frac{\text{Mass of solvent in kg}}{\text{Volume of solution in litre}}$$

(6) Mole Fraction (X)

It is defined as ***the ratio of the number of moles of one component (solute or solvent) to the total number of moles of all the components (solute plus solvent) present in the solution. It is denoted by 'X'***

Thus, $$X_{solute} = \frac{\text{Moles of solute}}{\text{Moles of solute} + \text{Moles of solvent}}$$

For example, in a solution containing n_1 moles of solute and n_2 moles of solvent, the mole fraction of solute (X_{solute}) and mole fraction of solvent ($X_{solvent}$) are

$$X_{solute} = \frac{n_1}{n_1 + n_2}, \quad X_{solvent} = \frac{n_2}{n_1 + n_2}$$

The sum of the mole fractions of all components present in the solution is always one and has no unit.

$$X_{solute} + X_{solvent} = \frac{n_1}{n_1 + n_2} + \frac{n_2}{n_1 + n_2} = 1$$

Mole fraction *of the components is always* ***temperature independent.***

Thus, in a binary solution, if we know the mole fraction of one component, the mole fraction of the other component can be calculated.

✎ Illustration 4 :

4.0 g of NaOH is contained in one decilitre of a solution. Calculate molality of solution and mole fraction of NaOH. [At. wt. Na = 23 ; O = 16; Density of NaOH solution is 1.038 g/cm³]

SOLUTION:

(a) Calculation of molality of solution

Moles of NaOH $= \frac{4}{40} = 0.1$ mole

Volume of solution = 1 Decilitre = 100 ml

Wt. of 100 ml solution of density 1.038 g/cm³ $= V \times d$
$= 100 \times 1.038$
$= 103.8$ g

So, the mass of the solvent = mass of the solution – mass of solute
$= 103.8 - 4 = 99.8$ g

$$\therefore \text{ Molality} = \frac{\text{Moles of solute}}{\text{Kg. of the solvent}}$$

$$= \frac{0.1}{99.8/1000} = \frac{0.1 \times 1000}{99.8} = 1.02 \text{ m}$$

(b) Calculation of mole fraction of NaOH.

Moles of NaOH = 0.1 mole

Mole of water in 99.8 g water $= \frac{99.8}{18}$
$= 5.55$ mole

$$\therefore \quad X_{NaOH} = \frac{\text{Moles of NaOH}}{\text{Moles of NaOH + Moles of water}}$$

$$= \frac{0.1}{0.1+5.55}$$

$$= \frac{0.1}{5.65}$$

$$= 0.017$$

(7) Mass Fraction :

Similar to mole fraction, mass fraction is defined as *the ratio of the mass of one component (solute or solvent) to the total mass of the solution (both components).* For a binary solution containing two components A and B, the mass fractions are

$$\text{Mass fraction of A} = \frac{w_A}{w_A + w_B}$$

$$\text{Mass fraction of B} = \frac{w_B}{w_A + w_B}$$

Illustration 5 :

Calculate mass fraction and mole fraction of ethyl alcohol and water containing 9.2 g alcohol in 18.0 g of water.

SOLUTION:

Mass of ethyl alcohol = 9.2g

Molecular mass of alcohol (C_2H_5OH) = 46 g mol^{-1}

Number of moles of alcohol in 9.2 g $= \frac{9.2}{46} = 0.2$ mol

Mass of water = 18g

So, number of moles of water $= \frac{18}{18} = 1.0$ mole

Mass fraction of alcohol $= \frac{9.2}{18+9.2} = \frac{9.2}{27.2} = 0.338$

$\therefore$ Mass fraction of water $= 1 - 0.338$

$= 0.672$

$$X_{ethanol} = \frac{0.2}{1.0+0.2} = \frac{0.2}{1.2} = 0.167$$

$$\therefore \quad X_{water} = 1 - 0.167$$

$$= 0.833$$

(8) Formality (F) :

The term formality was first of all used by Pauling to express the concentration of a solution. This is defined as *the number of gram formula weight of ionic solute present per litre of the solution.*

$$\text{Formality, } F = \frac{\text{Moles of the ionic solute}}{\text{Volume of solution in litres}}$$

$$= \frac{\text{Mass of the ionic solute in gram per litre}}{\text{Formula mass of solute}}$$

For example, formality of a solution containing 5.85 grams of common salt per litre of solution is 0.1 or the solution is 0.1 formal.

(9) Mole percent

Mole percent for a solution may be defined as the number of moles of a component (solute or solvent) in 100 moles of solute plus solvent.

Mathematically,

$$\text{Mole percent} = \text{Mole fraction} \times 100$$

For example, mole percent of a solution containing 6 moles of ethanol in 14 moles of water is calculated as follows

Mole fraction of ethanol, $X_{C_2H_5OH} = \frac{6}{6+14} = 0.3$

Therefore, Mole percent (ethanol) $= 0.3 \times 100 =$ **30 mole %**

KNOWLEDGE ENHANCER

When concentrations are extremely low, however, two closely related units become more convenient. These units are parts per million (ppm) and parts per billion (ppb), and they are particularly useful for expressing concentrations of trace amounts of a substance relative to the total amount. For example, one hears of dangerous dioxin levels in the soil in ranges of ppm and even ppb. Parts per million is obtained by multiplying the ratio of the mass of solute to mass of solution by 10^6 ppm rather than 100%. Parts per billion is obtained by multiplying the same ratio by 10^9 ppb. For example, if a solution has a mass of 1.00 kg and contains only 3.0 mg of a solute, it has the following concentration in percent by mass, ppm, and ppb.

$$\frac{3.0\times10^{-3}\,\text{g (solute)}}{1.0\times10^{-3}\,\text{g(solution)}}\times100 = 3.0\times10^{-4}\%$$

$$\frac{3.0\times10^{-3}\,\text{g}}{1.0\times10^{-3}\,\text{g}}\times10^{6}\,\text{ppm} = 3.0\,\text{ppm}$$

$$\frac{3.0\times10^{-3}\,\text{g}}{1.0\times10^{-3}\,\text{g}}\times10^{9}\,\text{ppb} = 3.0\times10^{3}\,\text{ppb}$$

CHECK POINT **How do we express the concentration of poisonous gases in air?**

Check Your Answer

The concentration of air pollutants like SO_2, SO_3, NO, NO_2 and CO_2 are expressed in ppmv (parts per million by volume).

SUSPENSION :

If we mix powdered sand with water and shake the mixture constantly, it appears to be somewhat homogeneous, but the sand particles soon settle when we stop shaking it. Nothing like this occurs when we dissolved salt or sugar in water. Small ions and molecules do not settle down in solution. The shaken mixture of sand and water is an example of a suspension. A supension may be defined as a heterogeneous mixture in which the solid particles are spread throughout the liquid without dissolving in it. They settle as precipitate if the suspension is left undisturbed for sometime. To form suspensions, particles must have dimensions larger than about 1000nm (1μm). Suspension that don't settle at once, like powdered sand in water, can nearly always be separated by filtration.

Properties of Suspension

1. A suspension is of heterogeneous nature. There are two phases. The solid particles represent one phase while the liquid in which these are suspended or distributed forms the other phase.
2. The particle size in a suspension is more than 100 nm (or 10^{-7}m).
3. The particles in a suspension can be seen with naked eyes and also under a microscope.
4. The solid particles present in the suspension can be easily separated by ordinary filter papers. No special filter papers are needed for the purpose.
5. The particles in a suspension are unstable. They settle down after sometime when the suspension is kept undisturbed. This is known as precipitate.

Other Example :

(i) Slaked lime suspension used for white-washing has particles of slaked lime suspended in water.

(ii) Paints in which the particles of dyes are suspended in turpentine oil.

IDEA BOX

You can perform an activity in your school lab or at home to differentiate between solution and suspension. Take two glass beakers of 500 ml and pour 250 mL of water in each of them. Now add 2 grams of common salt to one beaker and 1g of calcium carbonate to another beaker. Then stirr the contents in both beakers properly. First observe and list any differences or similarities between the two mixtures. Now darken the room and shine a flash light through each beaker and record your observations.

COLLOIDAL SOLUTION (COLLOIDS) :

When finely divided clay particles are dispersed throughout water, they eventually settle down of the water due to gravity. The dispersed clay particles are much larger than molecules and consist of many thousands or even millions of atoms. These type of mixtures are called suspensions. In contrast, the dispersed particles of a solution are of molecular size. Between these extremes lie dispersed particles that are larger than molecules, but not so large that the components of the mixture separate under the influeuce of gravity.

These intermediate types of dispersions are called colloidal dispersion, or simply colloids. Colloids form the dividing line between solutions and heterogeneous mixtures. Like solutions, colloids can be gases, liquids,or solids.

CHECK POINT **Can air be considered as colloid?**

Check Your Answer

No, sometimes it acts like as suspension due to smoke particulates, dust and fog. Generally air is considered as homogeneous mixture of gases.

Dispersed phase is the substance whose particles are dispersed in another phase. Actually particles of dispersed phase remain in colloidal range (i.e., 1– 200 nm). Whereas dispersion medium provides a medium for dispersion of particles. Dispersion medium consists of continuously inter linked molecules. Substance that tends to keep the colloidal particles far a part and prevents the growth of colloidal particles or coagulation is known as *stabilizing agent*.

Dispersed phase + Dispersion medium $\xrightarrow{\text{stabilizer}}$ colloidal system

(i) Classification of Colloids Based on the Physical State of the Dispersed Phase and Dispersion Medium.

Type	Dispersed phase	Dispersion medium	Common examples
Foam	Gas	Liquid	Soap suds, whipped cream
Solid foam	Gas	Solid	Pumic stone, polyurethane foam
Liquid aerosol	Liquid	Gas	Mist, fog, clouds, liquid air pollutants
Emulsion	Liquid	Liquid	Cream, milk, blood
Solid emulsion (gel)	Liquid	Solid	Butter, cheese, jams, jellies
Smoke	Solid	Gas	Dust, particulates in smog, storm
Sol	Solid	Liquid	Starch in water, proteins, starch, etc
Solid sol	Solid	Solid	Alloys, pearls, opals

CHECK POINT **Can we consider an alloy as a colloidal solution?**

Check Your Answer

Yes, alloys are colloidal solution in which dispersed phase and dispersion medium both are solid.

Do You Know!!

A substance is said to be in colloidal state when it is dispersed in another medium in the form of very small particles having size in the range 1-200 nm. (1×10^{-7} to 2×10^{-5} cm). The colloidal particle may consist of many atoms, ions, or molecules, or it may even be a single giant molecule. Gas in gas, always form homogeneous mixture and so never form colloids.

✓CHECK POINT | What is common in aqua sols and solid aerosols? How do they differ?

Check Your Answer

Aquasol and solid aerosol both have solid as the dispersed phase. They differ in dispersion medium. Aquasols have water as the dispersion medium while aerosols have gas as the dispersion medium.

(II) Classification Based on the Nature of Interaction Between Dispersed Phase and Dispersion Medium :

Colloidal systems, depending on the nature of interaction between the dispersed phase and the dispersion medium are classified into lyophobic (solvent hating) and lyophilic (solvent loving).

Do You Know!!

If water is the dispersion phase, then the colloids are either hydrophilic or hydrophobic.

(1) Lyophilic colloids : In this type of colloids, the dispersed phase has great attraction for the dispersion medium. In such colloids, the dispersed phase does not precipitate easily and the sols are quite stable. If the dispersion medium is separated from the dispersed phase, the sol can be reconstituted by simply remixing with the dispersion medium. Hence, these sols are called reversible sols. Examples of lyophilic sols include sols of gum, gelatin, starch, proteins and certain polymers in organic solvents.

(2) Lyophobic colloids : In this type of colloidal sols, the dispersed phase has little affinity for the dispersion medium. These colloids are easily precipitated on the addition of small amounts of electrolytes, by heating or by shaking and therefore are not stable. Once precipitated, it is not easy to reconstitute the sol by simple mixing with the dispersion medium. Hence, these sols are called irreversible sols. Examples of lyophobic sols include sols of metals and their insoluble compounds like sulphides and hydroxides. Lyophobic sols need stabilizing agents to prevent the dispersed phase from precipitating out.

Do You Know!!

Hydrophobic sols are often formed when rapid crystallization takes place. With rapid crystallization, many centres of crystallization called nuclei are formed at once. Ions are attracted to these nuclei and very small crystals are formed. These small crystals are prevented from settling out by the random thermal motion of the water molecules.

✓CHECK POINT | Why lyophilic colloidal sols are more stable than lyophobic colloidal sols?

Check Your Answer

This is because lyophilic sols are highly hydrated in the solution.

Differences Between Lyophilic and Lyophobic Colloids

	Property	Lyophilic colloids	Lyophobic colloids
1.	Ease of preparation	These are easily formed by direct mixing.	These are formed only by special methods.
2.	Reversible or irreversible nature	These are reversible in nature.	These are irreversible in nature.

3.	Particles nature	These particles of colloids are true molecules and are big in size.	The particles are aggregates of many molecules.
4.	Visibility	The particles are not easily visible even under ultramicroscope.	The particles are easily detected under ultramicroscope.
5.	Stability	These are very stable.	These are unstable and require traces of stabilizers
6.	Action of electrolytes	They are not easily precipitated by small amount of electrolytes. Very large quantities of electrolytes are required to cause coagulation.	They are easily precipitated by the addition of small amount of suitable electrolytes.
7.	Charge on particles	The particles do not carry any charge. The particles may migrate in any direction or even not under the influence of an electric field.	The particles move in a specific direction *i.e.*, either towards anode or cathode depending upon their charge.

CLASSIFICATION OF COLLOIDS BASED ON TYPE OF PARTICLES OF THE DISPERSED PHASE

(1) Multimolecular Colloids (2) Macromolecular Colloids (3) Associated Colloids.

1. Multimolecular Colloids :

In this type of colloids the colloidal particles are aggregates of atoms or small molecules with molecular size less than one nanometer (1 nm). For e.g., gold sol consists of particles of various sizes which are clusters of several gold atoms. The molecules in the aggregates are held together by Vander Waal forces. They have usually lyophilic character.

2. Macromolecular Colloids :

These are the substances having big size molecules (called macromolecules) which on dissolution form solution in which the dispersed phase particles have size in the colloidal range. Such substances are called **macromolecular colloids.** These macromolecules forming the dispersed phase are generally polymers having very high molecular masses. Naturally occurring macromolecules are starch, proteins and cellulose. Man made macromolecules are polymers such as polyethylene, nylon, plastics and polystyrene. These colloids are quite stable and resemble true solutions in many respects. They have usually lyophobic character.

3. Associated Colloids (Micelles) :

Certain substances behave as strong electrolytes at low concentration but at higher concentrations these substances exhibit colloidal characteristics due to the formation of aggregated particles. These aggregated particles are called micelles. Micelles are called associated colloids. The formation of micelles takes place only above a particular temperature called Kraft Temperature (T_k) and above particular concentration called the critical micelle concentration (CMC). For example, CMC for soaps is about 10^{-4} to 10^{-3} mol L^{-1}. On dilution, these colloids revert back to individual ions. Surface active molecules such as soaps and synthetic detergents form associated colloids in water. Micelles have both a lyophilic and lyophobic parts. Micelles may consists of more than 100 molecules.

✓ CHECK POINT | What type of colloidal sols are formed in the following?

(i) Sulphur vapours are passed through cooled water.

(ii) White of an egg is mixed with water.

(ii) Soap solution.

Check Your Answer

(i) Multimolecular because sulphur molecules associate together to form colloidal sol.

(ii) Macromolecular because protein molecules present in the white of the egg are macromolecules soluble in water.

(iii) Associated because $RCOO^-$ ions associate together to form micelles.

KNOWLEDGE ENHANCER

Mechanism of Micelle Formation

Micelles are generally formed by the aggregation of several ions or molecules with lyophobic as well as lyophilic parts. For example, sodium stearate ($C_{17}H_{35}COONa$) is a typical example of such type of molecules. The micelle may contain as many as 100 molecules or more. When sodium stearate is dissolved in water, it gives Na^+ and $C_{17}H_{35}COO^-$ ions.

$$\underset{\text{Sod. stearate}}{C_{17}H_{35}COONa} \rightleftharpoons \underset{\text{Stearate ion}}{C_{17}H_{35}COO^-} + Na^+$$

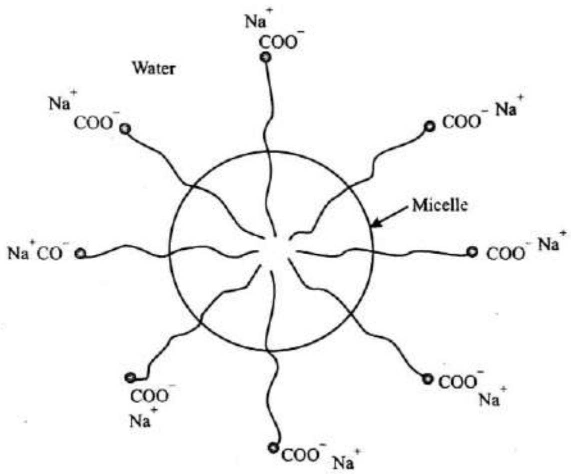
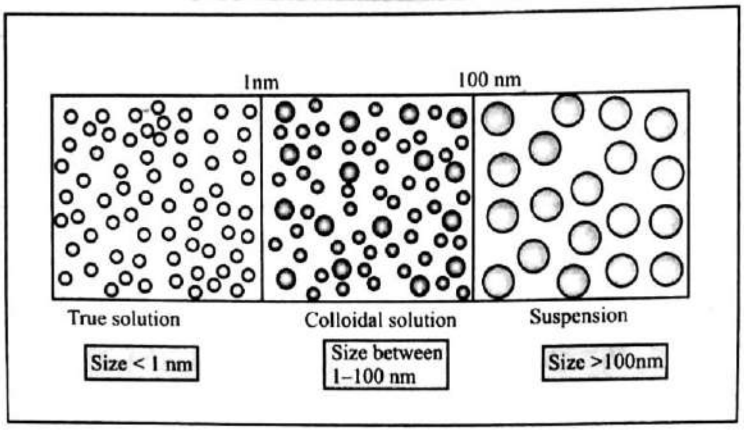


Fig : Aggregation of ions to form a micelle

The stearate ions associate to form **ionic micelles** of colloidal size. It has long hydrocarbon part of $C_{17}H_{35}$ radical which is lyophobic end and COO^- part which is lyophilic. In the figure, the chain correspond to stearate ion, $C_{17}H_{35}COO^-$. When the concentration of the solution is below its CMC (10^{-3} mol L^{-1}), it behaves as normal electrolyte. But above this concentration, it is aggregated to behave as micelles.

DIFFERENCE BETWEEN THE SOLUTION, COLLOIDAL SOLUTION AND SUSPENSION :

Property	True solutions	Colloidal solutions	Suspensions
• Particle size	Less than 10^{-7} cm	Between 10^{-5} and 10^{-7} cm	Greater than 10^{-5} cm
• Visibility of particles	Invisible to naked eye not visible under powerful microscope	Invisible to naked eye. Visible under powerful microscope	Easily visible
• Sedimentation of particles	Do not settle down	Settle down under high centrifugation	Settle down due to gravity
• Filtration through filter paper	No residue is formed	No residue is formed	Residue is formed
• Nature	Homogeneous	Heterogeneous	Heterogeneous
• Appearance	Transparent	Turbid	Opaque
• Diffusion through membranes	Readily	Diffuses slowly	Does not diffuse



PREPARATION OF COLLOIDS:

Preparation of lyophilic colloids needs no special method and the sol is easily prepared by bringing the D.P. in the contact of D.M. *e.g.*, colloids of gum, gelatin, agar-agar, proteins, starch etc. may be prepared by just shaking them with water. The two different techniques that can be employed to obtain a lyophobic sol are condensation methods and dispersion methods. In condensation method, as the name suggests, the atoms and molecules of the substance condense (aggregate) leading to the particles of colloidal dimension. The *condensation* can be brought about by both *physical* and *chemical* means.

Physical Methods :

(i) By exchange of solvent: A true solution of a solute in a solvent when mixed with another liquid (which is miscible with the solvent but does not dissolve solute in it) then a colloidal system is produced. For example, sulphur is molecularly dissolved in alcohol; an addition of excess amount of water to this solution produces colloidal solution of sulphur in water.

(ii) By excessive cooling: Cooling sometimes produces colloidal dispersions. An example of the method is to produce colloidal solution of ice in organic solvents like ether, chloroform etc., by freezing a mixture of solvent and water.

Chemical Methods :

(i) By hydrolysis: Addition of drop by drop of an concentrated solution of $FeCl_3$ on hot water result into hydrolysis of $FeCl_3$ to form$Fe(OH)_3$ solution.

$$FeCl_3 + 3H_2O \longrightarrow \underset{sol}{Fe(OH)_3} + 3HCl$$

Boiling of solution favours the reaction because the product HCl is removed in the form of vapours. $Cr(OH)_3$, $Al(OH)_3$ sols, etc, may also be prepared by this method.

(ii) By reduction: The colloidal solutions of metals are obtained by reduction of their compounds. For example, gold sol can be prepared on reducing a solution of gold (III) chloride with formaldehyde.

$$2AuCl_3 + 3HCHO + 3H_2O \longrightarrow \underset{sol}{2Au} + 3HCOOH + 6HCl$$

Gold sol can be prepared by reducing $AuCl_{3(aq)}$ by hydrazine or $SnCl_2$.

$$4AuCl_3 + 3NH_2NH_2 \longrightarrow \underset{sol}{4Au} + 3N_2 + 12HCl$$

$$2AuCl_3 + 3SnCl_2 \longrightarrow \underset{sol}{2Au} + SnCl_4$$

Colloidal sols of platinum, silver etc. can also be prepared in a similar manner.

Ni – Sol is obtained by heating solution of Ni $(CO)_4$ in benzene.

(iii) Oxidation: Sols of non-metals (like, S,P, etc,) are prepared by their oxidation. For example, sulphur sols are obtained when H_2S gas is bubbled through the solution of an oxidising agent like Br_2, HNO_3, Mn^{2+} etc. where H_2S is oxidized to elemental sulphur.

$$H_2S + Br_2 \longrightarrow 2HBr + \underset{sol}{S}$$

$$H_2S + 2HNO_3 \longrightarrow 2H_2O + 2NO_2 + \underset{sol}{S}$$

Do You Know!!

A colloidal solution of sulphur can also be obtained by adding dil. HCl to sodium thiosulphate.

$$Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + SO_2 + H_2O + \underset{sol}{S}$$

✓CHECK POINT **Which method is used to prepare phosphorus sol.**

Check Your Answer

Sol of phosphorus can be prepared by oxidation method.

(iv) Double decomposition: This method is often used to prepare various colloidal solutions. Sulphide sols are often obtained by this method. For example, on passage of H_2S through cold aqueous solutions of $AsCl_3$, $CdCl_2$, $Hg(CN)_2$, their sulphide sols are formed.

$$2AsCl_3 + 3H_2S \longrightarrow \underset{sol}{As_2S_3} + 6HCl$$

$$CdCl_2 + H_2S \longrightarrow \underset{sol}{CdS} + 2HCl$$

$$Hg(CN)_2 + H_2S \longrightarrow \underset{sol}{HgS} + 2HCN$$

Do You Know!!

Silver chloride sols, Barium sulphate sols are formed by allowing the following reactants to react in cold, dilute conditions.

$$AgNO_3 + NaCl \longrightarrow \underset{sol}{AgCl} + NaNO_3$$

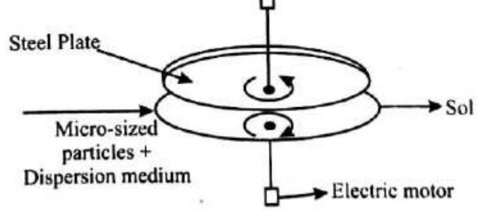
$$BaCl_2 + H_2SO_4 \longrightarrow \underset{sol}{BaSO_4} + 2HCl$$

Also, drop wise addition of $FeCl_3$ solution to solution of sodium ferrocyanide gives Prussian blue sol.

$$4FeCl_3 + 3Na_4[Fe(CN)_6] \longrightarrow Fe_4[Fe(CN)_4]_3 + 12NaCl$$

The dispersion methods employed for making lyophobic sols involve the following techniques.

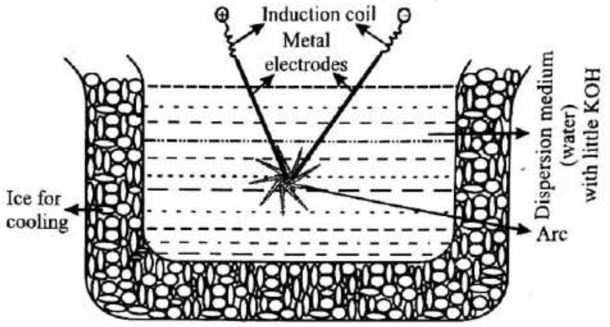
(i) Mechancial dispersion method : In this method, finely powdered substance (D.P.) is mixed with dispersion medium to obtain a coarse suspension, which is further introduced in colloidal mill. By this method, colloid of paints, varnishes, gammaxene, D.D.T. etc. are prepared.



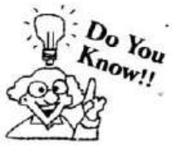
A colloidal mill

(ii) By Grinding method: This is a simple method for preparing metal sols (e.g., gold, platinum, silver and copper sol) and involves an electric arc between the two metal rods (made up of metal whose sol is to be prepored) partly dipped into the water as dispersion medium. The high electric arc tears the particles from rod (or wires) which are of colloidal size and remain dispersed in dispersion medium.

The heat generated during the process is removed by putting system under ice cold water. Little amount of KOH in water prevents growth of sol particles and stabilizes the dispersion. Purple of Cassius (Au sol in water) sol is obtained by this method.This method involves both dispersion and condensation, and is usually used to prepare metal sols like, Pt, Au, Cu, Ag, etc.



Bredig's arc method



This method is not suitable for sols having organic disperstion medium.

(iii) Peptization : The phenomenon of converting fresh precipitate into colloidal state by the action of electrolytesolute or solvent is known as peptization. The solute or solvents used are known as peptizing agents.

For example

(a) Freshly precipitated $Fe(OH)_3$ turns into colloidal state by the action of $FeCl_3$.

(b) Freshly precipitated stannic acid can be peptized by $NH_{3(l)}$ or HCl_{aq}.

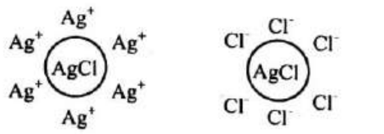
(c) Freshly precipitated HgS, CdS and NiS can be peptized by H_2S.

(d) Peptization of albumin in water of nitrocellulose in acetone or ethyl alcohol to form collodion.

The process of peptization thus involves the adsorption of suitable ions (supplied by the electrolyte added – particularly a common ion) and then split of electrically charged particles from the precipitate as colloidal particles. A coarse suspension of silver chloride on shaking with electrolytes produces AgCl sol. Shaking of AgCl suspension with $AgNO_3$ solution produces positively charged AgCl sol due to adsorption of Ag^+ ions whereas shaking of AgCl suspension with HCl produces negatively charged AgCl sol due to adsorption of Cl^- ions.

$$\underset{\text{precipitate}}{AgCl} + \underset{\text{From electrolyte}}{Ag^+} \longrightarrow \underset{\text{colloidal sol}}{AgCl.Ag^+}$$

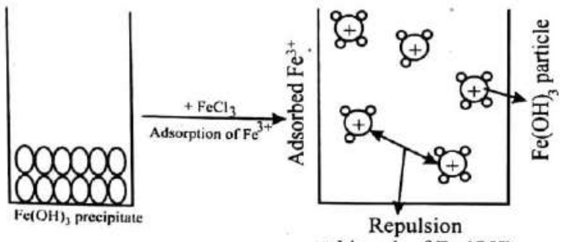
$$\underset{\text{precipitate}}{AgCl} + \underset{\text{From electrolyte}}{Cl^-} \longrightarrow \underset{\text{colloidal sol}}{AgCl.Cl^-}$$



+ve colloid –ve colloid

KNOWLEDGE ENHANCER

Mechanism of Peptization : The peptizing action of peptizing agent is due to preferential adsorption of common ion of electrolyte on to the surface of precipitate. As a result of adsorption, particle of precipitate acquires charge (+ve or – ve, depending upon nature of ion adsorbed) and thus are pushed apart giving a sol. Peptizing action of $FeCl_3$ when added in fresh precipitate of $Fe(OH)_3$ is shown in the Fig.



Peptization

✓CHECK POINT **What happens when a freshly prepared Fe $(OH)_3$ is shaken with a little amount of dilute solution of $FeCl_3$?**

Check Your Answer

Peptization takes place forming a positively charged colloidal sol of $Fe(OH)_3$.

PURIFICATION OF SOLS:

Sols so obtained are contaminated with two types of impurities and need purification.

(a) Insoluble impurities :

These are removed by simple filtration of impure sols. Impurities are retained on filter paper and sols are filtered.

(b) Soluble impurities :

The soluble impurities either of molecular nature or of ionic nature in colloidal solutions need special methods for their removal from sols.

Following techniques are used for this purpose :

Dialysis: The separation of soluble impurities from a colloidal solution on the basis of their different rates of diffusion through parchment membrane (or cellophane sheet) is known as dialysis.

This can be done by using a bag made of a semipermeable membrane. It has small pores which allows the small molecular / ionic species to pass through but not the colloidal particles which are larger in size as compared to the membrane pores. Thus, a colloidal solution is filtered in the bag (figure a) which is tied on the mouth and suspended in the liquid (the dispersion medium). Slow diffusion of molecules/ions from colloidal solution to the outer medium purifies the sol.

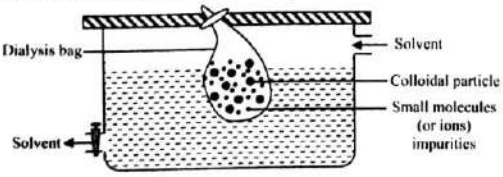


Figure: (a)

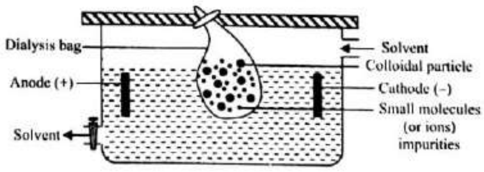


Figure: (b)

The dispersion medium or solvent which is distilled water generally is changed frequently to avoid accumulation of the crystalloids otherwise they may start diffusing back into the bag.

In case of ionic nature of impurities, dialysis can be speeded up by taking an advantage of electricity and the process is known as electrodialysis (figure b).

Do You Know!!

- *Kidneys in the human body act as dialysers to purify blood which is of colloidal nature. The most important application of dialysis process is the artificial kidney machine used for the purification of blood of the patients whose kidneys have failed to work. The artificial kidney machine work on the principle of dialysis.*
- *The condition at which the colloidal particles have no charge is known as isoelectric point.*

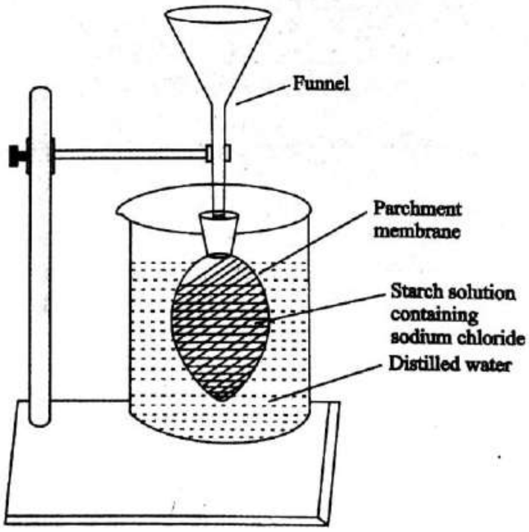
CHECK POINT **What happens when persistent dialysis of a colloidal solution is carried out?**

Check Your Answer

The stability of a colloidal sol is due to the presence of a small amount of the electrolyte. On persistent dialysis, the electrolyte is completely removed. As a result, the colloidal sol becomes unstable and gets coagulated.

IDEA BOX

- **Take a parchment membrane and fold it into shape of bag and Tie one end with stem of funnel attached to clamp stand as shown in figure.**



Now fill the parchment bag with starch sol containing common salt (NaCl). Take a 500 mL beaker and fill it three-fourth with distilled water and dip the parchment bag into distilled water. Now fix the position of funnel by means of clamp stand. Then allow to stand for about half an hour. After that withdraw few mL of water from beaker into two test tubes. Now add few drops of iodine to one and few drops of $AgNO_3$ solution to another test tube. Record your observations and on the basis of that draw a conclusion.

SPECIAL PROPERTIES OF COLLOIDS

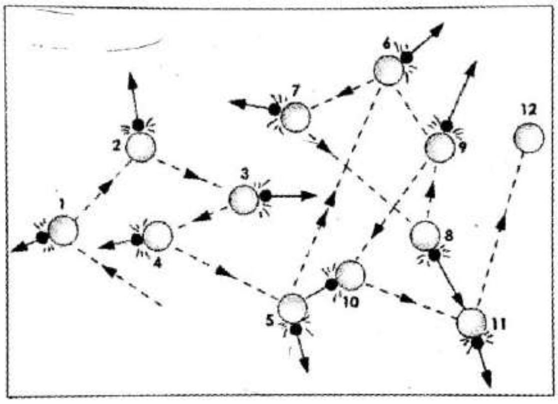
(1) Colligative Properties:

Like true solutions, colloidal solutions also exhibit colligative properties such as osmotic pressure, elevation in boiling point, depression in freezing point, lowering in vapour pressure. Since colligative properties of a solution depends upon the number of particles present in solution as well as on their weight. Since in colloidal state, there exists aggregates of thousands of molecules of high molecular weight and thus number of particles being relatively lower than true solutions and therefore the colligative properties are lesser than those observed for true solutions containing the same amount.

(2) Brownian Movement :

English Botanish Robert Brown noticed the irregular or chaotic motion of particles suspended in water. This was later on named as Brownian motion.

When a colloidal solution is viewed through a powerful microscope, the colloidal particles can be seen moving in a random zig-zag path. This zig-zag motion of colloidal particles is called Brownian movement. This random motion is due to collisions between the colloidal particles.



Brownian movement of colloidal particles

Example, when a beam of light passes through a dark room, the dust particles can be seen moving in rapid, random fashion.

(3) Electrophoresis :

Colloidal particles move towards the oppositely charged electrode when an external electrical field is applied. This phenomenon is called electrophoriesis. On applying direct current (dc), colloidal particles move and coagulate.

When electrophoresis, i.e., movement of particles is prevented by some suitable means, it is observed that the dispersion medium begins to move in an electric field. This phenomenon is termed electroosmosis.

(4) Tyndall Effect:

All colloidal solutions are capable of scattering light or opalescence.

When a beam of converging rays falls in colloidal solution, scattering of light by sol particles in all the directions, gives rise to a bright glowing cone when looked at it sideways. This is known as Tyndall effect.

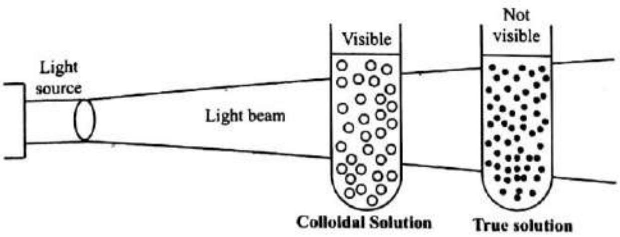


Figure: *Light scattering by colloid dispersions (Tyndall effect)*

The solution particles absorb light, become self luminous and then scatter light in all possible directions.

Some examples of Tyndall effect are:

(i) Blue colour of sky and sea water.

(ii) Visibility of tails of comets.

(iii) Twinkling to stars.

(iv) Visibility of sharp ray of sunlight entering through a slit in dark room.

(v) Visibility of projector path and circus light.

IDEA BOX

You can perform an activity in you school lab to understand tyndall effect. Take a wooden box, which is fitted with a convex lens on one side and a microscope on the other side, containing soap solution inside the wooden box. Place a powerful bulb on the side of convex lens and move it backward or forward till a narrow parallel beam of light is formed. Look through microscope and record your observations.

THE STABILITY AND INSTABILITY OF COLLOIDS AND COAGULATION:

The stability of a colloidal dispersion means it to remain in unaltered condition over a certain period of time. The instability means the breaking down of a colloidal dispersion into two phases.

(i) Spontaneous breaking up of a colloidal solution, i.e., the separation of dispersed phase from dispersion medium or destabilization of sol is known as ageing.

(ii) Destabilization of sols may also be made by artificial means and the phenomenon is known as **coagulation**.

The stability of a colloidal dispersion is usually achieved by using finer particles, inducing charge on the particles by addition of small quantity of electrolyte or by using the dispersion medium of high viscosity. Stable lyophobic dispersions can also be made by the coating of some polymers like starch, gelatin, gum, etc. Conversely, the instability or the coagulation of sol can be achieved by adding a substance (called coagulant) which will remove the protective layer or will neutralize the charge from the surface of colloidal particles by addition of excess of electrolyte. As a result particles of dispersed phase come closer grow in size and ultimately form precipitates.

Following are some applications of coagulation or flocculation :

(a) Coagulation of latex (sol) gives rubber.

(b) $BaCl_2$ solution is added to As_2S_3 sol., the Ba^{2+} ions are attracted by the negatively charged sol particles and their charge gets neutralised. This leads to coagulation.

(c) River water contaminated with various sol particles in it, on meeting with ocean shows their coagulation by salts present in sea water and forms delta.

KNOWLEDGE ENHANCER

According to **Hardy Schulze rule,** *greater the valency of the active ion or flocculating ion, greater will be its coagulating power.*

Thus, according to Hardy Schulze rule:

(*i*) The ions carrying the charge opposite to that of sol particles are effective in causing coagulation of the sol.

(ii) Coagulating power of an electrolyte is directly proportional to the valency of the active ions (ions causing coagulation.) For example, to coagulate **negative sol of As_2S_3**, the coagulating power of different cations has been found to **decrease** in the order as:

$$Al^{3+} > Mg^{2+} > Na^{+}$$

Similarly, to coagulate a **positive sol** such as $Fe(OH)_3$, the coagulating power of different anions has been found to **decrease in the order:**

$$[Fe(CN)_6]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^{-}$$

The *minimum concentration of an electrolyte which is required to cause the coagulation or flocculation of a sol is known as* **flocculation value.** It is usually expressed as millimoles per litre.

Blood (a colloid) is not coagulated by electrolytes present in blood (like, NaCl, $Ca_3(PO_4)_2$ etc.) because the proteins present in blooa serum are better protective colloids.
The proteins which are not coagulated at its iso-electric point are better protective colloid.

Illustration 6 :

In a coagulation experiment, 5mL of As_2S_3 is mixed with distilled water and 0.1M solution of an electrolyte AB so that total volume is 10mL. It was found that all solutions containing more than 4.6mL of AB coagulate within 5 minutes. What is the flocculation value of AB for As_2S_3Sol.?

SOLUTION:

A minimum of 4.6 mL of AB is required to coagulate the sol. The moles of AB in the sol is

This means that a minimum of 0.046 moles or 0.046 × 1000 = 46 millimoles are required for coagulating 1 litre of sol.

∴ Flocculation value of AB for As_2S_3 sol. = 46

CHECK POINT **What happens when a colloidal sol of Fe $(OH)_3$ is mixed with that of As_2S_3?**

Check Your Answer

$Fe(OH)_3$ sol being positively charged whereas As_2S_3 being negatively charged, their charges are neutralized on mixing. Hence, their mutual precipitation (coagulation) occurs.

PROTECTION OF COLLOIDS :

Lyophobic sols are less stable than lyophilic sols. However, their stability may be increased on addition of lyophilic sols. This phenomenon of stabilizing lyophobic sols by the addition of lyophilic colloids is known as protection. The lyophilic colloids used for this purpose are known as protective colloids. The protective colloids form a thin layer around the dispersed phase of lyophobic colloids and thus prevent them from coming close to each other and stabilize them. The protective character of various lyophilic substances is expressed in terms of gold number. Gold number of lyophilic substance is defined as "*the minimum amount of lyophilic colloid in milligrams which prevents the coagulation of 10 ml gold sol by 1 ml of 10% NaCl solution.*"

More is the gold number, lesser is the protective power of lyophilic colloid.

Substance	**Gold Number**
Gelatin	0.005 – 0.01
Haemoglobin	0.03 – 0.07
Gum Arabic	0.15 – 0.25
Sodium oleate	0.04 – 1
Starch	15 – 25

Gelatin, protein, gums and other macromolecular substances etc. are popular protective agents. A hydrophilic substance does not protect all hydrophobic colloids and protecting power varies for different lyophobic sols.

It may be noted that smaller the value of the gold number, greater will be protecting power of the protective colloid. Therefore, reciprocal of gold number is a measure of the protective power of a colloid.

Illustration 7

The coagulation of 100 mL of a colloidal solution of gold is completely prevented by the addition of 0.25g of starch to it before adding 1 mL of 10% NaCl solution. Calculate the gold number of starch.

SOLUTION:

Amount of starch added to 100 mL of gold sol. required to prevent coagulation of 1 mL of 10% NaCl solution

= 0.25g

or = 250 mg

Starch required to be added to 10 mL of gold sol. to completely prevent coagulation by 1 mL of 10% NaCl solution.

$$= \frac{250}{100} \times 10 = 25 \text{ mg}$$

∴ Gold number of starch = 25.

✓ CHECK POINT **What is the significance of reciprocal of 'gold number'?**

Check Your Answer

Smaller the gold number, greater is its protective power. Hence, reciprocal of gold number is a direct measure of the protective power of the colloid.

APPLICATIONS OF COLLOIDS :

Colloidal dispersions play a very significant role in natural processes in our daily life and in industries. Some of the important applications of colloids are following.

1. Food:

Most of our food preparations are colloidal in nature. Milk, butter and cream are example of emulsions, jam, jellies, ice-creams, salad dressing, bread etc., are all examples of food colloids.

2. Medicines:

Most drugs (insoluble in water) are administered as colloidal dispersions namely suspensions, emulsions. In the colloidal form the drug is easily absorbed by body tissues and is therefore more effective. Most skin ointments are emulsions.

3. Detergency:

Soaps and detergents by themselves are lyophilic colloids and therefore the entire detergent industry involves colloids.

4. Water Treatment:

Suspended/colloidal particles of undesirable muddy mass need to be removed before making water fit for drinking. The water cleansing process involves the coagulation of the suspended material by alum or high molar mass polyelectrolytes in water treatment plants.

Do You Know!!

- *Rivers carrying muddy water as suspension when come near sea, the high salinity (salt content) of the sea cause suspension to coagulate which ultimately settle down at the point of contact. As a result, the level of the river bed rises. Thus, there is the formation of the delta at the point where the river enters the sea.*
- *Artificial rain can be made by coagulating the water containing clouds in the sky.*
- *Colloidal $Fe(OH)_3$ is given to a person having poisoning due to arsenic because it absorbs arsenic and then can be vomited out.*

5. Rubber Industry:

Latex is a colloidal solution of negatively charged colloidal rubber particles. Rubber can be obtained from latex by coagulation.

6. In Metallurgical Operations :

Emulsions play an important role in industry. The metal ores are concentrated by froth-floatation process which involves the treatment of the pulverised ore in emulsion of pine oil.

EMULSIONS :

Emulsions are colloidal solutions in which both the dispersed phase and dispersion medium are liquids. Emulsions are broadly classified into two types. (i) Oil-in-water emulsion (ii) Water-in-oil emulsion. The substances which are added to stabilize the emulsions are called **emulsifier** or **emulsifying agent.** The substance that are commonly used as emulsifying agents are gum, soap of different forms, gelatin, albumin etc.

(I) Oil In Water Emulsion :

In this type of emulsion oil is the dispersed phase, while water is the dispersion medium. Examples are milk and vanishing cream.

Milk is an emulsion of soluble fats in water and here casein acts as an emulsifier. Vanishing cream is another example of this class. Such emulsions are called **aqueous emulsions.**

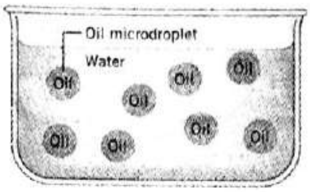


Figure : An oil-in-water emulsion

✓CHECK POINT | **Gelatin is generally added to ice creams. Why?**

Check Your Answer

Ice cream is an emulsion of milk or cream in water, i.e., oil-in-water type. Gelatin is added to act as an emulsifier, i.e., it helps to stabilize the emulsion.

(ii) Water in Oil Emulsion :

In this type of colloidal system water is the dispersed phase and oil acts as the dispersion medium. Examples of water in oil emulsions are butter, cold cream, cod liver oil and margarine (in which a soyabean product is the emulsifying agent).

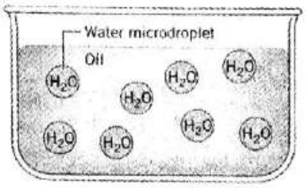


Figure : A water-in-oil emulsion

It may be noted that the two types of emulsions can be interconverted by simply changing the ratio of the dispersed phase and dispersion medium.

Emulsification is the process of making emulsions. Emulsions are made by shaking the dispersed phase and dispersion medium vigorously and then stabilizing the emulsion with an emulsifier. Most often soaps and detergents are added to stabilize emulsions. Stabilization is obtained by the coating of the drops of an emulsion by the stabilizer. This prevents the drops of the emulsion from combining together and separating out as a separate layer. The separation of an emulsion into its constituent liquids is called demulsification. The various methods used for demulsification are freezing, boiling, centrifugation, electrostatic precipitation or chemical methods which destroy the emulsifying agents.

EXERCISE 1

FIB Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. A solution with solute equal to its solubility is called ....solution.
2. Ionic compounds are more .... in water.
3. .... the size of the particles greater is the solubility.
4. Particles of .... solution can not be seen even under powerful microscope.
5. Suspension particles should have size larger than ....
6. In colloidal solution particle size should be between .... to ....
7. In emulsion both dispersed phase and .... are liquids.
8. .... involves movement of dispersed phase particle under electric field..
9. Chemical methods for preparation of colloids are hydrolysis, reduction, oxidation and ....
10. Most of the .... are administered as colloidal dispersions.
11. A solution is a .... mixture of two more substances. The major component of a solution is called the .... and the minor, the ....
12. Materials that are insoluble in a solvent and have particles that are visible to naked eyes, form a .... A suspension is a .... mixture.
13. Colloids are .... mixtures in which the particle size is too .... to be seen with the naked eye, but is big enough to scatter light.

T/F True/False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Like solids solubility of gases also increases with increase in temperature.
2. Sugar mixed in water is an example of suspension.
3. Mechanical stirring increases the solubility.
4. In smoke dispersed phase is solid whereas dispersion medium is gas.
5. In Lyophobic colloids, the dispersed phase has little affinity for the dispersion medium.
6. In suspensions particles do not settle down due to gravity.
7. Light beam becomes visible when passed through colloidal solution.
8. Dialysis involves difference in rate of diffusion of particles of dispersed phase and dispersion medium.
9. Sulphur sols are obtained by oxidation.
10. Deltas are formed in rivers carrying muddy water as suspension.
11. A suspension is a heterogeneous mixture.
12. A colloidal solution is heterogeneous in nature.
13. All solutions are mixtures, but not all mixtures are solutions.

MTC Match the Column

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in Column I have to be matched with statements (p, q, r, s) in Column II.*

I.

Column I	Column II
(A) Foam	(p) Whipped cream
(B) Emulsion	(q) Jellies
(C) Smoke	(r) Particulates in smog
(D) Gel	(s) Milk

II.

Column I	Column II
(A) Hydrolysis	(p) Sulphur sol
(B) Reduction	(q) $Fe(OH)_3$ sol
(C) Oxidation	(r) AgCl sol
(D) Double decomposition	(s) Gold sol

VSAQ Very Short Answer Questions

DIRECTIONS : *Give answer in one word or one sentence.*

1. What are colloids?
2. What are suspension?
3. Define solubility of solute and how does it vary with temperature?
4. In which range lies the size of colloidal particles?
5. If the path of light becomes visible on being passed through a solution, what type of solution is it?
6. Mass percent is one of the methods of expressing the concentration of a solution. In this methods what are the units of mass percent?
7. Name the dispersed phase and dispersion medium in case of an emulsion.

8. Name the dispersed phase and dispersion medium in case of dust-storm?
9. Give one example of a solution of gas in a liquid.
10. Which type of emulsion is milk?
11. Do suspension show the property of Tyndall effect?
12. Can we separate the components of a suspension by process of filtration?
13. Name the type of dispersed phase and dispersion medium in haze.
14. What type of change is burning of candle?
15. What is an aqueous solution ?
16. What is coagulation ?
17. What is emulsification ?
18. What is the number of components in a binary solution ? Name them.
19. Is a colldioal system homogeneous or heterogeneous?
20. Are the sols of metals hydrophobic or hydrophilic?
21. Define emulsification.
22. Why do colloidal solutions exhibitTyndall effect?
23. What happens when gelatin is added to gold sol?
24. How will you obtain a colloidal sol of arsenious sulphide?
25. What happens when an eletric field is applied to a colloidal dispersion?
26. Give an example of an associated colloid.
27. What type of substances form lyophobic sols?
28. What is collodion?

SAQ Short Answer Questions

DIRECTIONS : *Give answer in 2-3 sentences.*

1. Which one shows Tyndall effect and why ? True solution or colloidal solution.
2. Explain the cleansing action of soap.
3. Will the solubility of common salt in water decrease or increase with increase in temperature? Explain your answer.
4. What will happen if a saturated solution is
   (a) heated - (b) cooled
5. If we mix musturd oil with water, what type of colloidal solution is formed ?
6. What is meant by a non-aqueous solution ? Give one example.
7. Explain Brownian movement.
8. Write two differences between sols and emulsions.
9. Write two differences between multimolecular colloids and macromolecular colloids.
10. A solution contains 30 g of sugar dissolved in 370g of water. Calculate the concentration of this solution.
11. A solution is prepared by dissolving 2 g of solute (X) in 100 g H_2O. What is the percentage by mass concentration of solute ?
12. A solution contains 40 ml of ethanol mixed with 100 ml of water. Calculate the concentration in terms of volume by volume percentage of the solution.
13. If 110g of salt is present in 550g of solution, calculate the concentration of solution.
14. Identify the solutions among the following mixtures :
    (a) Soil (b) sea wate (c) air
    (d) coal (e) soda water
15. A solution contains 40g of common salt dissolved in 320 mL of water. Calculate the mass concentration of the solution.
16. 9.72 g of potassium chloride dissolves in 30g of water at 70°C. Calculate the solubility of potassium chloride at that temperature.
17. What is the main cause of charge on a colloidal solution?

LAQ Long Answer Questions

DIRECTIONS : *Give answer in four to five sentences.*

1. How are true solution, colloidal solution and suspension different from each other.?
2. Mention in detail about various applications of colloids
3. Explain in detail about classification of solution on the basis of amount of solute.
4. Discuss chemical methods for preparation of colloids in detail
5. What is a centrifuge ?
6. Diffrentiate between multimolecular, macromolecular and associated colloids.

EXERCISE 2

Multiple Choice Questions

DIRECTIONS : *This section contains 40 multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. If 18 g of glucose ($C_6H_{12}O_6$) is present in 1000 gm of an aqueous solution of glucose it is said to be
   (a) 1 molal (b) 1.1 molal
   (c) 0.5 molal (d) 0.1 molal
2. The amount of $KMnO_4$ required to prepare 100 ml of 0.1 N solution in alkaline medium is
   (a) 1.58 gm (b) 3.16 gm
   (c) 0.52 gm (d) 0.31 gm
3. 1.0 gm of pure calcium carbonate was found to require 50 ml of dilute HCl for complete reaction. The strength of the HCl solution is given by
   (a) 4 N (b) 2 N
   (c) 0.4 N (d) 0.2 N
4. The 5.85 g of NaCl and 1 kg of water is added to prepare a solution. What is the strength of NaCl in this solution ? (Molecular weight of NaCl = 58.5)
   (a) 0.1 Normal (b) 0.1 Molal
   (c) 0.1 Molar (d) 0.1 Formal
5. The molarity of pure water is
   (a) 55.6 (b) 50
   (c) 100 (d) 18
6. The number of moles of hydroxide (OH^-) ion in 0.3 litre of 0.005 M solution of $Ba(OH)_2$ is
   (a) 0.0075 (b) 0.0015
   (c) 0.0030 (d) 0.0050
7. Mole fraction of glycerine, $C_3H_5(OH)_3$ in a solution containing 36 gm of water and 46 gm of glycerine is
   (a) 0.46 (b) 0.40
   (c) 0.20 (d) 0.36
8. The no. of moles of KCl in 1000 ml of 3M solution is :
   (a) 1 (b) 2
   (c) 3 (d) 1.5
9. Which one of the following is not affected by temperature?
   (a) Molarity (b) Molality
   (c) Normality (d) Mole fraction
10. How many gm of CH_3OH would have to be added to water prepare 150 ml of a solution that is 2 M CH_3OH?
    (a) 9.6×10^3gm (b) 9.6 gm
    (c) 9.6×10^2 gm (d) 24 gm
11. Number of moles of a solute per kilogram of a solvent is called
    (a) molarity (b) normality
    (c) molality (d) formality
12. Normal solution is :
    (a) inert solution
    (b) acidic solution
    (c) one litre containing one equivalent
    (d) basic solution
13. An arsenious sulphide sol carries a negative charge. The maximum precipitating power for this sol is possessed by
    (a) K_2SO_4 (b) $CaCl_2$
    (c) Na_3PO_4 (d) $AlCl_3$
14. The extra stability of lyophilic colloids is due to
    (a) charge on their particles
    (b) a layer of medium of dispersion on their particles
    (c) the smaller size of their particles
    (d) the large size of their particles
15. Which of the following is a colloid ?
    (a) Sugar solution (b) Urea solution
    (c) Silicic acid (d) NaCl solution
16. Smoke is an example of
    (a) gas dispersed in liquid
    (b) gas dispersed in solid
    (c) solid dispersed in gas
    (d) solid dispersed in solid
17. Substances whose solutions can readily diffuse through parchment membrane are
    (a) colloids (b) crystalloids
    (c) electrolytes (d) non electrolytes
18. When dispersed phase is liquid and dispersion medium is gas then the colloidal system is called
    (a) smoke (b) clouds
    (c) jellies (d) emulsions
19. When a colloidal solution is observed under an ultramicroscope, we can see
    (a) light scattered by colloidal particles
    (b) size of the particle
    (c) shape of the particle
    (d) relative size
20. Brownian movement is discovered by
    (a) Robert Brown (b) Zsigmondy
    (c) Hardy-Schulze (d) Grahm
21. Tyndall effect in colloidal solutions is due to
    (a) scattering of light
    (b) reflection of light
    (c) absorption of light
    (d) presence of electrically charged particles
22. In colloidal state, particle size ranges from
    (a) 1 to 10 Å (b) 20 to 50 Å
    (c) 10 to 1000 Å (d) 1 to 280 Å

23. Cloud or fog is an example of colloidal system of
    (a) liquid dispersed in gas
    (b) gas dispersed in gas
    (c) solid dispersed in gas
    (d) solid dispersed in liquid
24. Which of the following forms a colloidal solution in water ?
    (a) NaCl (b) Glucose
    (c) Starch (d) Barium nitrate
25. Colloidal solution can be purified by
    (a) peptization (b) coagulation
    (c) dialysis (d) Bredig Arc method
26. Tyndall effect will be observed in
    (a) solution (b) precipitate
    (c) sol (d) vapour
27. Small liquid droplets dispersed in another liquid is called
    (a) gel (b) suspension
    (c) emulsion (d) true solution
28. Butter is a colloid formed when
    (a) water is dispersed in fat
    (b) milk is dispersed in fat
    (c) fat is dispersed in water
    (d) milk is dispersed in water
29. Which has least gold number ?
    (a) Gelatin (b) Starch
    (c) Albumin (d) Blood
30. In colloid particles, range of diameters is
    (a) 1 to 100 nm (b) 1 to 1000 cm
    (c) 1 to 1000 mm (d) 1 to 100 km
31. Which of the following statements is true about a colloidal system?
    (a) It carries a net electric charge
    (b) It consists of one phase only
    (c) It can be made out of two gases
    (d) It is electrically neutral as a whole
32. The electrolytic impurities of a sol can most easily be separated by
    (a) dialysis (b) electrosmosis
    (c) electrophoresis (d) electrodialysis
33. One desires to prepare a positively charged sol of silver iodide. This can be achieved by
    (a) adding small amount of $AgNO_3$ solution to KI solution in slight excess
    (b) adding small amount of KI solution to $AgNO_3$ solution in slight excess
    (c) mixing equal volumes of equimolar solutions of $AgNO_3$ and KI
    (d) None of these
34. Which of the following ionic substances will be most effective in precipitating the sulphur sol?
    (a) KCl (b) $BaCl_2$
    (c) $Fe_2(SO_4)_3$ (d) Na_3PO_4
35. Choose the correct statement
    (a) *Latex* is an example of solid-in-liquid sol
    (b) *Latex* is a negative sol
    (c) *Latex* is a positive sol
    (d) None of the above is correct
36. Which of the following statements is *not* true about the oil-in-water type emulsion?
    (a) On addition of small amount of water, no separate layer of water appears
    (b) On addition of oil, separate layer of oil is formed
    (c) Addition of an electrolyte causes the conductivity of the emulsion to increase
    (d) Addition of small amount of oil soluble dye renders the entire emulsion coloured.
37. Which one of the following colloidal solution is positive sol?
    (a) Blood
    (b) Clay soil
    (c) Smoke
    (d) Gelatin in strongly acidic solution
38. The solution of sugar in water contains
    (a) free atoms
    (b) free ions
    (c) free molecules
    (d) free atom and molecules
39. The most common solvent of Earth is...
    (a) gasoline (b) water
    (c) turpentine (d) None of the Above
40. Solutions with low concentrations of solutes are
    (a) concentrated (b) dilute
    (c) solvents (D) None of the above

MTOC *More than One Correct*

DIRECTIONS : *This section contains* **17** *multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Which one of the following is/are colloid(s)?
   (a) Sodium chloride (b) Starch solution
   (c) Cane sugar (d) Blood
2. Which of the following substances gives a positive charged sol?
   (a) Gold (b) A metal sulphide
   (c) Ferric hydroxide (d) Silver chloride
3. Which of the following is/are not a colloid(s) ?
   (a) Chlorophyll (b) Smoke
   (c) Ruby glass (d) Milk
4. Suspensions are
   (a) visible to naked eye
   (b) not visible by any means
   (c) invisible under electron microscope
   (d) visible through microscope
5. The colloidal solution of gelatin is known as
   (a) lyophilic sol (b) reversible sol
   (c) hydrophilic sol (d) All the above
6. Tyndall phenomena is not exhibited by
   (a) NaCl solution (b) starch solution
   (c) urea solution (d) $FeCl_3$ solution

7. Which of the following term is/ are related with colloids ?
   (a) Brownian movement(s)
   (b) Dialysis
   (c) Ultrafiltration
   (d) Wavelength
8. Colloidal solutions are purified by
   (a) dialysis (b) electrodialysis
   (c) ultrafiltration (d) electrophoresis
9. Which of the following is/are a colloidal solution(s)?
   (a) Smoke (b) Ink
   (c) Blood (d) Air
10. A colloid always
    (a) contains two phases
    (b) are heterogenous in nature
    (c) contains three phases
    (d) contains only water soluble particle(s)
11. Which of the following is/are characteristic(s) of hydrophobic sols?
    (a) They are highly susceptible to coagulation by addition of electrolytes
    (b) They have nearly the same surface tension and viscosity as that of dispersion medium
    (c) Their stability is due to both the electric charge and solvation of the particles
    (d) Sol particles can be seen under ultramicroscope
12. A sol of egg albumin can be coagulated by the addition of
    (a) electrolytes only
    (b) alcohol only
    (c) weak electrolytes only
    (d) None of these
13. Amongst the following statements, which is/are correct?
    (a) The ceaseless zig-zag motion of sol particles is due to the unbalanced bombardment of particles by the molecules of dispersion medium
    (b) The intensity of zig-zag motion increases with the increase in the size of the particles
    (c) The zig-zag motion of particles becomes intense at high temperature
    (d) This motion has a stirring effect which does not permit the particles to settle
14. In which of the following, the path of strong beam of light viewed from a direction perpendicular to that of the beam will be visible?
    (a) Starch solution (b) Smoke
    (c) Urea solution (d) Colloidal solution
15. Which of the following is/are true about the aqueous solution of soaps and detergents?
    (a) Their molecules or ions have colloidal dimensions
    (b) Their molecules or ions aggregate spontaneously in solution to form particles of colloidal dimensions
    (c) In these aggregates of ions, the polar ends are directed towards water and hydrocarbon ends towards the centre
    (d) The detergent action is due to the absorption of grease/ oil stain into the interior of these aggregates.
16. Organic colloids are
    (a) ferric hydroxide sol
    (b) starch
    (c) soaps
    (d) None of these
17. Which of the following statement(s) is/are true in respect of hydrophilic sols?
    (a) They are quite stable and are not easily coagulated
    (b) There is considerable interaction between dispersed phase and dispersion medium (water)
    (c) The sol particles are hydrated
    (d) They are very sensitive to coagulation by a small concentration of electrolytes

FITP *Fill in the Passage*

DIRECTIONS : *Complete the following passage(s) with an appropriate word/term to be filled in the blank spaces.*

I. Solutions can be classified in ___(1)___ ways. One depending upon the ___(2)___ of solute in solution. On the basis of concentration solutions are divided as a dilute, concentrated, saturated, unsaturated and ___(3)___ solution. Whereas on the basis of particle size solutions are divided into true, suspension and ___(4)___ solution.

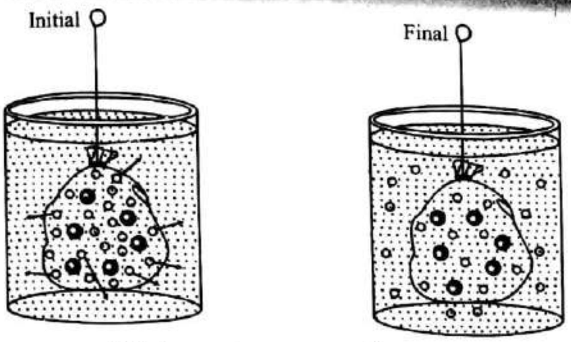
II. Colloids can be prepared by ___(1)___ and dispersion methods. The condensation can be brought about by both physical and ___(2)___ methods. Chemical methods for condensation of colloids are hydrolysis and reduction which are majorly used for preparation of $Fe(OH)_3$ and ___(3)___ sol. ___(4)___ method is majorly used for preparation of sulphur sols. There is an another method use to prepare various colloidal solutions called ___(5)___ .

PBQ *Passage Based Questions*

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

(I) Dialysis is used to separate the soluble solutes (small solute molecules and ions) from colloidal solutions. The technique makes use of a dialysing membrane (somewhat different from semipermeable membrane), which permits the small molecules and ions to pass through but retains large particles of colloidal dimensions.

The colloidal solution to be dialysed is placed inside a cellophane bag (dialysing membrane) which is immersed in pure water. Suppose, the colloidal solution contains NaCl, KCl, glucose, urea, starch, protein, etc.



Solution particles such as Na^+, Cl^-, glucose
Colloidal particles such as protien starch
Fig. Dialysis, the seperation of solution from colloids in wate

The small molecules and ions like glucose, urea, Na^+, K^+, Cl^- will pass through it into the surrounding water. However, the colloidal particles such as starch and protein molecules are retained inside the bag. Water molecules will also flow by osmosis into cellophane bag. Surrounding water is renewed from time to time. The process is hastened by subjecting an electric field to dialyser, particularly to remove electrolytic impurities.

1. Which of the following is not permitted to pass through a dialysing membrane?
   (a) Urea (b) KNO_3
   (c) Ethanol (d) Haemoglobin
2. If dialyzer is subjected to an electric field, what will happen?
   (a) Molecular impurities get removed quickly
   (b) Electrolytic impurities get removed quickly
   (c) All water soluble impurities get removed quickly
   (d) No effect of the field on the rate of dialysis
3. In case of chronic failure of kidneys, dialysis has found special use to remove the waste products of metabolism from the blood in human body. The sample of blood to be dialysed is placed in a dialysing membrane bag which in turn is immersed in pure water, continuously renewed. Which of the following passes over to pure water during the dialysis of blood?
   (a) Uric acid (b) WBC only
   (c) RBC only (d) Both WBC and RBC

II. An emulsion is a system in which the dispersion medium and the dispersed phase both are liquids. The liquids must be immiscible.

Emulsions are classified into two types :

(i) oil in water emulsion

(ii) water in oil emulsion

A stable emulsion usually requires an emulsifying agent, which forms film in the oil-water interface and thus prevents coalescence of the droplets.

1. The example of oil in water emulsion is
   (a) milk (b) opal
   (c) cod-liver oil (d) None of these
2. The example of water in oil emulsion is
   (a) jellies (b) opal
   (c) cod-liver oil (d) whipped cream
3. The emulsifying agent generally used is/are
   (a) soap (b) gelatin
   (c) both soap and gelatin
   (d) soap, gelation and other hydrophilic sols

A&R *Assertion and Reason*

DIRECTIONS : *Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect.**
(d) If **Assertion** is **incorrect** but **Reason** is **correct.**

1. **Assertion** : The solubility of a gas in a liquid increases with increase of pressure.
   Reason : The solubility of a gas in a liquid is directly proportional to the pressure of the gas.
2. **Assertion** : Lyophilic colloids are called as reversible sols.
   Reason : Lyophilic sols are liquid loving.
3. **Assertion** : Colloidal sols scatter light while true solutions do not.
   Reason : The particles in the colloidal sol move much slower than that of the true solution.
4. **Assertion** : Colloidal solution is electrically neutral.
   Reason : Due to similar nature of the charge carried by the particles, they repel each other and do not combine to form bigger particles.
5. **Assertion** : Milk is an example of water in oil emulsion.
   Reason : Emulsion contains liquid dispersed in liquid.
6. **Assertion** : Soaps and detergents belong to the category of macro-molecular colloids.
   Reason : The molecules of soaps and detergents are not of big size.
7. **Assertion** : Colloidal solutions are stable but the colloidal particles do not settle down.
   Reason : Brownian movement counters the force of gravity actively on colloidal particles.

MMQ Multiple Matching Questions

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in column I with entries in column II.*

1.

Column I	Column II
(A) $AgNO_{3\,(aq)}$ + little excess of KI	(p) Sol particles migrate towards cathode under electric field
(B) $KI_{(aq)}$ + little excess of $AgNO_3$	(q) Sol particles migrate towards anode under electric field
(C) Gelation sol at pH < isoelectric pH	(r) Sol particles are negatively charged
(D) Protein sol at pH > isoelectric pH	(s) Sol particles carry positive charge

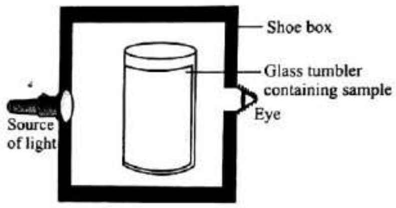
2.

Column I	Column II
(A) Sb_2S_3 sol	(p) Stabilized by electric charge on solparticles
(B) Gold sol	(q) Highly sensitive to coagulation by electrolytes
(C) Casein	(r) Intrinsic colloid
(D) Gum arabic	(s) Stabilized by electric charge and hydration of sol particles

HOTS Hots Subjective Questions

DIRECTIONS : *Answer the following questions.*

1. When a colloidal solution of sulphur is centrifuged in a centrifugal machine, what will you observe?
2. Why sky appears blue ?
3. How do fog differ from clouds ?
4. Classify the following as water-in-oil or oil-in-water type of emulsion.
   milk, vanishing cream, cold cream, butter
5. What is the name given to a class of colloidal solution to which butter belongs ? Explain.
6. Explain why particles of a colloidal solution do not settle down when left undisturbed, while in the case of a suspension they do.
7. You are given two samples of water labelled as 'A' and 'B'. Sample 'A' boils at 100ºC. and sample 'B' boils at 102°C. Which sample of water will not freeze at 0ºC? Comment.
8. (a) A solution is always a liquid. Comment.
   (b) Can a solution be heterogeneous?
9. A group of students took an old shoe box and covered it with a black paper from all sides. They fixed a source of light (a torch) at one and made another hole on the other side to view the light. They placed a milk sample contained in a beaker/tumbler in the box as shown in the fig. They were amazed to see that milk taken in the tumbler was illuminated. They tried the same activity by taking a salt solution but found that light simply passed through it?
   (a) Explain why the milk sample was illuminated. Name the phenomenon involved.
   (b) Same results were not observed with a salt solution. Explain.
   (c) Can you suggest two more solutions which would show the same effect as shown by the milk solution?



10. In a gaseous solution what is the state of the solvent ?
11. The solubility of sodium chloride in water increases with rise in temperature while that of lithium carbonate decreases. Explain
12. (a) Generally, the solubility of a crystalline substance (solid) increases with rise in temperature. Does it increase uniformly in every case ?
    (b) Name a substance whose solubility
    (i) increases rapidly with rise in temperature.
    (ii) increases gradually with rise in temperature.
    (iii) increases slightly with rise in temperature.
    (iv) decreases with rise in temperature.
13. Describe how you would prepare 100 g of a solution that is 0.5% phenolphthalein by mass.
14. A beaker contains a clear, colorless liquid. If it is water, how could you determine whether it contained dissolved table salt? Do not taste it!
15. List the following waters in order of increasing purity. Ocean water, Rain water and drinking water. Explain
16. A solution contains 50 mL of alcohol mixed with 150 mL of water. Calculate the concentration of this solution.
17. 12 grams of potassium sulphate dissolves in 75 grams of water at 60°C. What is its solubility in water at that temperature ?
18. Explain why filter paper can not be used to separate colloids.
19. Water is a universal solvent. Explain.
20. Calculate the concentration of a solution in volume percent made when 56g of water is mixed with 0.17 L of ethanol.
21. Why are aerated water bottles kept under water during summer ?

SOLUTIONS

EXERCISE – I

FILL IN THE BLANKS

1. saturated
2. soluble
3. Smaller
4. true
5. 1000 nm (1μm)
6. 10^{-7} cm, 10^{-5} cm
7. dispersion medium
8. Electro-dialysis
9. double decomposition
10. drugs
11. homogeneous, solvent, solute
12. suspension, heterogeneous
13. heterogeneous, small

TRUE/FALSE

1. False	2. False
3. True	4. True
5. True	6. False
7. True	8. True
9. True	10. True
11. True	12. True
13. True	

MATCH THE FOLLOWING

I. A – (p); B – (s); C – (r); D – (q)

II. A – (q); B – (s); C – (p); D – (r)

VERY SHORT ANSWER QUESTIONS

1. Colloids are mixtures with characteristics intermediate between a solution and a suspension. e.g. fine potteryclay and water.
2. Suspension are heterogeneous mixture of a solid and a liquid in which the solid does not dissolve. Suspension will settle when left standing undisturbed. e.g. soil and water, sand and water, etc.
3. Solubility of a solute is defined as the maximum amount that dissolves in a given amount of a solvent at a specified temperature. Solubility increases with increase in temperature.
4. It lies in the range 1 nm to 100 nm (1 nm = 10^{-9}m).
5. It is a colloidal solution.
6. It has *no units*. It is simply a ratio.
7. Dispersed phase – liquid
   Dispersion medium – liquid
8. Dispersed phase: solid (dust particles)
   Dispersion medium: gas (air)
9. Ammonia gas dissolved in water.
10. Milk is *oil–in–water* type emulsion.
11. Yes.
12. Yes.
13. Dispersion medium: gas
    Dispersed phase: solid
14. During burning of candle physical and chemical change both occurs simultaneously.
15. A solution in which water is solvent is called an aqueous solution.
16. The process of converting a colloidal solution into precipitate is called coagulation.
17. The process of making an emulsion from an oil is termed as emulsification.
18. Two. *solute* and *solvent*.
19. It is heterogeneous.
20. They are hydrophobic.
21. The process of making an emulsion from and oil and water is termed as emulsification.
22. This is because the size of the colloidal particles is such (10Å — 1000Å) that they can scatter light.
23. Gold sol which is lyophobic starts behaving like a lyophilic colloid when gelatin is added to it.
24. Arsenious sulphide is obtained by passing H_2S through arsenious oxide solution.
25. Colloidal particles move towards the oppositely charged electrode, get neutralized and coagulated (*electrophoresis*).
26. Soaps and detergents.
27. Substances such as metals, their sulphides, etc., which do not mix directly with the dispersion medium to form a colloidal sol.
28. The colloidal sol of cellulose nitrate in ethyl ` alcohol is called collodion.

SHORT ANSWER QUESTIONS

1. Tyndall effect is shown by colloidal solution. This is because of the size of colloidal particles (1nm to 100 nm) which can scatter the light falling on them. In true solution the size of particle is very small and they fail to scatter the light falling on them.
2. The dust particles present or oil drops sticking to clothes can not be easily removed by washing with water because water and oil do not form stable emulsion. Soap plays the role of *emulsifier* and helps in formation of a stable emulsion between water and oil. In this way soap helps in cleansing.

3. Solubility of common salt in water increases with increase of temperature. The dissolution of common salt in water is accompanied by absorption of heat (i.e. it is *endothermic*). Due to endothermic nature the solubility increases with increase in temperature.
4. (a) It becomes unsaturated.
   (b) Some solute gets deposited at the bottom of solution.
5. An oil in water type of colloidal solution is formed. Such type of colloidal solution is called *emulsion*.
6. A solution in which the solvent is not water is called a non-aqueous solution. e.g., A solution of iodine (solute) in carbon tetrachloride (solvent).
7. The zig-zag motion of colloidal particles is called Brownian movement. This type of motion is due to collosion of molecules of dispersion medium constantly with colloidal particles. During collisions, molecules of dispersion medium collosion of momentum to colloidal particles. You must have seen dust particles in a beam of sunlight coming through a slit in a dark room, which keeps on moving in zig-zag path.
8. (i) Sols are dispersions of solids in liquids while emulsions are dispersions of liquids in liquids.
   (ii) Sols are quite stable whereas emulsions are less stable.
9. (i) Multimolecular colloids are formed by aggregation of small molecules (diameter < 1nm) while macromolecular colloids are formed by macromolecules (polymers) and consist of single molecules.
   (ii) Multimolecular colloids are generally lyophobic whereas macromolecular colloids are generally lyophilic.
10. This solution contains a solid solute (sugar) dissolved in a liquid solvent (water), so we have to calculate the concentration of this solution in terms of the mass percentage of solute (sugar). We know that :

$$\text{Concentration of solution} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

Here, Mass of solute (sugar) = 30g

And, Mass of solvent (water) = 370g

So, Mass of solution = Mass of solute + Mass of solvent

$$= 30 + 370 = 400\text{g}.$$

Now, putting the values of 'mass of solute' and 'mass of solution' in the above formula, we get :

$$\text{Concentration of solution} = \frac{30}{400} \times 100 = \frac{30}{4} = 7.5\%$$

11. Percentage by mass

$$= \frac{\text{Mass of solute}}{\text{Mass of solute + Mass of solvent}} \times 100$$

$$= \frac{2}{2+100} \times 100 = \frac{2}{102} \times 100 = 1.96\%$$

12. Volume of solute (ethanol) = 40 ml

Volume of solvent (water) = 100 ml

Volume of the solution = 40 + 100 = 140 mL

volume percentage of solution

$$= \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

$$= \frac{40}{140} \times 100 = 28.6$$

13. Here, mass of solute (salt) = 110g

And, mass of solution = 550g

Now, we know that :

$$\text{Concentration of solution} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$= \frac{110}{550} \times 100 = \frac{100}{5} = 20 \text{ percent (or 20\%)}$$

Thus, the concentration of this salt solution is 20 percent (or it is a 20% salt solution).

14. Sea water and soda water are solutions.
15. 12.5%
16. 32.4g
17. The charge on the colloidal particles is due to adsorption of common ions of the electrolyte on the surface of the colloidal particles *e.g.*, Fe^{3+} from $FeCl_3$ on the surface of $Fe(OH)_3$ particles.

LONG ANSWER QUESTIONS

1.

Property	True solution	Colloidal Solution	Suspension
1. Appearance	They are clear and transparent	They are translucent .	They are opaque.
2. Visibility	Particles are notvisible to naked eye	Scattering of light by particle is observed under ultra-microscope.	Particles are visible to naked eye.
3. Particle size	It is less than 1 nm (nano meter)	It is between 1nm and 100 nm.	Particles size is more than 100 nm.
4. Diffusion	They diffuse quickly.	They diffuse slowly	They do not diffuse.
5. Setting	They do not settle	They do not settle	They settle down on standing
6. Filterability	They can pass through ordinary filter paper as well as animal membrane.	They pass through filter paper but not throgh animal membrane.	They do not pass through filter paper or membrane.

2. **Applications of Colloids :** Colloidal dispersions play a very significant role in natural processes in our daily life and in industries. Some of the important applications of colloids are following.

Food: Most of our food preparations are colloidal in nature. Milk, butter and cream are example of emulsions, jam, jellies, ice-creams, salad dressing, bread etc., are all examples of food colloids.

Medicines: Most drugs (insoluble in water) are administered as colloidal dispersions namely suspensions, emulsions. In the colloidal form the drug is easily absorbed by body tissues and is therefore more effective. Most skin ointments are emulsions.

Detergency: Soaps and detergents by themselves are lyophilic colloids and therefore the entire detergent industry involves colloids.

Water Treatment: Suspended/colloidal particles of undesirable muddy mass need to be removed before making water fit for drinking. The water cleansing process involves the coagulation of the suspended material by alum or high molar mass polyelectrolytes in water treatment plants.

Rubber Industry: Latex is a colloidal solution of negatively charged colloidal rubber particles. Rubber can be obtained from latex by coagulation.

3. (i) Depending on the Amount of Solute in Solution: on the basis of the amount of the solute present in solution, solutions are classified as

(1) Dilute Solution : The solution in which quantity of solute in a given mass of solvent is very small is called a dilute solution.

(2) Concentrated Solution : The solution in which quantity of solute in a given mass of solvent is very large is called a concentrated solution.

(3) Saturated Solution : If a solution contains dissolved solute equal to its solubility then it is called saturated solution.

(4) Unsaturated Solution : A solution in which amount of solute dissolved is less than its solubility at that temperature and more solute can be dissolved in it is called unsaturated solution.

(5) Supersaturated Solution : Sometimes it is also possible to dissolve more solute than its solubility. Such solutions are known as supersaturated solutions.

4. Chemical methods used for preparation of colloids are following

(i) **By hydrolysis:** Addition of drop by drop of an concentrated solution of $FeCl_3$ on hot water result into hydrolysis of $FeCl_3$ to form$Fe(OH)_3$ solution.

$$FeCl_3 + 3H_2O \longrightarrow \underset{sol}{Fe(OH)_3} + 3HCl$$

(ii) **By Reduction:** The colloidal solutions of metals are obtained by reduction of their compounds. For example, gold sol can be prepared on reducing a solution of gold (III) chloride with formaldehyde.

$$2AuCl_3 + 3HCHO + 3H_2O \longrightarrow \underset{sol}{2Au} + 3HCOOH + 6HCl$$

(iii) **Oxidation:** Sols of non-metals (like, S,P, etc,) are prepared by their oxidation. For example, sulphur sols are obtained when H_2S gas is bubbled through the solution of an oxidising agent like Br_2, HNO_3, Mn^{2+} etc. where H_2S is oxidized to elemental sulphur.

$$H_2S + Br_2 \longrightarrow 2HBr + \underset{sol}{S}$$

(iv) **Double Decomposition:** This method is often used to prepare various colloidal solutions. Sulphide sols are often obtained by this method. For example, on passage of H_2S through cold aqueous solutions of $AsCl_3$, $CdCl_2$, $Hg(CN)_2$, their sulphide sols are formed.

$$2AsCl_3 + 3H_2S \longrightarrow \underset{sol}{As_2S_3} + 6HCl$$

5. A centrifuge is a rotating machine which uses centrifugal force to separate solid particles from solution and immiscible liquids from each other. It is also used to separate the components of a suspension.

6. **Macromolecular Colloids :** These are the substances having big size molecules (called Macromolecules) which on dissolution form solution in which the dispersed phase particles have size in the colloidal range. Such substances are called **macromolecular colloids.** These macromolecules forming the dispersed phase are generally polymers having very high molecular masses. Naturally occurring macromolecules are starch, proteins and cellulose. Man made macromolecules are polymers such as polyethylene, nylon, plastics and polystyrene. These colloids are quite stable and resemble true solutions in many respects. They have usually lyophobic character.

Associated Colloids (Micelles) : Certain substances behave as strong electrolytes at low concentration but at higher concentrations these substances exhibit colloidal characteristics due to the formation of aggregated particles. These aggregated particles are called micelles. Micelles are called associated colloids. The formation of micelles takes place only above a particular temperature called Kraft Temperature (T_k) and above particular concentration called the critical micelle concentration (CMC). For example, CMC for soaps is about 10^{-4} to 10^{-3} mol L^{-1}. On dilution, these colloids revert back to individual ions. Surface active molecules such as soaps and synthetic detergents form associated colloids in water. Micelles have both a lyophilic and lyophobic parts. Micelles may consists of more than 100 molecules.

EXERCISE – 2

MULTIPLE CHOICE QUESTIONS

1. (d) Molality = $\dfrac{18 \times 1000}{180 \times 1000} = 0.1.$

2. (a) In alkaline medium the reduction of $KMnO_4$ takes place as

$$MnO_4^- + H_2O \longrightarrow MnO_4^- + OH^- + MnO_2$$

Eq. mass of $KMnO_4 = \dfrac{\text{Mol. mass}}{1} = 158$

Wt. of $KMnO_4$ needed

$= \dfrac{0.1 \times 100}{1000} \times 158 = 1.58\,g.$

3. (c) $CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$

$E_{CaCO_3} = \dfrac{\text{Mol. mass}}{2} = 50$

$N \times V = \dfrac{1}{50}$ or, $\dfrac{50 \times N}{1000} = \dfrac{1}{50}$;

or $N = 0.4$

4. (b) Molality = mol kg^{-1} = $\dfrac{5.85}{58.5} = 0.1$

5. (a) 1l of water weight 1 kg (at 4°C).

Hence, molarity of pure water

$= \dfrac{1000}{18} = 55.55$

6. (c) Molarity = $\dfrac{\text{Number of moles of solute}}{\text{Volume of solution in litres}}$

Number of moles of hydroxide (OH^-) ions

= Molarity of OH^- × Volume of solutions (l)

$= 2 \times 0.005 \times 0.3 = 0.003.$

7. (c) $n_{H_2O} = \dfrac{36}{18} = 2;$

$n_{glycerine} = \dfrac{46}{92} = 0.5$

Hence, $x_{glycerine} = \dfrac{0.5}{0.5+2} = 0.2$

8. (c) *Molarity of KCl (m)*

$= \dfrac{\text{No. of moles of solute}}{\text{volume of solution in litre}}$

$3 = \dfrac{\text{No. of moles of solute KCl}}{1 \text{ litre}}$

No. of moles of (KCl) = 3

9. (b) Molality of a solution is the number of moles of solute dissolved in 1000 g or 1 kg of solvent. It is independent of volume term. Therefore, it is not affected by rise or fall of temperature.

Hence, option (b) is correct.

10. (b) Molarity of a solution (M) = 2 M

Volume of a solution (V) = 150 ml

Molecular weight of $CH_3OH = 32$

Molarity of a solution (M)

$= \dfrac{\text{No. of moles of solute}}{\text{Volume of solution in litres}}$

$= \dfrac{\frac{w}{m}}{\frac{V}{1000}} = \dfrac{w \times 1000}{m \times V}$

According to question,

$w = \dfrac{M \times m \times V}{1000}$

$= \dfrac{2 \times 32 \times 150}{1000} = 9.6$ gm.

Hence, 9.6 gm of CH_3OH would have to be added to water.

11. (c) Molality is the number of moles of solute present in 1000 gm or 1 kg of solvent.

Therefore, option (c) is correct.

12. (c) The solution which has one gram equivalent in one litre is called normal solution.
13. (d) As_2S_3 sol carries a negatively charged particles so for coagulation, cations will be the effective ions, coagulation power of an effective ion increases with increase in its charge.
14. (b) The stability of a lyophilic sol is due to both the charge and solvation of particles, but largely due to the solvation factor. As in lyophilic colloids particles of dispersed phase has more affinity for dispersion medium.
15. (c) Those substances which can not pass through membrane are termed as colloids eg silicic acid. Whereas sugar solution, urea and NaCl can pass through the membrane.
16. (c) Smoke consists of carbon particles (solid) dispersed in air (gas).
17. (b) Crystalloids can easily be obtained in the crystalline form and their solution can diffuse rapidly through a vegetable or animal membrane [i.e., parchment membrane]; e.g. sugar, urea, salts, acids, etc.
18. (b) Cloud consists of fine droplets of water suspended in air.
19. (a) Scattering of light from the surface of colloidal particles–tyndall effect is observed. When a colloidal solution is observed under an ultramicroscope.
20. (a) Robert Brown, an English botanist observed that the particles in colloidal solution were in constant random motion, traversing no definite set paths, but travelling in zig-zag directions all over the field of view. This movement of colloidal particles is called Brownian movement.
21. (a) When a beam of light is passed through a colloidal solution, the path of the beam is illuminated and becomes visible as a blue bright streak when seen in a direction perpendicular to the incident beam. This phenomenon is called as Tyndall Effect. This phenomenon is due to scattering of light by the sol particles.
22. (c) Size of particles in colloidal state ranges from 10 to 1000 Å

Size of particles ——10Å —— 1000Å ——
True solution | particles in colloidal state | Suspension

23. (a) Fog is a colloidal system consisting water droplets dispersed in air.
24. (c) Starch molecules have colloidal dimensions whereas NaCl, glucose and $Ba(NO_3)_2$ are crystalloids and soluble in water.
25. (c) Collidal solutions can be purified by dialysis. It may be defined as the process of separating a crystalloid from a colloid by diffusion or filtration through a fine membrane. The process of dialysis can be quickened by using hot water (hot dialysis) or by applying an electric field (electrodialysis).
26. (c) Sol is a colloidal solution so, it will show Tyndall effect.
27. (c) When the dispersed phase and dispersion medium both are liquid, the colloidal system is called as an emulsion like milk, vasnishing cream, etc.
Option (c) is correct.
28. (a) Butter is obtained from milk which itself is an emulsion of fat dispersed in water, reverse is true for butter.
Option (a) is correct.
29. (a) Gelatin has the least gold no. as it has the greatest protective effect towards coagulation of colloids. The gold number of gelatin varies from 0.005– 0.01
30. (a) The colloidal particles have diameter 1-100 nm.
31 (d)
32. (d) Electrolytic (Ionic) impurities can be most easily removed on application of electric field.
33. (b) $KI + AgNO_3 \text{ (slight excess)} \longrightarrow AgI + KNO_3$

$$AgNO_3 \longrightarrow Ag^+ + NO_3^-;$$

$$AgI(s) + Ag^+ \longrightarrow [AgI]Ag^+$$

34. (c)
35. (b) *Latex* is a negative sol. *Latex* is an *emulsion* is which the rubber particles forming emulsion are stabilized by various proteins.
36. (d) Since, oil is the inner (dispersed) phase, the added dye will not be dissolved in the emulsion.
37. (d)
38. (c) Free molecules
39. (b)
40. (b)

MORE THAN ONE CORRECT

1. (b, d) Starch molecules have colloidal dimensions. Blood is a –vely charged colloidal system. Rest of the compounds, i.e., NaCl, urea & cane sugar form true solution in water.
2. (c, d) $Fe(OH)_3$ particles absorb Fe^{3+} ions and get peptized to give a positively charged sol. Similarly AgCl particles absorbs Ag^+ ions to give a positively charged sol.
3. (b,c,d) Chlorophyll. Smoke is an example of solid-gas colloid system Ruby glass is an example of solid-solid colloid system. Milk is an liquid-liquid colloid system.
4.. (a,d) Suspension particles are visible under a microscope and sometimes even to a naked eye.
5. (a,b) Gelatin is a lyophilic solution (lyo-liquid philic -love). Lyophilic colloids are also known as

reversible colloids since on evaporating the dispersion medium (i.e., water), the residue can again be easily reconverted into colloidal state simply by addition of the liquid i.e., water.

6. (a,c,d) Scattering of light (Tyndall effect) is exhibited by a colloidal solution. Among the given solutions starch solution is a colloid whereas other are example of true solution.
7. (a,b,c) Dialysis and ultrafiltration are the methods of purification of colloidal solutions Brownian movement is a property of colloidal solution. Only wavelength is not related with colloids.
8. (a,b,c) Colloidal solutions are not purified by electrophoresis. Movement of colloidal particles under the influence of electric field is called electrophoresis. Electrophoresis is the property of colloids not the purification method.
9. (a,b,c) Air is a homogeneous mixture of gases, mainly nitrogen and oxygen.
10. (a,b) A collidal solution is biphasic and heterogeneous. It is composed of two phases : 1. Dispersed phase; 2. Dispersion medium.
11. (a,b,d) The stability is attributed to electric charge on the sol particles.
12. (a,b,c) Addition of alcohol causes desolvation (dehydration) of hydrophilic egg albumin particles and electrolytes cause their charge to decrease.
13. (a,c,d)
14. (a,b,d) Urea solution is true solution and the urea molecules are much smaller than colloidal particles. Hence, no scattering of light.
15. (c, d)
16. (a,b,c) Organic colloids can be homo-polar sols (rubber in benzene), hydroxy sols (starch), heteropolar sols (protein, soaps, etc.)
17. (a,b,c) Hydrophilic sols have extra stability due to both the charge on the particles and their solvation.

FILL IN THE PASSAGE

(I) (1) two (2) concentration
(3) supersaturated (4) colloidal

(II) (1) condensation (2) chemical
(3) gold (4) Oxidation
(5) double decomposition

PASSAGE BASED QUESTIONS

PASSAGE - I

1. (d) Haemoglobin, being a very large particle, would not be able to pass through the dialysing membrane.
2. (b) The ions given by electrolytic impurities will run quickly under the applied electric field and hence will be removed easily.
3. (a) Uric Acid is the substance of low molecular mass, can pass through the dialysing membranes. Whereas the particles of other compounds being large in size cannot pass through.

PASSAGE - II

1. (a) Milk is an emulsion in which small drops of liquid fat are dispersed in water.
2. (c) Cod-liver oil is an emulsion in which particles of water are dispersed in oil.
3. (d) Soap, gelatin and other hydrophilic sols are useful emulsifying agents.

ASSERTION & REASON

1. (a) This is according to Henry's law which states that the solubility of a gas in given volume of a liquid at a particular temperature is directly proportional to the pressure of gas above the liquid. $m \propto p$, $m = kp$ where k = Henry's constant.
2. (a) If the dispersion medium is separated from the dispersed phase, the lyophilic sol can be obtained by simply remixing the disperse phase with the dispersion medium. That is why these sols are also called reversible sols.
3. (b) The size of the colloidal particles is large enough to scatter light while particles of a true solution are too small to scatter light.
4. (b) The particles of the colloids are electrically charged and carry positive or negative charge but colloidal solution as whole is neutral. The dispersion medium has an equal and opposite charge making the system neutral as a whole.
5. (d) Milk is an oil in water emulsion i.e., liquid fat is dispersed in water. Emulsions are colloids in which both dispersed phase and dispersion medium are liquids.
6. (d) Soaps and detergents are colloidal electrolytes and can not be regarded as macromolecules as they have individual molecules of very big size.
7. (a)

MULTIPLE MACHING QUESTIONS

1. A-(q, r); B-(p, s); C-(p, s); D-(q, r)
2. A-(p, q); B-(p, q); C-(r, s); D-(r, s)

HOTS SUBJECTIVE QUESTIONS

1. After sometime yellow precipitate of sulphur will settle down at the bottom of the tube and the solution will become colourless.
2. The blue colour of sky is due to *scattering of light* by *fine dust particles* which are present in the atmosphere.

3. Both fog and clouds are *liquid in gas* type of colloids. They differ in the fact that clouds are formed in the upper atmosphere but fog is formed in the region of atmosphere that is close to earth.
4. Milk – oil-in-water
   Vanishing cream – oil-in-water
   Cold cream – water-in-oil
   Butter – water-in-oil
5. Butter belongs to a colloidal solution in which *dispersion medium is liquid* and *dispersed phase is solid.* Such a colloidal solution is called a **gel**. When butter is pressed we find that drops of liquid come out. It shows the butter is a **gel**.
6. Particle size in a suspension is larger than those in a colloidal solution. Also molecular interaction in a suspension is not strong enough to keep the particles suspended and hence they settle down.
7. Sample 'B' will not freeze at 0°C because it is not pure water. At 1 atm, the boiling point of pure water is 100°C and the freezing point of pure water is 0°C.
8. (a) No. solid solutions and gaseous solutions are also possible. Examples brass and air
   (b) No, solution is a homogenous mixture of two or more substances
9. (a) Milk is a colloid and would show Tyndall effect.
   (b) Salt solution is a true solution and would not scatter light.
   (d) Detergent solution, sulphur solution.
10. Solvent is in gaseous state.
11. The process of dissolution of sodium chloride in water is an *endothermic process* (i.e. energy is absorbed in the process). In such a process solubility increases with temperature.
    The process of dissolution of lithium carbonate in water is an *exothermic process* (i.e. heat is evolved in the process). In such a process the solubility of solute decreases with increase in temperature.
12. (a) No, the solubility do not increases uniformly in every case.
    (b) (i) Potassium nitrate
    (ii) Potassium chlorate
    (iii) Sodium chloride
    (iv) Calcium acetate.
13. Since the solute (phenolphthalein) is a solid, the solution is percent by mass. Mass percent means the number of grams of solute per 100 g of solution.
    mass percent = (mass of solute/mass of solution) × 100%
    mass of solute = mass percent × mass of solution/100%
    = 0.5% × 100 g/100% = 0.5 g
    Since the total mass of the solution equals 100 g, the remaining 99.5 g of the solution is water. To prepare the solution, dissolve 0.5 g phenolphthalein in 99.5 g distilled water.
14. First heat the liquid to 100°C to evaporate the water. If there is a residue, measure the physical properties of the residue, such as color, density, and melting point. If the properties match those of NaCl, the water contained dissolved table salt. If the properties don't match, the residue is a different dissolved solid. If there is no residue, no dissolved solid is present.
15. Ocean water is the least pure because it contains a large amount of dissolved compounds. That is why it is not drinkable and cannot be used for crop irrigation.
    Drinking water also contains chlorine and some dissolved compounds but not as much as the ocean water. Rain-water is most pure but still contains some dissolved gases from the air.
16. This solution contains a liquid solute (alcohol) mixed with a liquid solvent (water), so we have to calculate the concentration of this solution in terms of volume percentage of solute (alcohol). Now, we know that :
    $$\text{Concentration of solution} = \frac{\text{Volume of solure}}{\text{Volume of solution}} \times 100$$
    Here, Volume of solute (alcohol) = 50 mL
    And, Volume of solvent (water) = 150 mL
    So, Volume of solution = Volume of solute + Volume of solvent
    = 50 + 150 = 200 mL
    Now, putting these values of 'volume of solute' and 'volume of solution' in the above formula we get :
    $$\text{Concentration of solution} = \frac{50}{200} \times 100 = \frac{50}{2} = 25\%$$
17. Here we have been given that 75 grams of water dissolves 12 grams of potassium sulphate. We have to find how much potassium sulphate will dissolve in 100 grams of water. Now,
    75g of water dissolves = 12g of potassium sulphate
    So,100g of water will dissolve $= \frac{12}{75} \times 100\text{g}$ of potassium sulphate = 16g of potassium sulphate
    Thus, the solubility of potassium sulphate in water is 16g at 60°C.
18. Generally colloids can not be separated by filtration since the size of the dispersed particles is smaller than that of the pores present in the filter paper.
19. Water is called a universal solvent because it dissolves almost all the solute to a large or small extent. This is due to :
    (i) its high dielectric constant
    (ii) its polar nature of bond
    This property of water can be used for several purposes such as :
    (i) in the preparation of food
    (ii) in soft and hard drinks
    (iii) in dyeing and cleaning clothes, etc.

20. Volume of water $= \dfrac{\text{mass}}{\text{density}} = \dfrac{56\text{g}}{1.0\text{gcm}^{-3}} = 56 \text{ cm}^3$

$= 56 \text{ mL}$

Volume of ethanol $= 0.17 \text{ L} = 0.17 \times 1000 \text{ mL} = 170 \text{ mL}$

$\therefore$ Volume of solution $= (56 + 170) \text{ mL} = 226 \text{ mL}$

$\therefore$ Concentration percent by volume

$= \dfrac{56}{226} \times 100 = 24.78\%$

21. Aerated water contains carbon dioxide (CO_2) dissolved under pressure. With the rise of temperature in summer, the solubility of the dissolved gas (CO_2) decreases i.e., free CO_2 gas is liberated in the bottle. The gas so set free consequently exert pressure on the walls of the bottle, which may even cause bursting of the bottle. In order to avoid the bursting of bottles, they are kept under water during summer as the solubility of CO_2 gas increases with decreases in temperature.