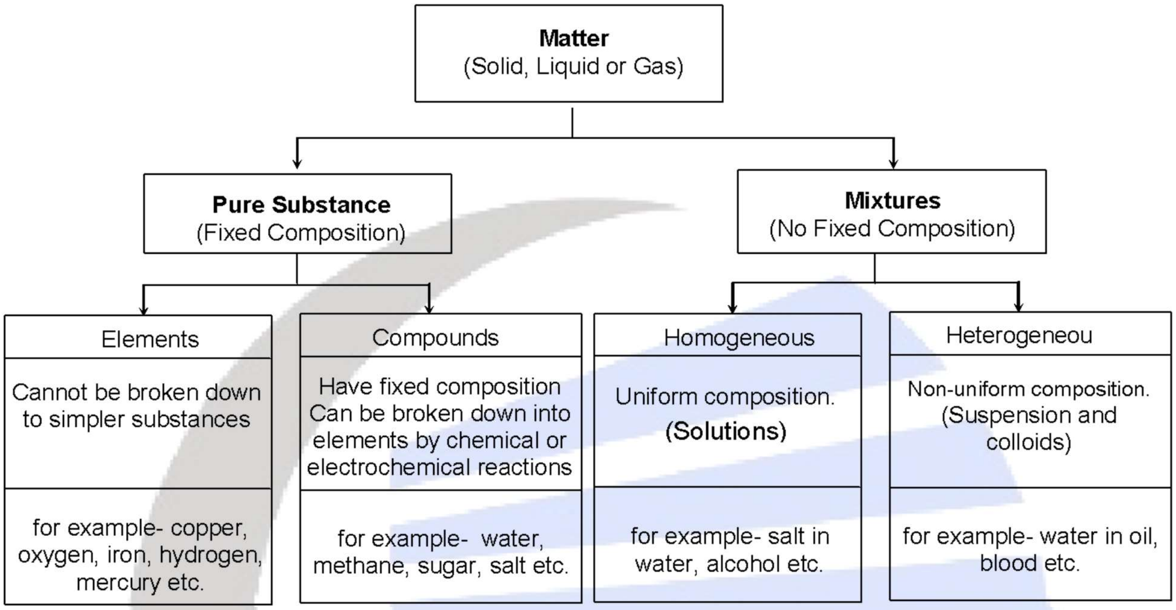
1. INTRODUCTION

All the matter around us is not pure, in fact, matter around us is of two types:



1.1 PURE SUBSTANCES

A pure substance is one, which is made up of only one kind of atoms or molecules.

1.2 IMPURE SUBSTANCES/ MIXTURES

A mixture is an impure substance which contains two or more different kinds of particles (atoms or molecules).

OR

A mixture is an impure substance which consists of two or more pure substances (elements or compounds) that are present in any ratio. The pure substances in the mixture do not react chemically.

Examples :

(i) Air is a mixture of various gases such as oxygen, nitrogen, inert gases (mainly argon), carbon dioxide, water vapours etc.

(ii) Milk is a mixture of water, fats and proteins.

(iii) Steel is a mixture of iron and carbon with small amounts of nickel and chromium.

(iv) Salt solution is a mixture of common salt in water.

(v) Gun powder is a mixture of sulphur, potassium nitrate and carbon (in the form of charcoal).

Other examples of mixture are: sugar solution, petrol, coal, soil, paints, glass, wood, dyes, soft drinks (coke, pepsi, limca etc), lemonade, face-cream, shaving cream, smoke, fog, mist etc.

1.2.1 Types of mixtures

Mixtures are of two types:

Mixtures

- Homogeneous Mixtures
- Heterogeneous Mixtures

(a) Homogeneous Mixtures: A mixture is said to be Homogeneous if all the components of the mixture are completely mixed together and are indistinguishable from one another.

In other words, a homogeneous mixture consists of only one phase. The single phase of the Homogeneous mixture may be a liquid, gas or solid.

Examples :

(i) A solution of sugar in water is a Homogeneous mixture in the liquid phase.

(ii) Air is a Homogeneous mixture of a number of gases.

(iii) Alloys are Homogeneous mixture of two or more metals in the solid phase. For example, brass is an alloy of Zn(30%) and Cu(70%).

Some more examples of Homogeneous mixtures are common salt solution, copper sulphate solution, sea water, lemonade, German silver, bronze, vinegar etc.

(b) Heterogeneous Mixtures: A mixture is said to be heterogeneous if all the components of the mixture are not thoroughly mixed and are distinguishable from one another.

In other words, heterogeneous mixtures have two or more distinct phases.

Examples :

(i) A mixture of sugar and sand is a heterogeneous mixture, because different parts of the mixture will have different sugar-sand compositions.

(ii) Gun powder is a heterogeneous mixture of three solids i.e., sulphur, charcoal and potassium nitrate.

(iii) Suspension of solids in liquids is a heterogeneous mixture, e.g. a suspension of chalk particles or sand in water is a heterogeneous mixture.

(iv) A mixture of two immiscible liquids is also a heterogeneous mixtures, e.g. a mixture of petrol and water is a heterogeneous mixture because petrol and water do not mix and hence form two separate layers. Some more examples of heterogeneous mixtures are: polluted air, soap solution, milk, ink, paint, glass, soil, dyes, muddy river water, flour in water, butter, milk of magnesia, cheese, face cream, shaving cream, hair spray, fog and mist etc.

Experiment to illustrate the concept of Homogeneous and heterogeneous mixtures.

- Let us divide the class into groups A, B, C, and D.
- Group A takes a beaker containing 50 mL of water and one spatula full of copper sulphate powder. Group B takes 50 mL of water and two spatula full of copper sulphate powder in a beaker.
- Groups C and D can take different amounts of copper sulphate and potassium permanganate or common salt (sodium chloride) and mix the given components to form a mixture.
- Report the observations on the uniformity in colour and texture.

Discussion :

(i) Both groups A and B have obtained homogeneous mixtures since the composition of these mixtures or solutions is uniform throughout.

(ii) Although both the groups have obtained copper sulphate solutions but the intensity of colour of the two solutions is different. The intensity of blue colour in the solution obtained by group B which contains two spatula full of copper sulphate is much higher than the solution obtained by group A which contains one spatula full of copper sulphate.

(iii) Both groups C and D have obtained heterogeneous mixtures since they not only have distinct boundaries but also their composition is not uniform.

Conclusion :

(i) Soluble substances such as copper sulphate, common salt or sugar when dissolved in water form homogeneous mixtures whose composition depend upon the amount of the substance dissolved.

(ii) When two or more solids which do not react chemically are mixed, they always form heterogeneous mixtures.

Differences between Homogeneous and heterogeneous mixtures

Homogeneous Mixtures	Heterogeneous Mixtures
1. They have a uniform composition throughout their mass. 2. They consist of only one phase. 3. They have no visible boundaries of separation between its constituents.	1. They contain physically distinct parts and have non-uniform compositions. 2. They consist of more than one phase. 3. They have visible boundaries of separation between its different constituents.

1.2.2 Properties of mixtures:

(i) A mixture may be Homogeneous or heterogeneous.

(ii) The composition of a mixture is variable.

(iii) A mixture does not have a definite melting point or a boiling point.

(iv) Energy is neither absorbed nor evolved during the formation of a mixture.

(v) The properties of a mixture are the properties of its constituents.

2. SOLUTION

A solution is a Homogeneous mixture of two or more chemically non-reacting substances whose composition can be varied within limits.

For example, lemonade is a solution of sugar, salt and lemon juice in water. These four components of solution do not react with each other since each constituent has its own taste in the lemonade. In other words, lemonade tastes the same throughout which shows that, there is homogeneity at the particle level in the solution so that, particles of sugar or salt are evenly distributed in the solution.

Components of a solution : A solution has **solvent** and **solute** as its constituents which are defined below :

Solvent : The component of solution that dissolves the other component in it (usually present in larger quantity) is called the **solvent**.

Solute : The component of the solution that is dissolved in the solvent (usually present in lesser quantity) is called the **solute**.

Example :

When sugar is dissolved in water to prepare sugar solution, sugar is called the **solute** while water is called the **solvent**.

Type of Solutions

- Solid solutions
  - Solid in solid
  - Liquid in solid
  - Gas in solid
- Liquid solutions
  - Solid in liquid
  - Liquid in liquid
  - Gas in liquid
- Gaseous solutions
  - Solid in gas
  - Liquid in gas
  - Gas in gas

2.1 SOLID SOLUTIONS

In these solutions, solid acts as the solvent, while solute can be either a solid, liquid or gas. Hence solid solutions are further classified into three categories:

(a) Solution of solid in solid : Metal alloys are the solutions of solids in solids, e.g., brass is a solution of zinc in copper. In this solution, copper (solid) acts as solvent and zinc (solid) acts as a solute.

(b) **Solution of liquid in solid :** Hydrated salts (salts containing water of crystallization) such as hydrated copper sulphate (blue vitriol), hydrated ferrous sulphate (green vitriol) etc. are the examples of **liquid in solid solutions.**

(c) **Solution of gas in solid :** Gases adsorbed on the surface of metals like nickel, platinum etc. are the examples of **gas in solid solutions**.

2.2 LIQUID SOLUTIONS

In these solutions, liquid acts as solvent, while solute can be either a solid, liquid or a gas. Hence liquid solutions are further classified into three categories :

(a) **Solution of solid in liquid :** A solution of sugar in water is an example of **solid in liquid solution.** Here, sugar (solid) is the solute and water (liquid) is the solvent. Similarly, a solution of iodine in alcohol known as **tincture of iodine** has iodine (solid) as the solute and alcohol (liquid) as the solvent. Thus, it is an example of solid in liquid solution.

(b) **Solution of liquid in liquid :** A solution of alcohol in water is an example of liquid in liquid solution. Here, alcohol (liquid) is the solute and water (liquid) is the solvent.

(c) **Solution of gas in liquid :** Aerated drinks like soda water etc. are gas in liquid solutions. These contain CO_2 (gas) as solute and water (liquid) as solvent.

2.3 GASEOUS SOLUTIONS

In these solutions, gas acts as the solvent while, solute may be a solid, liquid or gas. Hence, gas solutions are further classified into three categories:

(a) **Solution of solid in gas:** Iodine or camphor in air are the examples of solid in gas solutions. Here, camphor or iodine (solid) is the solute while air (gas) is the solvent.

(b) **Solution of liquid in gas :** Clouds, fog, mist etc. are the examples of liquid in gas solutions. Here, water drops (liquid solute) are dispersed in air (gas solvent).

(c) **Solution of gas in gas :** Air is a solution of gas in gas. Air is a Homogeneous mixture of many gases. Its two main gases are oxygen (21%) and nitrogen (78%). The other gases are present in very small quantities. Thus, in air, nitrogen gas (with larger amount) acts as the solvent while other gases (with smaller amount) act as the solute.

The nine types of solutions discussed above are summarized in the following table :

Name of the solution	Solute	Solvent	Examples
Solid solutions			
1. Solid in solid	Solid	Solid	Alloys like brass, bronze, German silver, etc.
2. Liquid in solid	Liquid	Solid	Hydrated crystals such as blue vitriol (hydrated copper sulphate).
3. Gas in solid	Gas	Solid	Gases adsorbed over the surface of metals (such as nickel, palladium, platinum, etc.) under pressure.

Liquid solutions			
4. Solid in liquid	Solid	Liquid	Sugar, common salt or other salts dissolved in water.
5. Liquid in liquid	Liquid	Liquid	Mixture of two miscible liquids such as acetone and water, alcohol and water, etc.
6. Gas in liquid	Gas	Liquid	Aerated drinks (here carbon dioxide is dissolved in water under pressure).
Gaseous solutions			
7. Solid in gas	Solid	Gas	Camphor in air or iodine in air.
8. Liquid in gas	Liquid	Gas	Clouds and fog [here, water drops (liquid) are dispersed in gas (air)].
9. Gas in gas	Gas	Gas	Air is a mixture of gases like nitrogen, oxygen, carbon dioxide, inert gases, etc.

2.4 CONCENTRATION OF A SOLUTION

Concentration of a solution may be defined as the amount of solute present in a given amount (mass or volume) of solution or the amount of solute dissolved in a given mass or volume of a solvent, thus,

$$\text{Concentration of solution} = \frac{\text{Amount of solute}}{\text{Amount of solution}}$$

$$\text{Or, Concentration of solution} = \frac{\text{Amount of solute}}{\text{Amount of solvent}}$$

Depending upon the amount of solute present in a solution, it can be called a dilute, or concentrated solution. For example, if we dissolve a few crystals of $CuSO_4$ in beaker *A* and one full spatula of $CuSO_4$ in beaker *B*, then the solution obtained in beaker *A* having small amount of solute ($CuSO_4$) is said to have low concentration and solution obtained in beaker *B* having large amount of solute ($CuSO_4$) is said to have high concentration. Hence, the solution obtained in beaker *A* is dilute as compared to that obtained in beaker *B*. Therefore,

Dilute solution : A solution having low concentration or having small amount of solute is known as dilute solution.

Concentrated solution : A solution having high concentration or having large amount of solute is known as concentrated solution.

2.4.1 Expressing the concentration of a solution

There are various ways of expressing the concentration of a solution. But, here we will learn only two methods :

(i) **Mass by mass percentage of a solution or mass percentage :** It is defined as the mass of the solute in grams dissolved in 100 grams of the solution.

Formula :

Mass by mass percentage of a solution = $\frac{\text{Mass of solute}}{\text{Mas of solution}} \times 100$

$= \frac{\text{Mass of solute}}{(\text{Mass of solute} + \text{mass of solvent})} \times 100$

[$\because$ mass of solution = mass of solute + mass of solvent]

(ii) **Mass by volume percentage of a solution :** It is defined as the mass of the solute in grams dissolved in 100 mL of solution.

Formula :

Mass by volume percentage of a solution = $\frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$

2.4.2 Saturated, Unsaturated and Supersaturated Solutions

A solution, in which no more solute can be dissolved at that temperature, is called a **saturated solution.**

A solution, in which more quantity of solute can be dissolved without raising its temperature, is called an **unsaturated solution.**

A solution which temporarily contains more solute than the saturation level (i.e. maximum solute) at a particular temperature, is called a **supersaturated solution.**

Test for saturated, unsaturated and supersaturated solutions

In order to test, whether a given solution is saturated or unsaturated, add some more solute to this solution and try to dissolve by stirring with glass rod keeping temperature constant. If more solute does not dissolve in the given solution, then it must be a **saturated solution** and if more solute dissolves, it must be an **unsaturated solution.**

On the other hand, supersaturated solution can be easily distinguished from the saturated solution simply by adding a few crystals of solute dissolved. If the precipitation of some additional solute occurs, it is a **supersaturated solution**; otherwise it is a saturated solution.

2.4.3 Solubility

The maximum amount of solute which can be dissolved in 100 gms of a solvent at a specified temperature is known as the **solubility** of that solute in that solvent (at that temperature).

For example : A maximum of 36 gms of common salt (NaCl) can be dissolved in 100 g. of water at 20°C (or 293 K). Therefore, the solubility of common salt in water at 20°C is 36 g.

Different substances have different solubilities in the same solvent. Let us understand with the help of an **experiment :**

- Take approximately 50 mL of water each in two separate beakers.

- Add common salt in one beaker and sugar or barium chloride in the second beaker with continuous stirring.
- When no more solute can be dissolved, heat the contents of the beaker.
- Start adding the solute again.
- Is the amount of common salt and sugar or barium chloride, that can be dissolved in water at a given temperature, the same ?
- What would happen if you were to take a saturated solution at a certain temperature and cool it slowly?

Discussion :

(i) The amounts of common salt, sugar and barium chloride that can be dissolved in water (50 mL) at room temperature are different.

(ii) When a saturated solution at a certain temperature is cooled, the solubility decreases and the amount of the solute which exceeds the solubility at lower temperature crystallizes out of the solution.

Conclusion: Different substances have different solubilities in a given solvent at the same temperature and, in general, the solubility decreases as the solution is cooled and the extra amount of solute crystallizes out.

3. SUSPENSION

A suspension is a heterogeneous mixture in which, the solute particles do not dissolve but remain suspended throughout the bulk of the medium.

For example, when an insoluble substance such as chalk powder, wheat flour or mud is added to water and the mixture stirred, we get a suspension in which the solids are dispersed in liquids.

3.1 SOME EXAMPLES OF SUSPENSION ARE

(i) Milk of magnesia is a suspension of magnesium hydroxide, $Mg(OH)_2$, in water.

(ii) Lime water (used for white wash) is a suspension of calcium hydroxide in water.

(iii) Paints are suspensions of coloured substances in water or some other liquid.

(iv) Bleaching powder in water is also a suspension since bleaching powder is insoluble in water.

3.2 PROPERTIES OF SUSPENSION

(i) A suspension is a heterogeneous mixture.

(ii) The solid particles of a suspension are so large in size (more than 10^{-5} cm or 10^{-7} m or 100 nm) that they are visible to the naked eye.

(iii) The particles of a suspension scatter a beam of light passing through it and makes its path visible.(show tyndall effect)

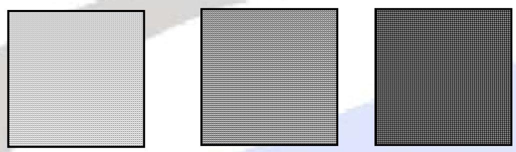
(iv) The solid particles of a suspension settle down when it is allowed to stand for sometime. In other words, a suspension is unstable.

(v) The particles of a suspension cannot pass through a filter paper. Thus, when a suspension is filtered, the solid particles remain as a residue on the filter paper.

(vi) Suspensions are either opaque or translucent.

4. COLLOIDAL SOLUTION

Solutions in which the size of the particles lie in between those of true solutions and suspensions are called **colloidal solutions** or simply **colloids.**



True solution | Colloidal solution | Suspension

Particle sizes of a true solution, a colloidal solution and a suspension.

Though colloids appear to be homogeneous to us, but actually they are found to be heterogeneous. So, colloid is not a true solution, therefore, to distinguish it from the true solution, the term **sol** is used in place of solution (i.e. **colloidal sol**)

Some examples of colloids are: soap solution, starch solution, ink, blood, milk, jelly etc.

4.1 DISPERSED PHASE AND DISPERSION MEDIUM

Components of a colloidal solution are the **dispersed phase** and the **dispersion medium**.

The solute like component which has been dispersed or distributed throughout a solvent-like medium is called the **dispersed phase** or the **discontinuous phase**.

The solvent like medium in which the dispersed phase has been distributed or dispersed is called the **dispersion medium** or the **continuous phase**.

4.2 TYPES OF COLLOIDS

Colloids are classified according to the state (solid, liquid or gas) of the dispersion medium and the dispersed phase. A few examples are given in table as follows:

Common examples of colloids

Dispersed phase	Dispersing Medium	Type	Example
Liquid	Gas	Aerosol	Fog, clouds, mist
Solid	Gas	Aerosol	Smoke, automobile exhaust
Gas	Liquid	Foam	Shaving cream

Liquid	Liquid	Emulsion	Milk, face cream
Solid	Liquid	Sol	Milk of magnesia, mud
Gas	Solid	Foam	Foam, rubber, sponge, pumice
Liquid	Solid	Gel	Jelly, cheese, butter
Solid	Solid	Solid Sol	Coloured gemstone, milky glass

4.3 PROPERTIES OF A COLLOID

(1) **Heterogeneous Nature :** A colloid is a heterogeneous mixture.

(2) **Size of particles :** Size (diameter) of particles in a colloid lies in the range 1–100 nm $(10^{-7} - 10^{-5}\text{ cm})$ i.e. in between those of true solutions and suspensions.

(3) **Stability :** Colloidal sols are quite stable i.e., colloidal particles do not settle when left undisturbed.

(4) **Visibility :** Colloidal particles are not visible to the naked eye.

(5) **Filterability :** Colloidal particles cannot be separated from the dispersion medium by filtration. However, a special technique of separation known as centrifugation can be used to separate the colloidal particles.

(6) **Tyndall effect :** The colloidal particles are big enough to scatter light passing through it. As a result, the path of light becomes visible. This **scattering of beam of light by colloidal particles is called the 'Tyndall effect'.** Lets understand -

When the beam of light from a torch is passed through a true solution of copper sulphate, Tyndall effect is not observed, i.e., the path of light is not visible (Figure a) However, when the same light is passed through a mixture of water and milk, Tyndall effect is observed and the path of light becomes visible (Figure b). The reason for this observation is that the particles of a true solution are so small that they do not scatter light and hence the path of light is not visible, i.e., Tyndall effect is not observed. In contrast, the particles of a colloidal solution are big enough to scatter light and hence path of light becomes visible, i.e., the Tyndall effect is observed.

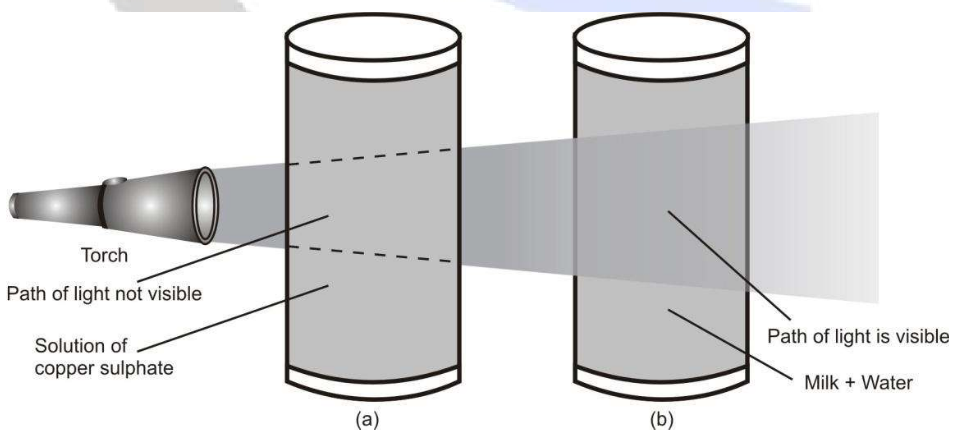


Figure : (a) Solution of copper sulphate does not show Tyndall effect *(b) Mixture of water and milk shows Tyndall effect.*

Differences between true solution, colloidal solution (sol) and suspension

Property	True Solution	Colloidal Solution	Suspension
1. Particle size (Diameter)	< 10^{-7} cm (or 10^{-9} m or 1 nm)	Between 10^{-7} □ 10^{-5} cm (10^{-9} to 10^{-7} m or 1 nm □ 100 nm)	> 10^{-5} cm (or 10^{-7} m or 100 nm)
2. Appearance	Clear and transparent	Translucent	Opaque
3. Nature	Homogeneous	Heterogeneous	Heterogeneous
4. Filterability	Pass through ordinary filter paper as well as animal membranes (having pores smaller than filter paper).	Pass through ordinary filter paper but not through animal membranes.	Neither pass through filter paper nor- through animal membranes.
5. Settling of particles	Particles do not settle down on standing, i.e., true solutions are stable.	Colloidal particles also do not settle on keeping, i.e., colloids are also stable.	Particles of suspens-ion settle down on standing, i.e., suspensions are unstable.
6. Visibility	Solute particles are not visible even under a microscope.	Particles themselves are invisible but their presence can be detected under an ultra microscope.	Particles are genera-lly visible to the naked eye.
7. Tyndall effect	Does not scatter light and hence does not show Tyndall effect.	Shows Tyndall effect due to scattering of light.	Shows Tyndall effect.

5. SEPARATION OF A MIXTURE

Different methods or techniques are used to separate the individual components of a mixture, whether homogeneous or heterogeneous. There can be three cases :

(i) Mixture of two solids

(ii) Mixture of a solid and a liquid

(iii) Mixture of two liquids

5.1 SEPARATION OF A MIXTURE OF TWO SOLIDS

All the mixtures containing two solid substances can be separated by one of the following methods :

(i) By using a suitable solvent

(ii) By the process of sublimation

(iii) By using a magnet

5.1.1 Separation by a Suitable Solvent

In some cases, one constituent of a mixture is soluble in a particular liquid solvent whereas the other constituent is insoluble in it. This difference in the solubilities of the constituents of a mixture can be used to separate them. For example, sugar is soluble in water whereas sand is insoluble in it, so a mixture of sugar and sand can be separated by using water as solvent.

5.1.2 Separation by Sublimation

The changing of a solid directly into vapours on heating, and of vapours into solid on cooling is called sublimation. The process of sublimation is used to separate those substances from a mixture which sublime on heating. The substances like ammonium chloride, iodine, camphor, naphthalene and anthracene sublime on heating and can be recovered in the form of a sublimate by cooling their vapours. **Let us perform an activity to separate a mixture of salt and ammonium chloride by sublimation.**

Ammonium chloride (NH_4Cl) undergoes sublimation whereas salt (NaCl) does not undergo sublimation. Hence, on heating in a china dish, only ammonium chloride changes directly from solid to gaseous state and thus its vapours are deposited on the stem of the inverted funnel due to cooling as shown in figure. Pure NH_4Cl is, thus separated by sublimation whereas, the salt (NaCl) is left behind in the China dish.

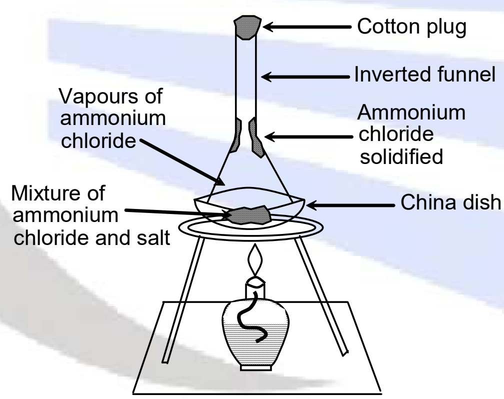


Figure Separation of Ammonium chloride by sublimation

5.1.3 Separation by a Magnet

Iron is attracted by a magnet. This property of iron is used to separate it from a mixture. So, if a mixture contains iron as one of the constituents, it can be separated by using a magnet. For example, a mixture of iron filings and sulphur powder can be separated by using a magnet. This is because iron filings are attracted by a magnet (and stick to it), but sulphur is not attracted by a magnet.

5.2 SEPARATION OF A MIXTURE OF A SOLID AND A LIQUID

All the mixtures containing a solid and a liquid are separated by one of the following processes :

(i) By filtration
(ii) By centrifugation
(iii) By evaporation
(iv) By crystallization
(v) By chromatography

5.2.1 Separation by Filtration

The process of removing insoluble solids from a liquid by using a filter paper is known as filtration. Filtration is used for separating insoluble substances from a liquid. A mixture of chalk and water is separated by filtration. A mixture of sand and water can also be separated by filtration. The tea-leaves are separated from prepared tea by the method of filtration.

5.2.2 Separation by Centrifugation

We can separate the suspended particles of a substance in a liquid very rapidly by using the method of centrifugation. Centrifugation is done by using a machine called centrifuge. Centrifugation is a method for separating the suspended particles of a substance from a liquid in which the mixture is rotated (or spun) at a high speed in a centrifuge. **Let us perform an activity to separate cream from milk by centrifugation.**

Procedure : Take some full cream milk in a test tube and centrifuge (or rotate) it at very high speed in centrifuging machine for 2-3 minutes.

Observation : The cream will separate from the milk.

Discussion: When the milk is rotated or churned at very high speed, the lighter fat particles collide with each other to form cream which stays on the surface, while the heavier particles of milk are forced to come to the bottom. As a result, separation occurs and hence cream can be separated from the milk.

Conclusion : Liquid mixtures which contain solute particle, which easily pass through a filter paper can be separated by using centrifugation technique.

Applications of Centrifugation:

(i) The technique of centrifugation is used in diagnostic laboratory for blood and urine tests.

(ii) It is used in dairies and homes to separate butter from cream.

(iii) Centrifugation technique is also used in washing machine to squeeze out water from wet clothes.

5.2.3 Separation by Evaporation

The changing of a liquid into vapours (or gas) is called evaporation. Evaporation is used to separate a solid substance that has dissolved in water (or any other liquid). The dissolved substance is left as a solid residue when all the water (or liquid) has evaporated. The use of process of evaporation for separating a mixture is based on the fact that liquids vaporize easily whereas solids do not vaporize easily. The common salt dissolved in water can be separated by the process of evaporation. **Let us perform an activity to obtain coloured component (dye) from blue/black ink by evaporation-**

Procedure : Put a few drops of blue / black ink on watch glass and place it on a beaker half full of water as shown in figure. Now start heating the beaker.

Observation : A coloured component (dye) will be left on the watch glass.

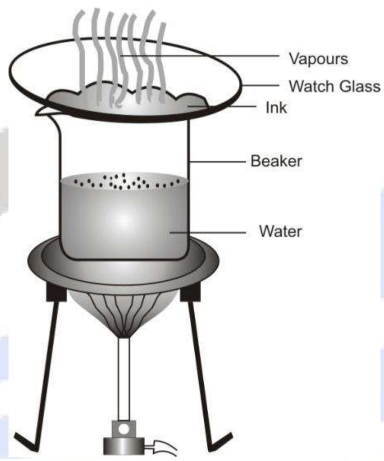


Figure: separation of coloured component (dye) from Blue/Black ink by evaporation

Discussion : Blue/black ink is a mixture of dyes in water, when water in the beaker is heated, the steam thus formed will in turn, heat up the ink. As a result the volatile component (solution) of the mixture i.e., water gets evaporated. While the non-volatile component (solute) of the mixture i.e. dyes remain as the residue.

Conclusion : The method of evaporation can be used to separate the volatile component (solvent) of the mixture from its non-volatile solute.

5.2.4 Purification by Crystallisation

The process of cooling hot, concentrated solution of a substance to obtain crystals (purest form of a substance having definite geometrical shapes) is called crystallization. **Let us perform an activity to obtain pure copper sulphate from an impure sample by crystallization method.**

Procedure : Take about 5g of impure sample of copper sulphate and dissolve it in minimum amount of water in a china dish to make copper sulphate solution. Filter the impurities out. Heat the copper sulphate solution gently on water bath to evaporate water and obtain a saturated solution. Then stop heating. Allow the hot, saturated solution of copper sulphate to cool slowly, for a day.

Observation and Discussion : Crystals of pure copper sulphate are formed by leaving the impurities behind in the solution. This is because, when a saturated solution of copper sulphate is allowed to cool, crystals of copper sulphate separate out. All these crystals have a definite shape and hence look alike. We can separate these crystals from the liquid by the process of filtration and then dry.

Conclusion : When a saturated solution of a substance is allowed to cool, crystals of the substance having definite geometrical shapes separate out.

Application of crystallization : Crystallization can be used to purify :

(i) Salt that we get from sea water.

(ii) Alum (Phitkari), copper sulphate, nitre (potassium nitrate) etc., from impure samples.

Advantages of crystallization over evaporation :

Crystallization is a better technique than 'evaporation to dryness' because of the following reasons :

(i) Some solids (like sugar) decompose or get charred on heating to dryness during evaporation.

(ii) The soluble impurities do not get removed in the process of evaporation. But such impurities get removed in crystallization.

5.2.5 Separation by Chromatography

Chromatography is a technique of separating two (or more) dissolved solids which are present in a solution in very small quantities. **Let us perform an activity to obtain different dyes from black ink by chromatography.**

The dye in the black ink is not a single colour, but it is a mixture of 2 or 3 colours. In other words, black ink is a **mixture** of different colour dyes (solute) in water (solvent), which can be easily identified with the help of **paper chromatography**.

Paper chromatography is the technique used for separation of those solutes that dissolve in same solvent. The separation by this technique is based upon the principle that though, two (or more) solutes are soluble in the same solvent, but their solubilities may be different.

Procedure : Take a thin strip of filter paper. Draw a line on it with a pencil nearly 3cm above the lower edge. Put a small drop of black ink with the help of pen at the centre of line and let it dry. Suspend the filter paper into a glass containing water so that spot of ink on the paper is just above the water level (figure). Leave it undisturbed for some time.

Observation : The water gradually rises up the filter paper by capillary action and different coloured dyes present in the ink get separated as shown in figure.

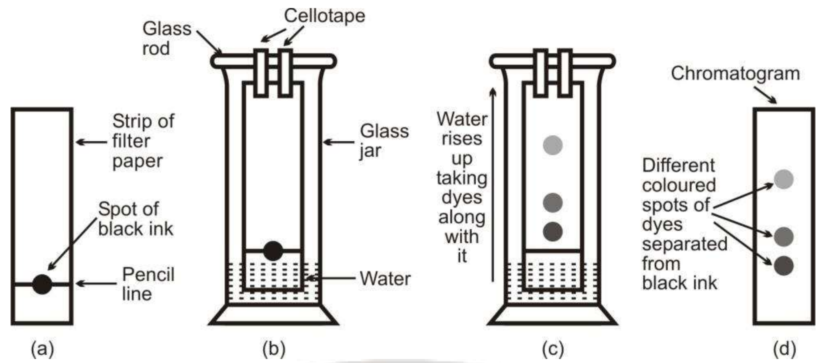


Figure separation of different coloured dyes by chromatography

Discussion : As water rises up the filter paper, it takes along with it dye particles present in ink. Since, ink is a mixture of two or more coloured dyes, the dye which is more soluble in water, rises faster and produces a coloured spot on the paper at a higher position.

The less soluble dyes present dissolve a little later, rise slower and form coloured spots at lower heights. In this way all the dyes present in black ink get separated (by forming separate different coloured spot)

Conclusion : Separation of different coloured dyes present in black ink occurs on a chromatographic paper due to their different solubilities in water.

Hence, from above experiment we conclude that, the dye in black ink is not a single colour, but a mixture of 2 or 3 colours.

Application of chromatography :

(i) Separation of coloured substances present in dyes.

(ii) Separation of pigments from natural colours.

(iii) Separation of drugs from blood.

(iv) Monitoring the progress of a reaction.

(v) Separation of amino acids obtained by hydrolysis of proteins.

5.3 SEPARATION OF A MIXTURE OF TWO (OR MORE) LIQUIDS

All the mixtures containing two (or more) liquids can be separated by one of the following two methods :

(i) By the process of distillation.

(ii) By using a separating funnel.

5.3.1 Separation by Distillation

Distillation is the process of heating a liquid to form vapour, and then cooling the vapour to get back liquid. Distillation can be represented as :

$$\text{Liquid} \underset{\text{Cooling}}{\overset{\text{Heating}}{\rightleftharpoons}} \text{Vapour (or gas)}$$

The distillation method is of two types:–

(a) Simple distillation method

(b) Fractional distillation method

Separation of a mixture of miscible liquids is done either by simple distillation method or by fractional distillation method.

(a) Separation of a mixture of two miscible liquids by simple distillation method

Simple distillation method is used for the separation of components of a mixture containing two or more miscible liquids which boil without decomposition and have sufficient difference (30–50K) in their boiling points. **Let us perform an activity to separate a mixture of two miscible liquids like acetone (B.P. 329 K) and water (B.P. 273K) by simple distillation method-**

Procedure : Take the miscible mixture of acetone and water in a distillation flask. Fit it with a thermometer. Arrange the apparatus as shown in figure. Heat the mixture gently noticing the temperature in the thermometer.

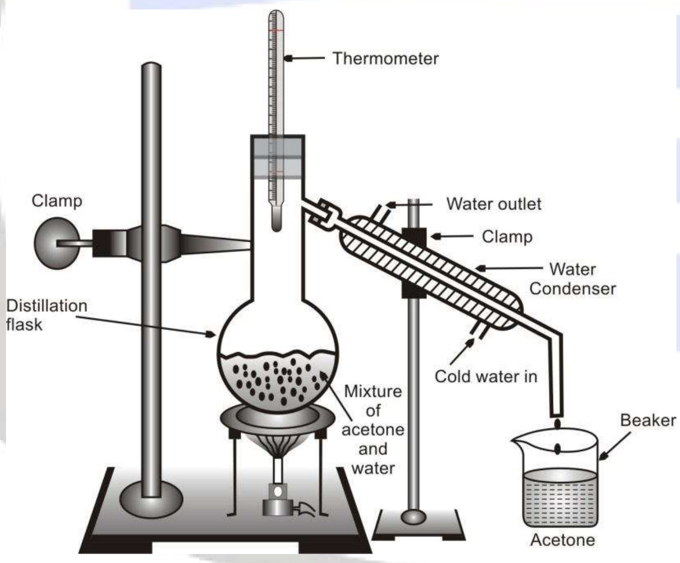


Figure separation by simple distillation method

Observation : Acetone vaporizes, condenses in the condenser and can be collected from the condenser outlet. Water is left behind in the distillation flask.

Discussion : When the mixture is heated, the vapours of substance having the low boiling point i.e. vapours of acetone are first formed. These travel upwards. On passing through the condenser, they get condensed to form liquid acetone (called **distillate**) which is collected in the beaker.

Conclusion : Separation of the components of a mixture containing two miscible liquids which boil without decomposition and have sufficient difference (30-50 K) in their boiling points can be separated out by simple distillation. This is because at the boiling point of each liquid, the vapours almost entirely consist of that liquid.

Application of simple distillation

The technique of distillation can be used to separate:

(i) a mixture of ether (b.p. 308 K) and toluene (b.p. 384 K).

(ii) a mixture of hexane (b.p. 342 K) and toluene (b.p. 384 K).

(iii) a mixture of benzene (b.p. 353 K) and aniline (b.p. 457 K) or nitrobenzene (b.p. 483 K)

(b) Separation of mixture of two or more miscible liquids by fractional distillation

Fractional distillation is the process of separating two (or more) miscible liquids by distillation, the distillate being collected in fractions, boiling at different temperatures. The separation of two liquids by fractional distillation depends on the difference in their boiling points. Fractional distillation is carried out by using a fractionating column.

Similarly, different gases from air and different fractions (like kerosene, petrol and diesel etc.) from petroleum products, are also separated by fractional distillation.

Fractional distillation is carried out using a **fractionating column** which is fitted in between the distillation flask and the condenser as shown in figure. Fractionating column is a tube packed with glass beads. The beads provide surface for the vapours to cool and condense repeatedly.

(a) Let us perform an activity to separate a mixture of two miscible liquids alcohol and water by Fractional distillation-

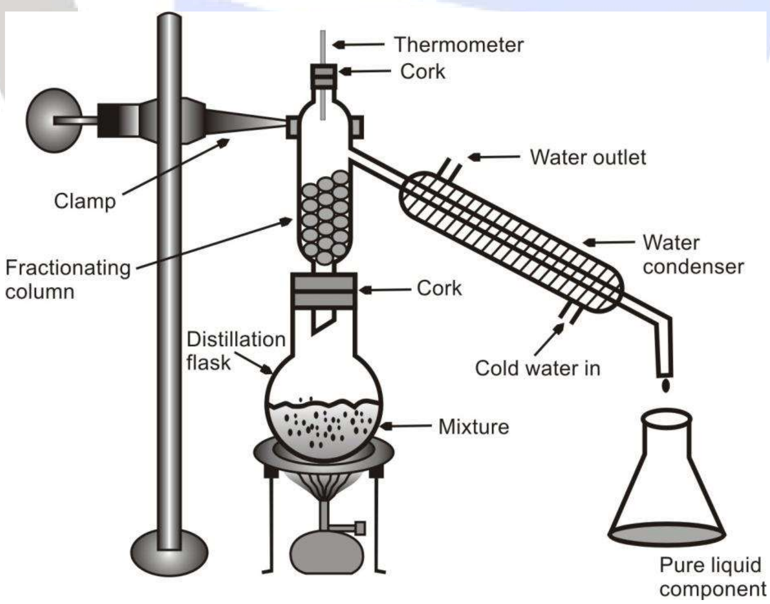


Figure: separation by fractional distillation method

Alcohol (or ethanol), and water are miscible liquids. The boiling point of alcohol is 78^0C and the boiling point of water is 100^0C. Since the boiling points of alcohol and water are different, therefore, a mixture of alcohol and water can be separated by fractional distillation. The apparatus used for fractional distillation of alcohol and water mixture is shown in figure.

The mixture of alcohol and water is heated in a distillation flask fitted with a fractionating column. When the mixture is heated, both alcohol and water form vapours as their boiling points approach. The alcohol vapour and water vapour rise up in the fractionating column. The upper part of the fractionating column is cooler, so as the hot vapours rise up in the column, they get cooled, condense and trickle back into the distillation flask. As the experiment goes on, the fractionating column warms up by the heat released by the condensed vapours. After some time, a temperature gradient is created in the fractionating column, the temperature at the top of the column being much less than at its bottom.

When the temperature at the top of the fractionating column reaches 78^0C (which is the boiling point of alcohol), then alcohol vapour passes into the condenser, gets cooled and collects in a beaker kept at the other end of the condenser. In this way, all the alcohol distils over and gets separated. It is collected as the first fraction.

Having collected the alcohol fraction, the flask is heated more strongly so that the thermometer shows a temperature of 100^0C, which is the boiling point of water. When the temperature at the top of the fractionating column becomes 100^0C, water vapour passes into the condenser, gets cooled and condenses. This pure water is collected in another beaker as the second fraction. Heating is continued till all the water distils over. In this way, the alcohol-water mixture has been separated into two fractions boiling at 78^0C and 100^0C, respectively.

(b) We can obtain different gases from air by fractional distillation-

Air is a Homogeneous mixture of a number of gases such as nitrogen, oxygen, argon, carbon dioxide, helium, neon, krypton and xenon. The major components of air are : nitrogen (78.03%), oxygen (20.09%) and argon (0.93%). All the remaining gases of air constitute only 0.05% of gas.

The various gases of air are separated from one another by the fractional distillation of liquid air. For this purpose, air is first compressed by increasing the pressure and then cooled by decreasing the temperature to get liquid air (liquid air is an extremely cold liquid which contains all the component gases in liquid form). The liquid air is then subjected to fractional distillation (or allowed to warm up slowly in a fractional distillation column). As a result, the various liquefied gases present in it, boil off at different temperatures (according to their boiling points) and collected separately at different heights in the fractional distillation column.

Since the boiling point of nitrogen is lowest, i.e., –196°C or 77 K, therefore, it gets distilled first of all, followed by argon with boiling point –186°C or 87 K, while oxygen has the highest boiling point i.e. –183°C or 90 K, therefore, it gets distilled last of all.

The flow chart for the separation of gases of air is shown-

Air

↓ Compression by increasing pressure and cooling by decreasing temperature

Liquid Air

↓ Allow to warm up slowly in fractional distillation column.

Gases get separated at different heights according to their boiling points.

↓

Boils first	Boils second	Boils third
Nitrogen (78.03% by volume) B.P. –196°C or 77K	Argon (0.93% by volume) B.P. –186°C or 87K	Oxygen (20.09% by volume) B.P. –183°C or 90K

The actual apparatus used for separation of gases is shown in figure.

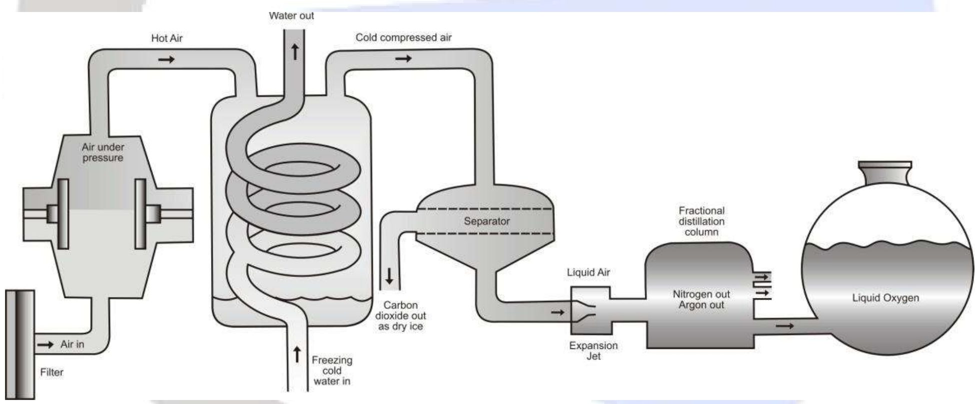


Figure separation of different gases from air by fractional distillation method

5.3.2 Separation by Separating Funnel

A mixture of two immiscible liquids can be separated by using a separating funnel (shown in Figure). The separation of two immiscible liquids by a separating funnel depends on the difference in their densities.

Let us perform an activity to describe how a mixture of two immiscible liquids is separated by using a separating funnel-

Procedure : Pour a mixture of kerosene oil and water (i.e., a mixture of two immiscible liquids) in a separating funnel. Keep the mixture undisturbed for some time.

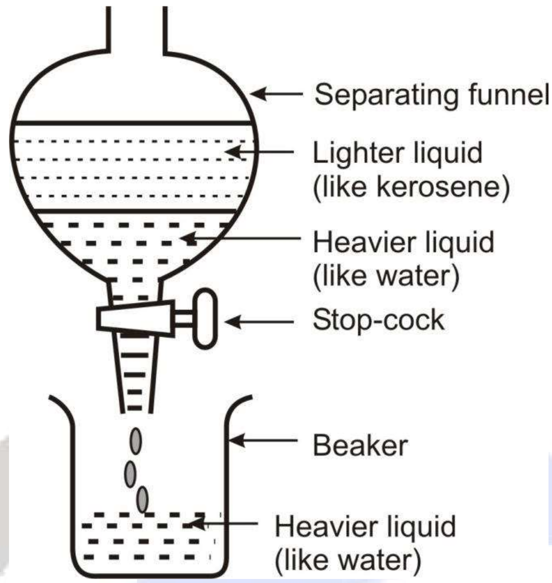


Figure: separation of two immiscible liquid by separating funnel

Observation : Two separate layers of kerosene and water are formed in the separating funnel in such a way, that kerosene forms upper layer while water forms the lower layer.

On opening the stop-cock of the funnel, two layers can be separated out.

Discussion : The mixture separates into two layers according to the densities of the liquids in it. The heavier liquid or denser liquid (i.e. water) forms lower layer whereas the lighter liquid having low density (i.e., kerosene oil) forms the upper layer.

Conclusion : A mixture of two immiscible liquids can be separated by using a separating funnel which is based upon the principle that, immiscible liquids separate out into different layers depending upon their densities.

Applications of solvent separation:

(i) This technique is used to separate a mixture of oil and water or mixtures of any two immiscible liquids like benzene and water, chloroform and water, ether and water, carbon tetrachloride and water, etc.

(ii) In the blast furnace, during extraction of iron, two separate layers are formed. The upper layer consists of the molten slag while the lower layer consists of molten iron. The lighter slag is removed from the top by this technique to leave the molten iron at the bottom of the furnace.

6. PURIFICATION OF DRINKING WATER

In cities, drinking water is supplied to our homes from the water works. The water works of a city are usually situated near the bank of a river or a lake. The river and lake water contains a number of suspended solids and harmful bacteria. These must be removed before the water to be supplied to homes for drinking purposes.

The purification of river water or lake water is done in the following steps :

(i) **Sedimentation tank :** The water from river or lake is first passed through the sedimentation tank. Here, the water is allowed to stand for some time. During this time, many suspended solids settle down at the bottom of the tank.

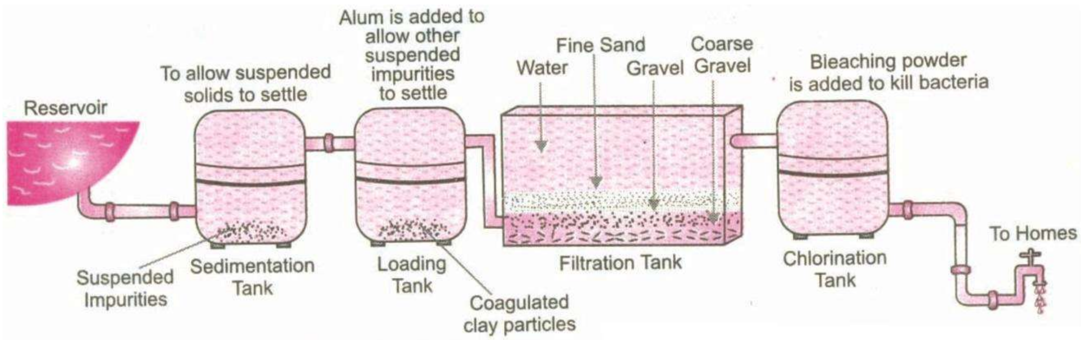


Figure apparatus used for purification of impure water

(ii) **Loading tank:** From sedimentation tank, water is sent to the loading tank. In the loading tank, some alum (phitkari) is added to the water. The colloidal particles of clay present in water are negatively charged. They do not settle down in the sedimentation tank. However, when alum is added, these negatively charged particles get neutralized by the positively charged aluminium ions present in alum. In this way, suspended clay particles get loaded with aluminium ions, become heavy and settle down at the bottom of the tank.

(iii) **Filtration tank:** After the removal of insoluble solids and other suspended impurities, the water is passed through a filtration tank. The filtration tank has three layers. At the bottom of the tank is placed coarse gravel. Above it is placed fine gravel and on the top of gravel is placed a thick layer of fine sand. These layers of sand and gravel act as filters. The impure water is introduced at the bottom. As the water rises above, all the impurities present in water are retained and the pure water leaves the tank at the top.

(iv) **Chlorination tank:** The water obtained from the filtration tank is introduced into the chlorination tank where it is treated with bleaching powder or some other germicides to kill bacteria.

The water obtained after the above treatments is free from all types of impurities and bacteria and is supplied to our homes for drinking purposes.

7. PHYSICAL AND CHEMICAL CHANGES

All the changes taking place around us can be classified into the following two types:

(a) Physical changes and

(b) Chemical changes

7.1 PHYSICAL CHANGES

Those changes in which no new substances are formed, are called physical changes. In a physical change, the substances do not change their chemical identity but there occurs only a change in some of their physical properties such as physical state, shape and size, etc.

Therefore, after the physical change, the substance can be easily converted back to their original state, shape and size, etc. by some physical process.

Thus physical changes are temporary and hence it can be easily reversed.

7.1.1 Examples of Physical Changes

(i) **Melting of ice and freezing of water to form ice:** When ice is heated, it melts to form liquid water, conversely, when water is cooled in a refrigerator, it freezes to form ice. Since both ice and liquid water are made up of same water molecules (H_2O), no new substance is formed during melting of ice and freezing of water. Hence melting of ice and freezing of water to form ice are physical changes.

(ii) **Boiling of water to form steam and condensation of steam to form water:** When water is heated, it boils to form steam, conversely, when steam is cooled, it condense to form water. Since both steam and water are made up of water molecules (H_2O), no new substance is formed during, boiling of water and condensation of steam. Hence, boiling of water to form steam and condensation of steam to form water are the physical changes.

(iii) **Preparing a solution:** If we dissolve some common salt in water, it (salt) disappears in water and forms a salt solution. So, a change has taken place in making salt solution.

Now, if the salt solution is heated, till all the water evaporates, a white powder of common salt which we had dissolved in water earlier is obtained.

This means that no new substance has been formed by dissolving common salt in water to make salt solution. Thus preparing of a solution is a physical change.

(iv) **Breaking a glass tumbler:** When a glass tumbler breaks, it forms many pieces. Each broken piece of glass tumbler is still glass. So, during the breaking of a glass tumbler, only size and shape of glass has changed but no new substance has been formed. So, the breaking of glass tumbler is a physical change.

(v) **Glowing of an electric lamp:** When an electric bulb is switched on, an electric current passes through its filament. The filament of bulb becomes white hot and glows to given light. When the current is switched off, the filament returns to its normal condition and the bulb stops glowing. No new substance is formed in the bulb during this process. So, the glowing of an electric bulb is a physical change.

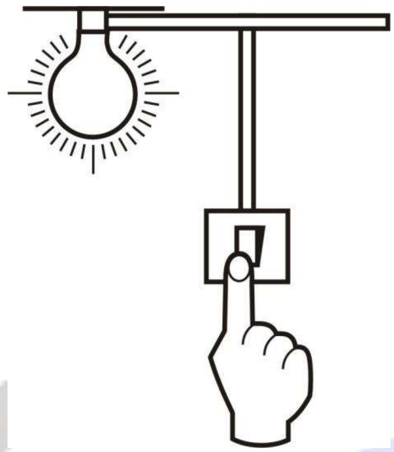


Figure showing glowing of an electric lamp

Some other examples of physical changes: Melting of wax, mixing of iron filing and sand, rotation of fan, formation of clouds, mist and fog, stretching of a rubber band, tearing a piece of cloth or paper, knitting of wool into a sweater, melting of glass etc. are some examples of physical changes.

7.1.2 Chemical changes

Those changes in which new substances are formed are called chemical changes. In a chemical change, the original substances lose their chemical identity and get converted into new substances. The new substances thus formed cannot be converted into original substances by any physical process. Thus, chemical changes are permanent and hence are irreversible.

7.1.3 Examples of chemical changes

(i) Burning of piece of paper

(ii) Burning of magnesium ribbon

(iii) Burning of hydrogen in air or oxygen

(iv) Rusting of iron

Some more examples of chemical changes are:

Burning of candle-wax, burning of fuels, burning of incense stick, electrolysis of water, cooking of food, digestion of food, making a cake, frying of an egg to make omelet, formation of curd or cheese from milk, growth of plants, cutting of trees etc.

Differences between physical and chemical changes.

Physical change	Chemical change
1. No new substance is formed in a physical change.	1. A new substance is formed in a chemical change.

2. A physical change is a temporary change.	2. A chemical change is a permanent change.
3. A physical change is easily reversible.	3. A chemical change is usually irreversible.
4. Very little heat (or light) energy is usually absorbed or given out in a physical change.	4. A lot of heat (or light) energy is absorbed or given out in a chemical change.
5. The mass of a substance does not alter in a physical change.	5. The mass of a substance does alter in a chemical change.

8. PURE SUBSTANCES

A pure substance is one, which is made up of only one kind of atoms or molecules.

8.1 WHAT ARE THE TYPES OF PURE SUBSTANCES?

On the basis of the nature of constituent particles, pure substances are of two types:

Pure substances

Elements | Compounds

A pure substance, which is made up of only one kind of atoms is called an element, while that which is made up of only one kind of molecules is called Compound.

8.1.1 Elements

- An element is defined as the simplest form of a pure substance, that cannot be broken down into simpler substances by any physical or chemical method.
- There are 115 elements known at present, out of which 92 elements are naturally occurring and 23 elements are man made.
- Majority of elements are solids, e.g. sodium, carbon etc.
- Eleven elements are gases at the room temperature, e.g. hydrogen, oxygen, nitrogen etc.
- Only two elements are liquid at room temperature, e.g. mercury and bromine.

All the elements have been classified into following three classes on the basis of their properties:

Elements

Metals | Non-metals | Metalloids

(a) Metals

A metal is an element that is malleable and ductile and conducts electricity.

Examples: Iron, copper, platinum, gold, silver, zinc, aluminium, sodium, potassium etc.

Properties of metals

(i) Metals are malleable i.e. they can be hammered or beaten into thin sheets.
(ii) Metals are ductile i.e. they can be drawn into wires.
(iii) Metals are lustrous (or shiny) and can be polished. The shiny surface of metals makes them good reflectors of light. e.g. silver metal is an excellent reflector of light.
(iv) Metals usually have silver or grey colour except gold which is yellow and copper which is reddish brown.
(v) Metals are good conductors of heat and electricity i.e. they allow heat and electricity to pass through them easily.
(vi) Metals are generally hard. However, metals like sodium and potassium are quite soft and can be easily cut with a knife.
(vii) Metals have high tensile strength. However sodium and potassium metals have low tensile strength.
(viii) Metals have high melting and boiling points. However, gallium and carsium have low melting points.
(ix) Metals generally have high densities except sodium and potassium which have low densities.
(x) Metals are sonorous, i.e., they make a ringing sound when hit.

(b) Non-Metals

A non-metal is an element that is neither malleable nor ductile and does not conduct electricity.

Example: Sulphur, hydrogen, oxygen, chlorine, iodine, neon, argon, carbon, diamond and graphite (allotropic forms of carbon) etc.

Properties of non-metals

(i) Non-metals are not malleable, i.e. they cannot be hammered or beaten into thin sheets.
(ii) Non-metals are not ductile, i.e. they cannot be drawn into wires.
(iii) Non-metals are non-lustrous or dull in appearance except graphite and iodine.
(iv) Non-metals have many different colours e.g. sulphur is yellow, phosphorus is white or red, graphite is black, chlorine is yellowish, bromine is reddish-brown whereas hydrogen and oxygen are colourless.
(v) Non-metals are bad conductors of heat and electricity i.e. they do not allow the heat and electricity to pass through them easily except graphite.
(vi) Non-metals are generally soft except diamond which is extremely hard non-metal.
(vii) Non-metals have low tensile strength.
(viii) Non-metals have comparatively low melting and boiling points (except diamond and graphite having high melting point)
(ix) Non-metals have low densities (except iodine having high density)
(x) Non-metals are not sonorous i.e., they do not make ringing sound when we strike them.

The comparison among the properties of metals and non-metals can be shown more clearly by the following table:

Comparison Among the Properties of Metals and Non-Metals

Metals	Non-Metals

1. Metals are malleable and ductile. That is, metals can be hammered into thin sheets and drawn into thin wires. 2. Metals are good conductors of heat and electricity. 3. Metals are lustrous (shiny) and can be polished.	1. Non-metals are brittle. They are neither malleable nor ductile. 2. Non-metals are bad conductors of heat and electricity (except diamond which is a good conductor of heat, and graphite which is a good conductor of electricity). 3. Non-metals are non-lustrous (dull) and cannot be polished (except iodine which is a lustrous non-metal).

(c) Metalloids

The elements having properties intermediate between properties of metals and non-metals are called **metalloids.**

Example : Boron (B), Silicon (Si) and Germanium (Ge) etc.

8.1.2 Compound

A compound is a pure substance that is made up of two or more elements, chemically combined together in a fixed proportion by mass.

For example:

- Water (H_2O) is a compound made up of two elements, hydrogen and oxygen, chemically combined in a fixed proportion of 1:8 by mass.
- Lime (CaO) is a compound made up of two elements–calcium and oxygen.
- Marble ($CaCO_3$) is a compound made of three elements–calcium, carbon and oxygen.

Properties of compounds

(i) A compound is always made up of same elements combined together in a fixed proportion by mass.

(ii) The constituent elements of a compound cannot be separated by physical methods.

(iii) A compound is a Homogeneous substance i.e. properties and nature of all portions of a compound are same throughout.

(iv) The properties of a compound are entirely different from those of its constituent elements. e.g. water (H_2O) is a compound made up of oxygen and hydrogen. Both hydrogen and oxygen are gases. Hydrogen catches fire and oxygen is a supporter of combustion. But water is a liquid and extinguishes fire. Thus, water has properties different from its constituents.

(v) A compound has a fixed melting point and fixed boiling point.

(vi) Formation of a compound is accompanied by evolution or absorption of energy i.e. energy is either given out or absorbed during the preparation of a compound.

Differences between an element and a compound

S.No.	Element	Compound
1.	An element consists of same kind of atoms.	A compound is formed from different kinds of atoms.

2.	An element cannot be split up by physical or chemical methods.	A compound can be split up into new substances by chemical methods.
3.	Number of elements known is limited. Only 115 elements are known.	Number of known compounds is very large.

Differences between a mixture and a compound

S.No.	Mixture	Compound
1.	The composition of a mixture is variable. The constituents in a mixture may be present in any proportion.	The composition of a compound is fixed. The constituents in a compound are present in a fixed proportion by mass.
2.	The constituents of a mixture can be separated by physical methods.	The constituents of a compound cannot be separated by physical methods.
3.	A mixture may be homogeneous or heterogeneous.	A compound is a homogeneous substance.
4.	A mixture shows the properties of its constituents.	The properties of a compound are entirely different from its constituents.
5.	A mixture does not have a fixed melting point and boiling point.	A compound has a fixed melting point and boiling point,
6.	Energy is neither absorbed nor evolved during the preparation of a mixture.	Energy is either absorbed or evolved during the formation of a compound.