CHEMISTRY

# IS MATTER AROUND US PURE?

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# IS MATTER AROUND US PURE : CHEMISTRY

## Introduction

A pure substance is a single substance and is made up of one kind of particles. The particles may be either atoms or molecules. A pure substance is uniform or homogeneous throughout because it consists of only one kind of particles. These particles are similar to one another and cannot be separated by physical methods.

## Elements and Compounds

The pure substance which is made up of one kind of atoms only is called an element and the pure substance which is made up of one kind of molecules only is called a compound. Examples of elements are hydrogen, carbon, oxygen, sulphur, copper, silver, gold, etc. Examples of compounds are water, alcohol, carbon dioxide, ammonia, sodium chloride, etc.

## Types of Elements

Elements can be classified into metals, non-metals and metalloids on the basis of their properties.

- **Metals**
  - Metals are solids at room temperature except mercury, which is a liquid at room temperature.
  - Metals are malleable which means that they can be hammered into thin sheets. Gold and silver are the most malleable metals.
  - Metals are ductile i.e. they can be drawn into thin wires. Gold is most ductile followed by silver, copper and aluminium.
  - Metals are good conductors of heat and electricity Silver is the best conductor and lead is the poorest conductor of heat. Silver is the best conductor of electricity followed by copper, gold, aluminium and tungsten.
  - Metals have lustre i.e, they have shining surfaces. Silver has a shining white surface, gold has yellow and copper has reddish brown.
  - Metals have high tensile strength. Sodium and potassium are quite soft hence have low tensile strength.
  - Metals are generally hard. Sodium and potassium are soft can be cut with a knife.
  - Metals are sonorous i.e. they produce a ringing sound when hit.
  - Metals have generally high densities.
  - Metals have generally high melting and boiling points. Sodium and potassium have low melting points. (371 and 336 K respectively).
  - Gallium and cesium become liquid at slightly higher temperature than room temperature (303 K).
- **Non-Metals**
  - Non-metals are either gases, liquids or solids at room temperature. Bromine is liquid a room temperature. Boron, carbon, sulphur and phosphorus are solids. Hydrogen, oxygen, nitrogen, etc. are gases.
  - Non-metals are brittle. They are not malleable or ductile. They break into pieces when hammered Non-metals are bad conductors of heat and electricity. Graphite an allotropic form of carbon is good conductor of electricity due to its special crystalline structure in which one electron of carbon remains free.
  - Non-metals have no lustre. Solid non-metals have generally dull surfaces. Iodine has a shining lustre and a crystalline structure.
  - Non-metals are generally soft. Diamond, an allotropic form of carbon, is the hardest natural substance known.
  - Non-metals have low tensile strength i.e, they are not strong and their bonds break easily.
  - Non-metals are non-sonorous.
  - Non-metals have comparatively low melting and boiling points except boron, graphite and diamond have high boiling points.
- **Metalloids**

  Elements which have properties of both metals and non-metals are called metalloids or semimetals. Their intermediate conductivity makes them semiconductors. Silicon, germanium, arsenic, antimony, tellurium are common examples of metalloids.

## Compound

- A compound is a pure substance which contains two or more elements combined together in a fixed proportion by mass. e.g. carbon dioxide is always made up of the same two elements, carbon and oxygen combined together in a fixed proportion of 3:8 by mass.
- The properties of a compound are entirely different from the properties of its constituents, e.g. water is a liquid while its constituents are gases. Hydrogen is a combustible gas and oxygen is a supporter of combustion while water is used to extinguish fire.

- The constituents of a compound cannot be separated by physical means. Each compound has a fixed molecular formula, melting point and boiling point. A pure solid compound has a fixed sharp melting point while impure solids have lower melting point than the pure solid. A pure liquid compound has a fixed boiling point while impure liquid has higher boiling point than the pure liquid.
- A compound is homogeneous in nature. Its composition remains same throughout the compound.
- Energy changes are accompanied by formation of compounds. Heat, light or electricity are either evolved or absorbed during formation of a compound.
- Compounds can be classified into inorganic and organic compounds on the basis of their structures.

  They can also be classified into acids, bases and salts on the basis of their properties. Sodium chloride, calcium carbonate, carbon dioxide, sulphuric acid etc. are inorganic compounds. Alcohol, ether, sugar, oils, hydrocarbons, etc. are organic compounds. Sulphuric add, nitric acid, hydrochloric acids are common acids. Sodium hydroxide, potassium hydroxide, ammonium hydroxide, etc. are common bases. Calcium carbonate, zinc sulphate, copper sulphate, ammonium chloride, sodium carbonate, etc. are common examples of salts.

## Differences between an element and a compound

| | Element | Compound |
|---|---|---|
| **1.** | An element consists of the same kind of atoms. | A compound is composed of different kinds of atoms. |
| **2.** | A monoatomic element cannot be split up into its components by physical or chemical methods. | A compound can be split up into its components by chemical methods. |
| **3.** | Only limited number of elements are known. | Number of known compounds are quite large. |
| **4.** | The property of an element is the property of its atom. | The property of a compound is quite different from that of its constituent atoms. |

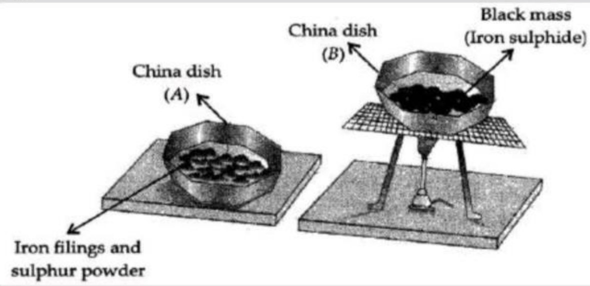
## Impure Substances or Mixtures

- A mixture is a substance in which two or more pure substances are mixed in any proportion without any chemical combination. A mixture does not have a definite formula or composition.
- A mixture does not have a fixed melting or boiling point.
- The mixture shows the properties of all its components.
- A mixture can be separated into its components by physical means since they are not chemically bonded.

## ACTIVITY CORNER

**To distinguish between mixtures and compounds**

In two separate china dishes marked (A) and (B), take mixture of nearly 50 g of iron filings and 3 g of powdered sulphur. Keep the dish (A) as such while heat the dish (B) to red hot for some time and then cool it.




- **Observations:**
  - In the china dish (A) both iron filings and sulphur powder retain their colour.
    In the dish (B) a black mass will be formed.
  - Bring a magnet near the mass present in both the dishes. Iron filings will readily cling to the magnet in dish (A) while this will not happen in dish (B).
  - Transfer a small amount of the mass from dish (A) into a glass tube. Add carbon disulphide (liquid) to it and shake for some time. The yellow powder will dissolve leaving behind the iron filings in the tube. Repeat the same experiment with the mass present in dish (B) also.
    Nothing will happen.
- **Conclusion:**
  - In the china dish (A), both iron filings and powdered sulphur are in the form of a mixture.
    In the dish (B), a chemical reaction has resulted upon heating and the black mass of iron sulphide is formed. It is a compound.
    Iron+ Sulphur $\xrightarrow{\text{Heat}}$ Iron sulphide
  - Iron filings present in dish (A) are attracted towards the magnet. Since iron sulphide is a

compound, it is not attracted towards the magnet.

- Carbon disulphide has dissolved sulphur present in dish (A) leaving behind iron filings.

It will not dissolve iron sulphide present in dish (B).

## Differences between a mixture and a compound

| Mixture | Compound |
|---|---|
| 1. A mixture is obtained when two or more elements or compounds just mix together without involving the formation of any new compound. | 1. Elements react together to form a new compound. |
| 2. A mixture is formed as a result of a physical change. | 2. A compound is formed as a result of a chemical change. |
| 3. The constituents of a mixture can be easily separated by physical methods such as filtration, evaporation, distillation, sublimation, extraction with solvents, magnet, etc. | 3. The constituents of a mixture cannot be separated by physical methods but can be separated only by chemical or electrochemical reactions. |
| 4. A mixture shows the properties of its constituents. | 4. The properties of a compounds are altogether different from those of its constituents. |
| 5. The composition of a mixture is variable, i.e., the constituents of a mixture can be present in any proportion. Therefore, a mixture does not have a fixed formula. | 5. The composition of a compound is always fixed, *i.e.,* the constituent elements are always present in a fixed proportion by mass. Therefore, a compound has a definite formula. |
| 6. A mixture does not have a fixed melting point, boiling point, etc. | 6. A compound has a fixed melting point, boiling point, etc. |
| 7. A mixture may be homogeneous or heterogeneous. | 7. A compound is a homogeneous substance. |
| 8. Energy (in the form of heat or light) is neither absorbed nor evolved during the formation of a mixture. | 8. Energy (in the form of heat or light) is either absorbed or evolved during the formation of a compound. |

## Types of Mixtures

Depending upon the nature of the components of a mixture, mixtures can be classified into homogeneous and heterogeneous mixtures.

## Types of Mixtures

| | Type of mixture | Homogeneous mixture | Heterogeneous mixture |
|---|---|---|---|
| **1.** | Gas in gas | Clean air | – |
| **2.** | Gas in liquid | Aerated water (water + carbon dioxide + oxygen) | – |
| **3.** | Gas in solid | Hydrogen in palladium | – |
| **4.** | Liquid in liquid | Alcohol and water | Oil and water |
| **5.** | Liquid in solid | Mercury in amalgamated zinc | – |
| **6.** | Solid in liquid | Sodium chloride in water | Chalk in water |
| **7.** | Solid in solid | Alloys, *e.g.* bronze, brass | Iron filings and sand, gun powder |

- **Homogeneous Mixture**

A mixture is called homogeneous if all the components are mixed uniformly and there is no clear boundary of separation between them. The composition of a homogeneous mixture is uniform throughout. The components cannot be seen with naked eyes or under a microscope.

- Air is a homogeneous mixture of a number of gases like oxygen, nitrogen, carbon dioxide, inert gases, etc.
- A solution of alcohol and water is a homogeneous mixture of two liquids.
- An alloy is a homogeneous mixture of two or more metals and non-metals in solid state (Brass is an alloy of zinc and copper).
- A solution of sugar in water is a homogeneous mixture of a solid and a liquid.

- **Heterogeneous Mixture**

  A mixture is called heterogeneous if its composition is not uniform throughout and the components have visible boundaries of separation with them. The components of a heterogeneous mixture can be seen by naked eyes or under a microscope.

  - A mixture of sugar and sand is a heterogeneous mixture of two solids.
  - Oil and water is a heterogeneous mixture of two liquids.
  - Water and chalk powder is a heterogeneous mixture of a solid and a liquid.

## ILLUSTRATION

**1.** How will you justify that water is a compound?

**Sol.** Water is considered to be a compound due to the following reason:

(a)Water cannot be separated into its constituents i.e., hydrogen and oxygen by physical methods.

(b) Properties of water are entirely different from its constituents hydrogen and oxygen. Hydrogen is combustible while oxygen supports combustion. Water is quite different from the two and it extinguishes fire.

(c) Heat and light are given out when water is formed by burning hydrogen and oxygen.

(d) The composition of water is fixed. Its constituent's hydrogen and oxygen are present in the ratio of 1:8 by mass.

(e) Water has a fixed boiling point of $100^{o}C$ (or 373K) under atmospheric pressure of one atmosphere (or 760 mm).

**2.** How will you justify that air is mixture and not a compound?

**Sol.** The justification can be done on the basis of the following points in its support:

(i) The composition of air is not always the same. At high altitudes, the percentage of oxygen decreases. Similarly, in industrial towns, we normally say that the air is more polluted. This means that the percentages of carbon monoxide, sulphur dioxide and other poisonous gases in air has increased.

(ii) The major constituents of air can be easily separated by physical methods such as liquefaction, fractional distillation, etc.

(iii) The different gases present in air do not lose their identities. For example, air supports combustion which means that it contains oxygen. Similarly, air turns lime water milky. This establishes the presence of carbon dioxide in air.

(iv) No energy changes or no chemical reactions occur when the constituents of air tried to be mixed.

All these evidences support the fact that air is a mixture and not a compound.

## Physical and Chemical Changes

Two types of changes take place during the formation of compounds and mixtures. A compound is formed as a result of chemical reaction while a mixture is formed only by mixing the constituents without any chemical reaction.

- **Physical Change**
  - Physical change involves a change in physical state of a substance, size and its appearance.
  - No new substances are formed.
  - Change is temporary and can be reversed.
  - No change in the mass or composition of constituents.
  - Not much gain or loss of energy occurs.

  Examples- Dissolving salt or sugar in water, sublimation of iodine, bending a glass tube, etc.

- **Chemical Change**
  - The change in which new substances are formed in a chemical reaction by interacting with other is called a chemical change.
  - A chemical change is a permanent change and cannot be reversed to give back substances in original structure.
  - The original substances lose their identities and properties.

- Energy changes occur in a chemical reaction.
- The change in mass and composition takes place. Examples- Burning of magnesium in air, rusting of iron, digestion of food, baking of cake, burning of hydrogen in air or oxygen to give water, burning of fuels, ripening of fruits, etc.

## Differences between Physical and Chemical Changes

| Physical change | Chemical change |
|---|---|
| 1. A physical change brings about changes in physical properties of the substance such as physical state, shape and size, etc. For example, ice (solid) melts to form water (liquid). | 1. A chemical change brings about changes in the chemical properties of the substance. For example, iron undergoes rusting to form hydrated iron oxide. The chemical properties of hydrated iron oxide are different from those of iron. |
| 2. There is no change in the chemical composition of the substance during the physical change. Thus, both ice and steam have the same chemical composition (made up of water molecules) as that of liquid water. | 2. There is always a change in the chemical composition of the substance during a chemical change. For example, iron and rust have different chemical composition. |
| 3. No new substance is formed in a physical change. | 3. A new substance is always formed during a chemical change. |
| 4. Physical changes are temporary and hence are easily reversible. | 4. Chemical changes are permanent and hence are irreversible. |
| 5. Small amounts of heat and light energy is usually absorbed or given out during a physical change. | 5. Large amounts of heat and light energy are always absorbed or given out in a chemical change. |

### ILLUSTRATION

**3.** Why is burning of a candle involves both physical and chemical change?

**Sol.** When a candle is burnt, the following two changes occur.
1. Melting of wax.
2. Burning of thread and was.
The melting of wax is a physical change whereas the burning of thread and wax is a chemical change. Hence, the burning of a candle involves both physical and chemical change.

## Solution

A solution is a homogeneous mixture of two or more non-reacting substances whose composition can be varied within certain limits. The solution which has only two components is called binary solution. A binary solution is made by dissolving one component into another.

- **Components of a Solution**
  - The component which is dissolved is called solute. The solute is present in small amount. Solution may or may not be in the same state of matter as the solute.
  - The medium in which solute is dissolved is called the solvent. The solvent is present in a larger amount. Solution will be in the same state of matter as the solvent.
- **Types of Solution**
  Due to three states of matter nine different types of binary solutions are possible. Three groups of solutions can be formed depending upon the nature of the solvent.
  - Solid solution: The solvent is solid.
  - Liquid solution: The solvent is liquid.
  - Gaseous solution: The solvent is gas.
  The nine types of binary solutions discussed above are summarized in the following table:

| Name of solution | Solute | Solvent | Examples |
|---|---|---|---|
| **Solid solutions** | | | |
| 1. Solid in solid | Solid | Solid | Alloys like steel, brass, bronze, German silver, solder, etc. |
| 2. Liquid in solid | Liquid | Solid | Hydrated crystals such as blue vitriol (hydrated copper sulphate), dental amalgam (mercury liquid and silver solid). |
| 3. Gas in solid | Gas | Solid | Gases adsorbed over the surface of the 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, tincture of iodine. |
| 5. Liquid in liquid | Liquid | Liquid | Mixture of two miscible liquids such as acetone and water, alcohol and water, vinegar (acetic acid 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. |

- **Properties of Solution**
  - A solution is a homogeneous mixture.
  - The particle size of a solution is very small (< 1 nm or $10^{-9}$ m) in diameter. So they cannot be seen by naked eye or by ordinary microscope.
  - Due to small size the solute particles do not scatter a beam of light passing through a solution.
  - The solution can pass through a filter paper without separation of solute particles. The solute particles present in a solution do not settle down if solute is kept for a long time shows that solutions are stable.
  - A solution is always transparent in nature. It may be coloured or colourless.
  - The components of a solution do not react chemically with each other.
- **Aqueous and Non-aqueous Solution**
  A solution in which water acts as a solvent is called aqueous solution while the solution; which any other liquid acts as a solvent is called non-aqueous solution. Solution of come-on salt or sugar in water is an aqueous solution. Solution of sulphur in carbon disulphide or solution of iodine in alcohol is non-aqueous solution.
- **Saturated and Unsaturated Solution**
  A solution becomes saturated if no more solute can be dissolved into it at that temperature contains maximum amount of solute which can be dissolved into it and on addition of an more solute to the solution, the solute starts settling at the bottom. The solution in which more solute can be dissolved at the given temperature is called an unsaturated solution. A saturate solution becomes unsaturated on heating because it can dissolve more solute if the temperature is increased.
- **Supersaturated Solution**
  Under certain conditions a solution may temporarily contain more solute than the saturation level at a particular temperature. Such a solution is called supersaturated solution. Super saturate solutions separate out the extra solute by adding a small crystal of solute.
- **Concentrated and Dilute Solution**
  Between the two solutions one which has larger proportion of solute is called concentrated a compared to the one which has lesser proportion of solute. The solution with lesser solute called dilute solution.
- **True Solution**
  The solution in which particles of solute are so thoroughly mixed with the solvent that they cannot be distinguished from each other even under a powerful microscope is called a true solution.

## Solubility

The maximum amount of solute in grams that can be dissolved in 100 grams of the solvent at a given temperature to form a saturated solution is called solubility of a solute at that particular temperature.

$$\text{Solubility} = \frac{\text{Weight of solute in saturated solution}}{\text{Weight of solvent in saturated solution}} \times 100$$

## ACTIVITY CORNER

**To demonstrate that different substances have different solubilities**

- 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 beakers.
- 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.

- **Observations:**
  - The amounts of common salt, sugar and barium chloride that can be dissolved in water (50 mL) at room temperature are different.
  - When a saturated solution at a certain temperature is cooled, the solubility decreases and the amount of the solute which exceeds the solubility at the 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.

- **Effect of Temperature on Solubility**
  - Solubility of solids in liquids increases with increase in temperature and decreases with decrease in temperature.
  - Solubility of solids in liquids remains unaffected by the change in pressure.
  - Solubility of gases in liquids increases with decrease in temperature and decreases with increase in temperature.
  - Solubility of gases in liquids increases on increasing the pressure and decreases on decreasing the pressure.

## ILLUSTRATION

**4.** 2.5 g of a solute are dissolved in 25 g of water to form a saturated solution at 298 K. Find out the solubility of the solute at this temperature.

**Sol.** Mass of the solute = 2.5 g

Solubility of the solute

$$=\frac{\text{Wt. of the solute}}{\text{Wt. of the solvent}}\times 100=\frac{2.5}{25}\times 100=10g$$

**5.** (a) What mass of potassium chloride would be needed to forma saturated solution in 50 g of water at 298 K? Given that solubility of the salt is 46/100 g at this temperature.

(b) What will happen if this solution is cooled?

**Sol.** (a) Mass of potassium chloride in 100 g of water in saturated solution = 46 g

Mass of potassium chloride in 50g of water in saturated solution $=\frac{(46)}{(100)}\times(50)=23\,g$

(b) When the solution is cooled, the solubility of salt in water will decrease. This means that upon cooling, salt will start separating from the solution in crystalline form.

## Concentration of Solution

The concentration of a solution may be defined as the amount of solute present in a given amount (mass or volume) of solution and can be expressed in various ways given below.

- **Mass Percentage**
  - The mass of the solute in grams dissolved in 100 grams of solution is called mass by mass percentage.

    Mass by mass percentage can be calculated as:

$$w/w=\frac{mass\ of\ solute}{mass\ of\ solute+mass\ of\ solvent\ (solution)}\times 100$$

  - The mass of the solute in grams dissolved in 100 mL of solution is called mass by volume percentage.

    Mass by volume percentage can be calculated as: $w/\upsilon=\frac{\text{mass of solute (mL)}}{\text{volume of solution (mL)}}\times 100$

- **Volume Percentage**
  - The volume of the solute in mL dissolved in 100 mL of solution is called volume percentage

    Volume by volume percentage of a solution can be calculated as:

$$\upsilon/\upsilon=\frac{\text{volume of solute}}{\text{volume of solution}}\times 100$$

- **Parts per Million or Parts per Billion (ppm or ppb)**
  - The ppm unit is used for expressing concentration of trace amounts of substance present in the total amount of solution.
  - Parts per million or parts per billion can be calculated as: $ppm=\frac{\text{mass of solute}}{\text{mass of solution}}\times 10^6$

$$ppb=\frac{\text{mass of solute}}{\text{mass of solution}}\times 10^9$$

- **Molarity**

  It is defined as the number of moles of the solute per litre or per $dm^3$ of the solution. It is denoted by M.

$$\text{Molarity(M)}=\frac{\text{Number of moles of solute}}{\text{Number of litres of solution}}$$

- **Molality**

  It is defined as the number of moles of the solute dissolved in kg (1000 g) of the solvent. It is denoted by m.

$$Molarity(m) = \frac{Number\ of\ moles\ of\ solute}{Number\ of\ kilogram\ of\ solvent}$$

- **Normality**
  It is defined as the number of gram equivalents of solute present per litre of solution. It is denoted by N.

$$Normality\,(N) = \frac{Number\ of\ gram\ equivalents\ of\ solute}{Number\ of\ litres\ of\ solution}$$

## ILLUSTRATION

**6.** A solution contains 40 g of common salt in 320 g of water. Calculate the concentration in terms of (i) mass by mass percentage of the solute (ii) mass by mass percentage of the solvent.

**Sol.** Mass of common salt (solute) = 40 g
Mass of water (solvent) = 320 g
$\therefore$ Mass of the solution
= Mass of the solute + Mass of the solvent
= 40 + 320 = 360 g
Thus,
(i) mass by mass percentage of the solvent

$$= \frac{\text{Mass of the solute}}{\text{Mass of solution}} \times 100 = \frac{40}{260} \times 100 = 11.1\%$$

(ii) Mass by mass percentage of solvent
= 100 – (mass by mass percentage of solute)
= 100 – 11.1 =88.9%

**7.** A solution contains 5 mL of alcohol in 70 mL of water. Calculate the volume by volume percentage of the solute.

**Sol.** Volume of alcohol (solute) = 5 mL
Volume of water (solvent) = 70 mL
$\therefore$ Volume of the solution
= Volume of alcohol + Volume of water
= 5 + 70 = 75 mL
Thus, volume by volume percentage of solute

$$= \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100 = \frac{5}{75} \times 100 = 6.66\%$$

**8.** A solution contains 35 g of common salt in 300 g of water. Calculate the concentration of the solution.

**Sol.** Concentration of solution

$$= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

Mass of common salt = 35 g
Mass of water = 300 g
Mass of solution = (300+35) = 335 g
Concentration of solution

$$= \frac{(35)}{(335)} \times 100 = 10.45\%$$

**9.** A solution with mass of 1.00 kg contains 3 mg of solute. Express this concentration in ppm and ppb.

**Sol.** $$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$

$$= \frac{3\times10^{-3}\,g}{1\times10^{3}\,g} \times 10^6 = 3\,ppm$$

$$\text{ppb} = \frac{3\times10^{-3}\,g}{1\times10^{3}\,g} \times 10^9 = 3\times10^3\,\text{ppb}$$

## Suspension

A suspension is a heterogeneous mixture in which the solute particles are spread throughout the solvent without dissolving in it. The particle size of a suspension is large (> 100 nm or $10^{-7}$ m) and can be seen by naked eyes. The solid particles of a suspension settle down when allowed to stand for some time hence suspensions are unstable. The solid particles of a suspension do not pass through a filter paper, they remain on the filter paper as residue. Suspensions are either opaque or translucent.
Few examples of suspension are chalk and water mixture, muddy water, milk of magnesia, lime water, a suspension of calcium hydroxide in water used for white washing, bleaching powder in water, etc.

## Colloidal Solution

A colloidal solution is heterogeneous in nature with the particle size between the true solution and suspension. Colloids appear to be homogeneous but actually are heterogeneous.
The particle size lies between 1-100 nm or $10^{7} - 10^{-5}$ cm. Common example of colloids are smoke, ink, blood, milk, jellies, butter, etc.

- **Dispersed Phase and Dispersion Medium**
  The component present in smaller proportion (similar to solute in solutions) which is dispersal in a solvent like medium is called **dispersed phase.** The component present in larger proportion (similar to solvent in solutions) in which dispersed phase is distributed is called **dispersion medium.**

## States of Matter

Depending on the states of dispersed phase and dispersion medium eight different types of colloids are possible because gases mix to form homogeneous mixtures.

## Common example of colloids

| Dispersed phase | Dispersion medium | Type | Examples |
|---|---|---|---|
| 1. Solid | Solid | Solid sol | Coloured gemstones, milky glass |
| 2. Solid | Liquid | Sol | Starch sol, muddy water, milk of magnesia, white of an egg, paints, latex, blood plasma, gelatin, etc. |
| 3. Solid | Gas | Solid aerosol Gel | Smoke, dust-storm, automobile exhaust, etc. |
| 4. Liquid | Solid | Emulsion | Jelly, cheese, butter, curd, shoe polish, etc. |
| 5. Liquid | Liquid | | Milk, face cream, cod liver oil. |
| 6. Liquid | Gas | Aerosol | Fog, clouds, mist, sprays. |
| 7. Gas | Solid | Solid foam | Pumice stone, foam, rubber (sponge), bread, etc. |
| 8. Gas | Liquid | Foam | Froth, whipped cream, soap lather, shaving |

- **Lyophilic and Lyophobic Colloids**
  Depending upon the interaction between dispersed phase and dispersion medium colloids are classified as lyophilic (solvent-loving) and lyophobic (solvent hating) colloids.

- **Lyophilic colloids:** In this type of colloids, the dispersed phase has great attraction towards the dispersion medium. If dispersion medium is separated from dispersed phase, the sol can be reconstituted by simply mixing with the dispersion medium. Hence, they are also called reversible sols. e.g. gum, starch, gelatine and polymers in organic solvents.

- **Lyophobic colloids:** In this type of sols, the dispersed phase has very little affinity for dispersion medium. They require some stabilizing agent to prevent the precipitation of the sol and once precipitated they cannot be reconstituted by simply adding the dispersion medium. Hence they are called irreversible sols. e.g. sols of metals and their insoluble compounds.

- **Multi molecular, Macromolecular and Associated Colloids**
  Based on the type of particles of the dispersed phase, colloids are classified as multi molecular, macromolecular and associated colloids. The colloids in which small molecules aggregate together to attain the size of the colloidal particles are called **multi molecular colloids** e.g. Sulphur (Sg).
  Macromolecules have large sizes, comparable to colloidal particles, the solutions of such molecules are called **macromolecular colloids,** e.g. starch, cellulose, protein, etc.
  The substances which behave as electrolytes at low concentrations and have size smaller than colloidal particles but at higher concentrations the molecules aggregate to form particles of colloidal size, are called **associated colloids,** e.g. the molecules of soaps and detergents are of small size but in concentrated solutions the molecules associate to form micelles.
  The minimum concentration the electrolyte required for the formation of a colloid is called **Critical micelle concentration** (CMC) and the temperature above which the micelle is formed called **Kraft temperature** $(T_K)$. Soap when dissolved in water, dissociates to give negative and positive ions.

$$C_{17}H_{35}COONa \rightleftharpoons C_{17}H_{35}COO^- + Na^+$$

## Emulsions

Colloids in which both dispersed phase and dispersion medium are liquids are called Emulsions. The emulsions are of two types:

- **Oil-in-Water Emulsions**
  When oil is the dispersed phase and water is dispersion phase e.g. milk (in which liquid fat is dispersed in water) and vanishing cream.
- **Water-in-Oil Emulsions**
  When oil acts as dispersion phase and water is dispersed in it e.g. butter and cold cream.
  The process of making an emulsion is called **emulsification.**

For stabilizing an emulsion, an emulsifying agent is required along with dispersed phase and dispersion medium. Some common emulsifying agents are soaps, detergents, proteins, gum, agar, etc.

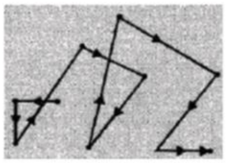
The separation of an emulsion into its constituents is called **demulsification.**

The two layers of oil and liquid separate into layers by boiling, freezing, centrifugation, etc.

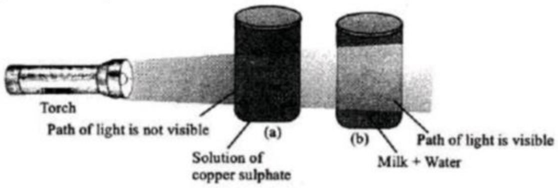
## Properties of Colloids

Since the particle size of colloids lies between true solution and suspension, they show some specific properties.

- **Brownian Movement**
  Colloidal particles are in a state of constant and zig-zag motion when viewed under an ultra-microscope. This motion arises due to the collision of the colloidal particles with the particles of dispersion medium.



- **Tyndall Effect**
  The scattering of a beam of light by colloidal particles is called Tyndall effect. Due to scattering of light, the path of the light becomes visible. When a beam of sunlight enters a dark room through a small hole from the window, the path of light becomes visible and dust particles present in air can be seen in the rays of light.
  Sky looks blue due to scattering of light by dust particles present in air.




**Diagrammatic illustration of Tyndall effect**

- **Electrophoresis**
  All the colloidal particles of a particular colloid carry same charge which may be either positive or negative. When an electric field is applied to a colloidal sol, the charged particles towards the oppositely charged electrode depending on the charge present on them. This movement of charged colloidal particles under the influence of an electric field is called electrophoresis.
- **Coagulation**
  The process by which the colloidal particles are separated by addition of small amount of electrolyte is called coagulation. It is generally carried out by addition of electrolytes like sodium chloride, barium chloride, alum, etc.
- **Applications of Colloids**
  - **Smoke precipitators:** Smoke contains carbon particles dispersed in air. The carbon particle a can be precipitated or coagulated by applying electric field.
  - **Cleansing action of soaps** by forming micelles.
  - **Sewage disposal:** Sewage water which contains colloidal particles of dirt, mud, etc. can be coagulated by passing it through metallic electrodes.
  - **Medicines:** A number of medicines are in the form of colloidal dispersions or emulsions.
  - **Production of rubber:** Rubber is produced from latex by coagulation with acetic acid.
  - **In preparation of paints.**
  - **For extraction of metals.**

## Comparison of characteristics of true solution, colloidal solution and suspensions

| 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 $1nm-100nm$) | $>10^{-5} cm$ (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 does not pass through semi permeable membranes. | Neither pass through filter paper nor through semi permeable membranes. |
| 5. Settling of particles | Particles do not settle down on standing, *i.e.,* true | Colloidal particles also do not settle on keeping, *i.e.,* colloids are also | Particles of suspension settle down on standing i.e., |

| | | | |
|---|---|---|---|
| | solutions are stable. | stable. However, they can be made to settle by centrifugation. | suspensions are unstable. |
| 6. Visibility | Solute particles are not visible even under a microscope. | Particles themselves are generally invisible but their presence can be detected under an ultra-microscope. | Particles are visible to the naked eye. |
| 7. Tyndall effect | Does not scatter light and hence does not show Tyndall effect. | Shows Tyndall effect due of scattering of light. | Tyndall effect may be observed. |

## Separating Components of a Mixture

The separation of a mixture depends upon the nature, physical state and difference in properties of various constituents of the mixture.

- **Evaporation** dissolved in a liquid. The solution is heated on a water bath or sand bath. The liquid evaporates leaving the solid behind.

### ILLUSTRATION

**10.** How can you recover common salt from its solution in water?

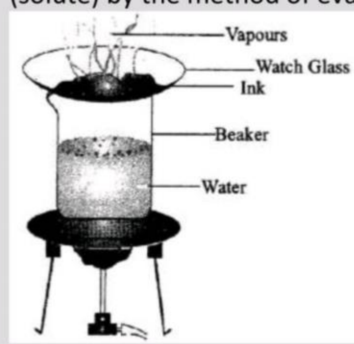
**Sol.** Common salt may be recovered from its aqueous solution by evaporating the water from the solution. Common salt present in sea water is collected in large shallow ponds and left in the sun for some days. Water is evaporated and common salt is left behind in the ponds.

- **Centrifugation**
  This method is based on the principle that when a mixture containing very small particles is rotated at a high speed the lighter particles come on the surface and heavier particles settle down.

### ACTIVITY CORNER

**To obtain coloured component (dye) from blue or black ink**

- Make a water-bath by taking water in a beaker or make a sand bath by taking sand in an iron vessel.
- Put few drops of ink on a watch glass.
- Put the watch glass on water or sand bath and start heating.
- Observations:
  Water starts evaporating and after some time complete water evaporates leaving behind blue or black residue on the watch glass.
- **Conclusion:**
  The volatile component of a solution (solvent) can be separated from the non-volatile component (solute) by the method of evaporation.




To separate cream from milk

- Take some full cream milk in a test tube.
- Keep the test tube in a centrifuging machine for two minutes.
- **Observations:**
  Since cream is lighter than milk, it comes to the surface and is skimmed off.
- **Conclusion:**
  Centrifugation method can be used to separate out butter from cream and squeezing out water from wet clothes in washing machines.

- **Separation Using a Separating Funnel**
  A mixture of two immiscible liquids can be separated by using a separating runnel. Two liquids which do not mix with each other are called immiscible liquids. These liquids form heterogeneous mixture. On standing they separate out into two separate layers depending upon their densities,

### ILLUSTRATION

**11.** What are the examples of separation of mixture on the basis of their densities?

**Sol.** (i) A mixture of carbon tetrachloride (lower layer) and water (upper layer).

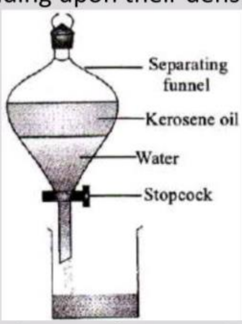
(ii) During extraction of iron in blast furnace two separate layers of slag and iron are formed.
The molten slag form upper layer and the heavier molten iron form lower layer. The layers are removed through separate holes in the furnace.

- **Sublimation**
  This process is used to separate those solids from their mixtures which directly pass to the vapour state on heating without passing through the liquid state.

## ACTIVITY CORNER

**To separate a mixture of kerosene oil and water**

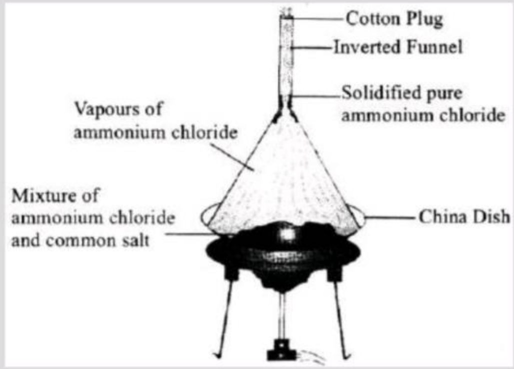
- Pour the mixture of kerosene oil and water in a separating funnel.
- Allow the mixture to stand for some time so that separate layers of oil and water are formed.
- Open the stop cock and let the water run out carefully.
- Close the stop cock and take out the oil in another container.
- **Observations:** Water being heavier forms the lower layer and is separated first.
- **Conclusion:** The immiscible liquids separate out in layers depending upon their densities.




**To separate a mixture of ammonium chloride and common salt**

- Take a mixture of ammonium chloride and common salt in a china dish.
- Put an inverted funnel over the china dish.
- Put a cotton plug at the stem of the funnel and start heating it slowly.
- **Observations:** The vapours of pure ammonium chloride sublimate and are deposited near the neck of the funnel while common salt, the non-sublimate remains in the china dish as residue.
- **Conclusion:**

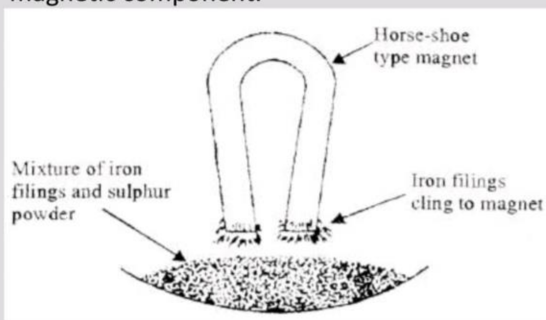
- A sublimable volatile component can be separated from a non- volatile component of the mixture.
- Other substances which can be separated by this method are camphor, naphthalene, anthracite, benzoic acid, iodine, etc.




- **Magnetic Separation**
  This method is based on the property of iron of getting attracted by magnet. The mixture in which one component is magnetic in nature can be separated out by this method.

**To separate a mixture of iron and sulphur**

- Take a mixture of iron filings and sulphur powder.
- Move a horse shoe magnet on the mixture.
- **Observation:**
- Iron filings get attracted to the magnet and sulphur powder is left behind.
- **Conclusion:**
  Non- magnetic component can be separated from magnetic component.

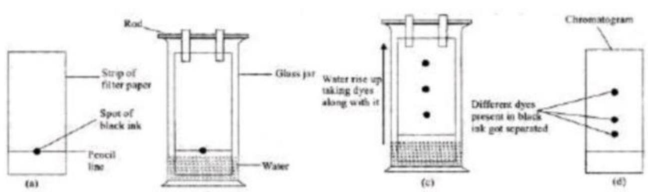



- **Chromatography**
- This is a modern method used for separation of mixture into their components and to test the purity of components. The name chromatography is based on Greek word kroma means colour and graphy means writing because it was first used to separate coloured substances found in plants. Separation of different components of a mixture based upon their different solubilities in the same solvent is known as chromatography.

## ACTIVITY CORNER

**To separate the components of ink by chromatography**

- Take a thin strip of special chromatographic filter paper.
- Draw a line using a pencil about 3 cm from the bottom.
- Put a small drop of ink from a sketch pen or a fountain pen at the centre of this line and let it dry [fig. (a)].
- Suspend the filter paper in jar or beaker containing water just to dip the end of the filter paper and to keep the spot of ink above the water level [fig. (b)].
- Leave the jar undisturbed for some time.
- **Observations.**
  The water rises up on the filter paper and as it moves up, it takes along with it the particles of ink. Two or three coloured spots are seen on the filter paper different heights [fig. (c)].
- When the water reaches the maximum height the filter paper is removed and dried. The paper containing different coloured spots is known as chromatogram [fig. (d)].
- Conclusion:
  The coloured component which is more soluble in water, rises faster and produces a spot at higher position while the least soluble component remains at the bottom.

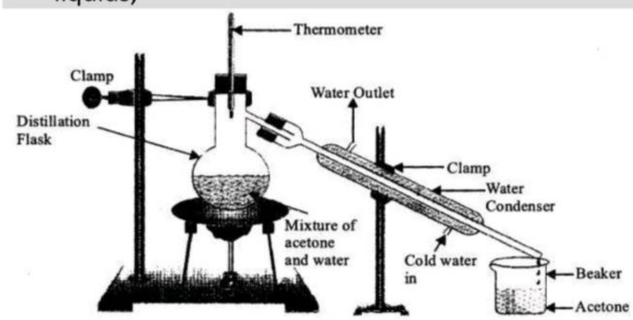



- **Distillation**
  If liquids in a mixture are miscible and have different boiling points, they can be separated by distillation. Distillation involves conversion of a liquid into vapours and then condensing the vapours back into liquid. Distillation is used only if the liquids have a difference in boiling point of more than 25 K.

## ACTIVITY CORNER

**To separate a mixture of acetone and water by distillation**

- Set up the distillation apparatus as shown in the figure.
- Take mixture of acetone and water in the distillation flask fitted with a thermometer.
- Connect the water inlet pipe to the cold water.
- Start heating the mixture slowly.
- **Observations:**
  On heating, the acetone starts boiling first and is converted into vapours at 329 K. The vapours are cooled, condensed and collected in the beaker.
- As the heating continues the water starts boiling at 373 K. The vapours are cooled, condensed and collected in another beaker.
- The non-volatile impurities, if present are left in the flask.
- Conclusion:
  The method can be used to separate a non-volatile solid from a volatile liquid like salt and water solution or an impure mixture of liquids with different boiling points and non-volatile impurities or mixture of two or more miscible liquids,



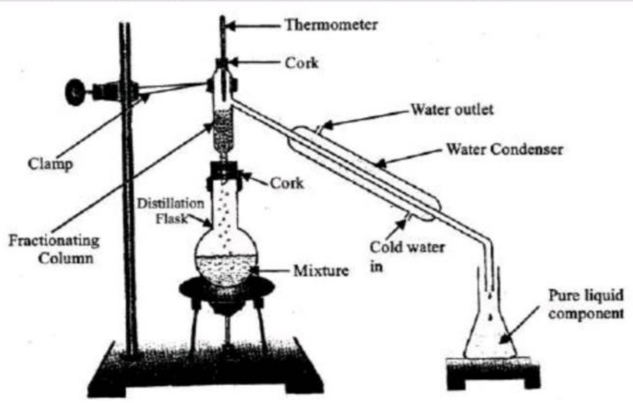

- **Fractional Distillation**
  If the boiling point of the two miscible liquids of the mixture are very close to one another, i.e., less than 25 K or so, the separation cannot be achieved by the simple distillation method as described above. This is due to the reason that at the boiling point of the more volatile liquid of the mixture there will be sufficient vapours of the less volatile liquid as well. As a result, both the liquids of the mixture will distil together and the separation cannot be achieved.
  The separation of such a liquid mixture into individual components can, however, be achieved by fractional distillation, which involves repeated distillations and condensations. Fractional distillation is carried out using a fractionating column. It usually consists of a long glass tube with a wide bore packed with glass beads or small stones or porcelain pieces. The actual purpose of the fractionating column is to increase the cooling surface area and to provide hurdles or

obstructions to the ascending vapours and descending liquid.

## ACTIVITY CORNER

**To separate a mixture of alcohol and water**

- Take a mixture of ethyl alcohol (b. pt. 351 K) and water (b. pt. 373 K) in a distillation flask provided with a fractionation column.
- Start heating the liquid mixture till the mixture starts boiling.
- **Observations:**
  - More volatile liquid is condensed first and collected in the flask.
  - Less volatile liquid with high boiling point is collected next in another flask.
- **Conclusion:**
  On heating, vapours of alcohol (low boiling point escape from the flask and get condensed more readily).
  At the same time the vapours of water (high boiling point) fall back in the flask after getting condensed through fractionating column. When whole of the alcohol has distilled, the temperature starts rising on further heating. When the vapour pressure of water becomes. Equal to atmospheric pressure, it starts boiling. The vapours are condensed and collected.




- **Fractional Distillation of Air**
  Air is a homogeneous mixture of many gases which can be separated by fractional distillation.
  Air is cooled and compressed by applying pressure and decreasing temperature. Air is compressed to form liquid air called liquefied air. Liquid air is subjected to fractional distillation and different gases are separated according to their boiling points.

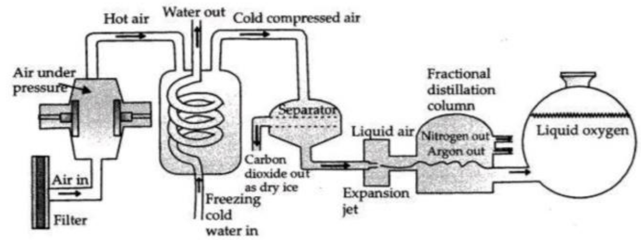



**Fig. Separation of components of air**

The flow diagram for the method is as follows:

Air

Compressed and cooled by increasing pressure and decreasing temperature.

↓

Liquid Air

↓

Allowed to warm up slowly in fractional distillation column

↓

Gases get separated at different heights

↓

| | Oxygen | Argon | Nitrogen |
|---|---|---|---|
| Boiling Point (°C) | -183 | -186 | -196 |
| % in Air by Volume | 20.9 | 0.9 | 78.1 |

**Flow diagram shows the process of obtaining gases from air**

## ILLUSTRATION

**12.** Is air a mixture or a compound? Give three reasons.

**Sol.** Air is a mixture and not a compound as discussed below:
(i) The properties of a mixture are in between those of its constituents. The two major components of air are oxygen (20.9% by volume) and nitrogen (78.1% by volume).
In Oxygen, any fuel burns brightly but in nitrogen it gets extinguished. In contrast, in air the fuel burns slowly.
(ii) The components of a mixture can be separated by simple physical methods. For example, the components of air can be separated by fractional distillation of liquid air.
(iii) The composition of a mixture is variable. The composition of air is also variable. It has more oxygen in the country side than in big cities.

**13.** What is the function of fractionating column in fractional distillation?

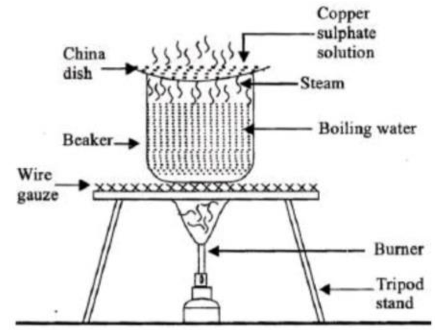
**Sol.** A fractionating column obstructs the up wards movement of the vapours of the liquids. As a result, the energy (latent heat of fusion) which is released by the high boiling liquid is taken by the low boiling liquid. It remains in the vapour state. The high boiling liquid by releasing energy condenses and falls back in the distillation flask. Thus, fractionating column helps in the separation of the components from a mixture.

- **Crystallization**
  The process by which a pure soluble substance is separated in the form of crystals from its hot and saturated solution on cooling is called crystallization.
  Crystallization is better than simple evaporation as a method to get pure solids from liquids as:
  (i) some solids may decompose or get charred when heated to dryness.
  (ii) on evaporation some dissolved impurities may also get deposited with the solid while in crystallization, crystals of pure solid are crystallized leaving the impurities in the solution.

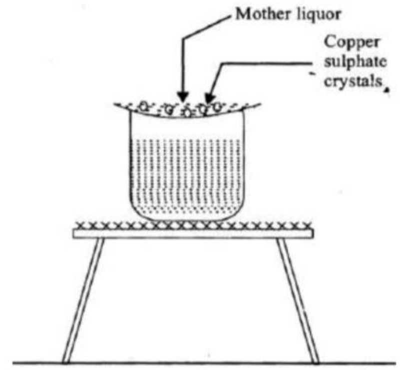
## ACTIVITY CORNER

**To separate pure crystals of copper sulphate by crystallization**

- Take about 5 g of impure copper sulphate and dissolve it in minimum amount of water.
- Filter the solution to remove the impurities.
- Heat the solution in a china dish to evaporate some water to get a saturated solution.
- Leave the solution undisturbed for a few hours.
- **Observations:**
  - Pure copper sulphate crystals separate out.
  - The liquid left after removing the crystals is called mother liquor and is separated from the crystals by decantation.
- **Conclusion:**
  The crystallization method is used to purify solids e.g. to remove impurities from salt which we get from sea water.

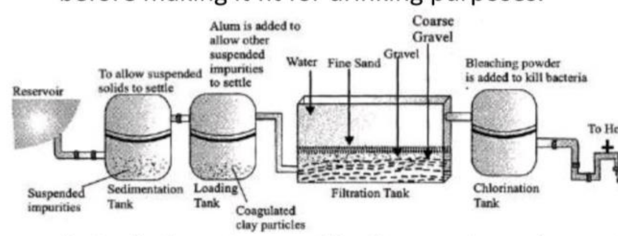


(a)



(b)

- **Purification of Drinking Water**
  A number of dissolved and suspended impurities are too removed from the river or lake water before making it fit for drinking purposes.




A typical water purification system in water works.

A typical water works involved in the process includes the following processes.

**(i) Removal of suspended impurities (Sedimentation tank)** - Water is allowed to stand for some time so that suspended impurities are settled down.

**(ii) Removal of colloidal particles (Loading tank)** - To remove the small particles present in colloidal state some alum is added to water. Particles like clay get neutralized and are coagulated at the bottom of the tank.

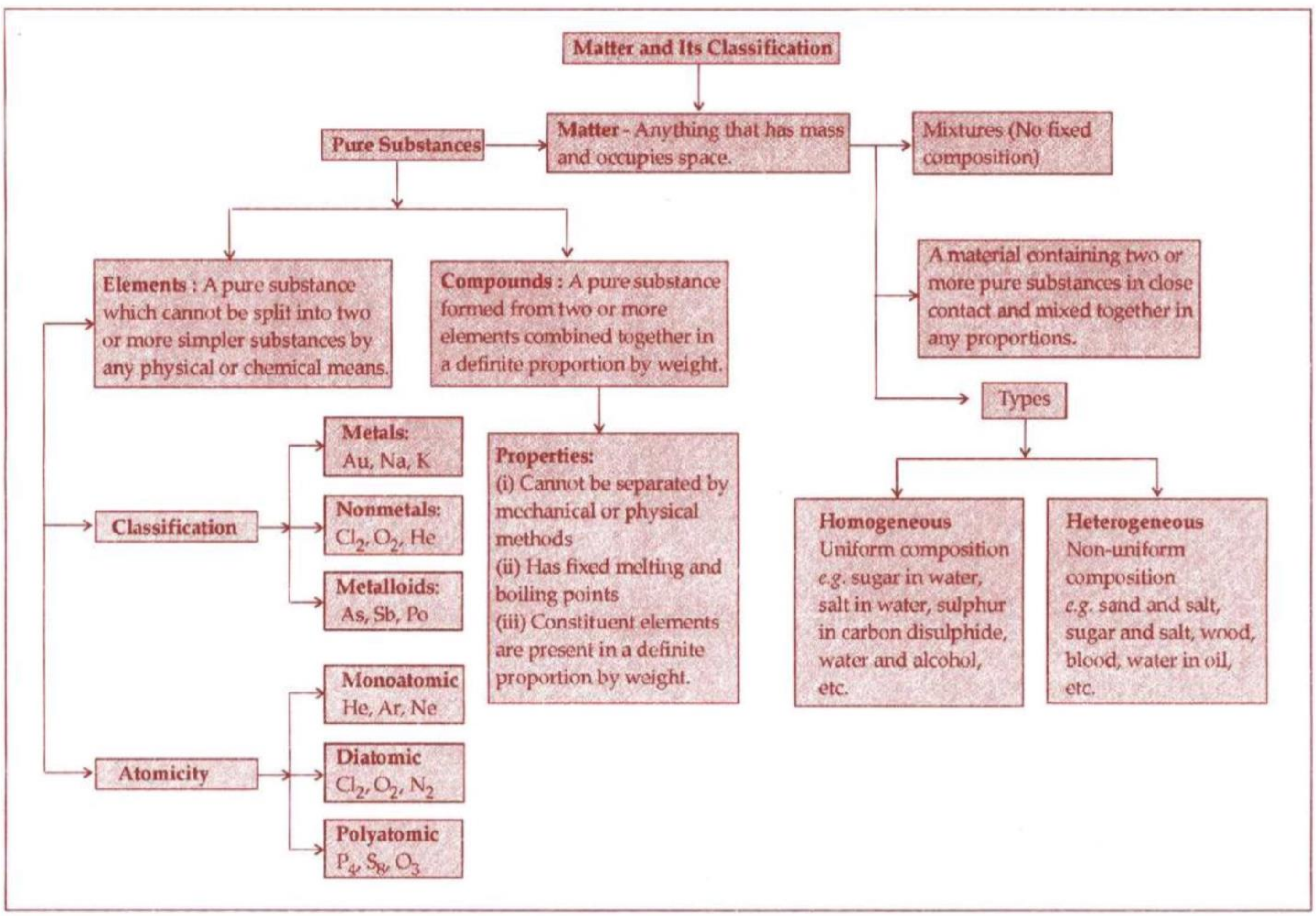
**(iii) Filtration of impure water (Filtration tank)** - The water from which insoluble impurities have been removed is passed through filtration tank which has three layers. Coarse gravel at the bottom, fine gravel in the centre and fine sand at the top acts as filters. Impure water is introduced from the bottom. The impurities are retained in the three layers of gravel and pure water goes to the top and sent to chlorination tank.

**(iv) Chlorination tank -** Filtered water is treated with bleaching powder or ozone or any other germicide to kill bacteria. The pure water is now supplied to homes for drinking purposes.

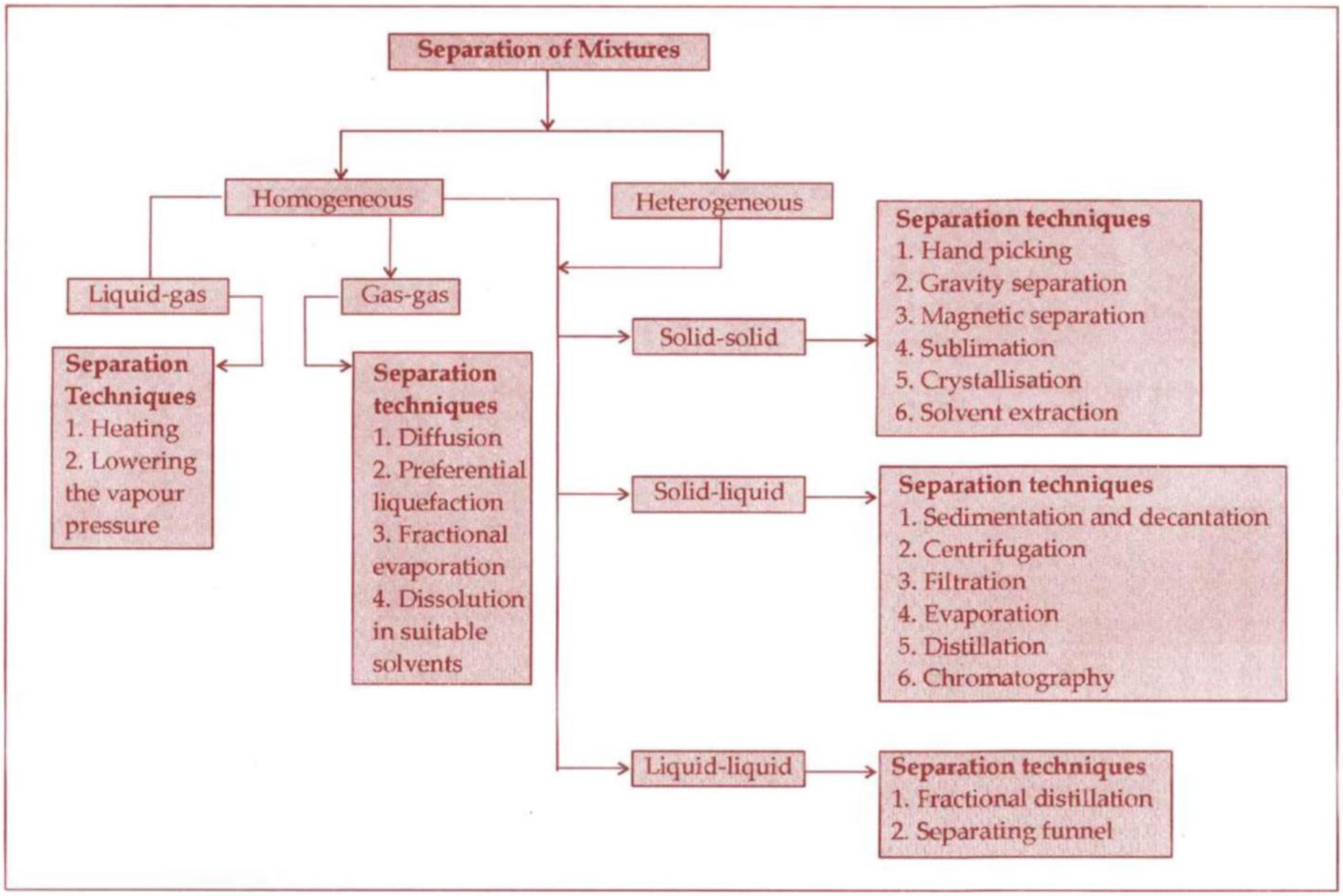
## Do You Know

- Formation of deltas in the sea at the mouth of a river is due to the precipitation (or coagulation) of the colloidal clay in the river water.
- A large number of medicines and pharmaceutical preparations are colloidal in nature. Such colloidal medicines are easily adsorbed by the body tissues and therefore are more effective.
- Full-cream milk contains 6% fat, standard milk contains 3% fat and double toned milk contains 1% fat.
- First man-made element is technetium.
- Saline-glucose solution administered to patients suffering from dehydration is a solution of glucose and various salts in water.
- Cough syrups invariably contain alcohol and water.
- Eye and ear drops are aqueous solutions of boric acid or various antibiotics.
- An aqueous solution of $H_2O_2$ is used as a bleaching agent in dental treatment and textile industry.
- An aqueous solution of potassium permanganate or phenol is used as disinfectant.

## CONCEPT MAP



## CONCEPT MAP




## ESSENTIAL POINTS For COMPETITIVE EXAMS

### Summary of the separation techniques

- **Separating the Components of Solid Mixtures**

| Method | When to apply | Example |
|---|---|---|
| 1. Hand-picking | When the constituents are bigger in size and distinctly visible. | Stones + rice, gram + wheat |
| 2. Sieving | When the sizes of constituent particles are different and not distinctly visible. | Bran + flour |
| 3. Magnetic separation | When one of the constituents is attracted by a magnet. | Iron + sand |
| 4. Sublimation | When one of the constituents sublimes on heating. | Ammonium chloride + common salt, iodine + sand |

- **Separating the Components of Solid-Liquid Mixtures**

| Method | When to apply | Example |
|---|---|---|
| 1. Sedimentation | When the mixture is heterogeneous and the solid constituent is heavy. | Sand + water, dirt particle + muddy water |
| 2. Centrifugation | When the mixture is homogeneous and one of the constituents is heavy. | Milk + cream |
| 3. Filtration | When one of the constituents dissolves in a solvent. | Tea, muddy water metal pieces and engine oil |

| | | |
|---|---|---|
| 4. Evaporation is non-volatile. | When the solid present in the liquid carbon disulphide | Solution of sulphur in |
| 5. Distillation | Any mixture whether homogeneous or heterogeneous. | Solution of sugar or salt in water |
| 6. Chromatography | When the constituents are soluble in the same solvent. | Components of ink |

- **Separating the Components of Liquid Mixtures**

| Method | When to apply | Example |
|---|---|---|
| 1. Distillation | When liquids are miscible and their boiling points differ by a wide margin. | Acetone + water |
| 2. Fractional distillation | When liquids are miscible and their boiling points differ by a small margin. | Components of petroleum |
| 3. Use of separating funnel | When the liquids are immiscible. | Oil + water |

## Summary of the Separation Techniques

- **Vacuum distillation (Distillation Under Reduced Pressure)**
  This type of distillation process is used for purification of high boiling liquids and liquids which decompose at or below their normal boiling points.
  Boiling point of a liquid is the temperature at which its vapour pressure becomes equal to atmospheric pressure. If the outer pressure is reduced (by suction pump or vacuum pump), the liquid boils at lower temperature without decomposition, e.g., glycerol (b.pt. 563 K) can be distilled at 453 K under 12 mm Hg pressure without decomposition. Cane sugar juice is concentrated by this method in sugar industry.
- **Steam Distillation**
  This type of distillation process is used for the separation and purification of organic compounds (solid or liquid) which are volatile in steam, immiscible with water, possess a high vapour pressure of about 10-15 mm Hg at 373 K and contain non-volatile impurities. In this process steam is passed through the organic mixture to be distilled so that the distilling mixture consists of steam and volatile organic compound, which follows that
  Atmospheric pressure = Vapour pressure of organic substance + vapour pressure of steam.
  It is obvious from the above relation that organic compounds distil below its normal boiling point without decomposition. For example, aniline can be distilled at 371.5 K against its normal boiling point 457 K. o-Nitro phenol can be separated from p-nitrophenol, since o-nitro phenol is volatile in steam. Some other compounds which can be purified by this method are nitrobenzene, bromobenzene, aniline, essential oils, turpentine oil, sandal wood oil, o-hydroxy acetophenone, etc.
- **Azeotropic Distillation**
  Azeotropes are constant boiling mixtures, which distil as a single compound at a fixed temperature.
  Components of an azeotropic mixtures cannot be separated by fractional distillation. The most common example of azeotropic mixture is ethanol and water (rectified spirit) in the ratio of 95.87 : 4.13.
  Constituents of azeotropic mixture can be separated by azeotropic distillation. In this method a third component is used in distillation. The process is based on the fact that dehydrating agents like benzene, carbon tetrachloride, diethyl ether, etc. depress the partial pressure of one component so that the boiling point of that component is raised sufficiently and thus other component will distil over.
  Dehydrating agents having low boiling point (e.g., $C_6H_6, CCl_4$, ether, etc.) depress the partial vapour pressure of alcohol more than that of water whereas dehydrating agents having high boiling point e.g., glycerol, glycol, etc. depress the partial vapour pressure of water more than that of alcohol.
- **Differential Extraction**
  This method of purification is used for the separation of an organic compound, from its aqueous solution by shaking it with a suitable solvent such as ether, chloroform or benzene.
  The solvent chosen should be immiscible with water and dissolve the organic compound to be separated. If the extracting solvent is used in several installments instead of a single lot, the extraction is more efficient.
  Organic compounds which are less soluble in organic solvents are extracted by continuous extraction using **Soxhiet extractor.** Vanilla can be extracted from vanilla beans by **Soxhiet extractor.**
- **Chromatography**
  This method of purification was first discovered by a Russian botanist Tswett in 1906. This method

has a wide application for separation, purification, identification and characterization of the constituents of complex substances (solids, liquids or gases) such as ammo acids, sugars, vitamins, hormones and plant pigments, etc.

The technique of chromatography depends on the selective distribution of components of the mixture between two phases, one stationary phase or fixed phase and other mobile phase. The stationary phase can be solid or liquid. The mobile phase may be liquid or gas. The mixture to be separated is dissolved in mobile phase and passed over stationary phase. Different components in two phases can be separated either by adsorption or partition.

- **Adsorption chromatography:** This method is based on the different adsorption affinity of various components of a mixture for the suitable adsorbent such as alumina, silica gel, magnesium oxide etc. The component which has maximum affinity for the adsorbent is adsorbed first near to the starting point and thus components with different adsorption affinity are adsorbed at different distances from the starting point. Hence different bands or chromatograms are formed at different parts of the adsorbant. Different components can be recovered from these bands by elution and analyzed.

If a column of suitable adsorbent is used in the process we call it column chromatography.

But if the process takes place on a thin layer of adsorbent coated on a glass plate, then it is known as thin layer chromatography.

- **Partition chromatography:** It is a liquid-liquid chromatography in which both the mobile phase and stationary phase are liquids. Paper chromatography is an important type of partition chromatography in which the stationary phase is water which is adsorbed or chemically bound to special type of paper called chromatographic paper and mobile phase is another liquid which is a mixture of two or three solvents with water as one of the components. A spot of the mixture of components to be separated is applied on the paper, as the solvent rises upon the paper, different components of mixture travel with solvent through different distances depending upon their solubility or partitioning between stationary and mobile phase. The separated compounds can be analyzed for characterization.

## Relation between Percentage by Weight and Percentage by Volume

We know that % by weight

$$= \frac{(\text{weight of solute})g}{(\text{weight to solution})g} \times 100 \qquad \text{...(i)}$$

% by volume $= \frac{(\text{weight of solute})g}{(\text{volume of solution})mL} \times 100$

Dividing (i) by (ii), we get $\frac{\%\text{ by weight}}{\%\text{ by (volume}} =$

$$\frac{(\text{weight of solute/weight of solution})\times 100}{(\text{weight of solute/volume of solution})\times 100}$$

$$\Rightarrow \frac{\%\text{ by weight}}{\%\text{ by volume}} = \frac{\text{volume of solution}}{\text{weight of solution}}$$

$$= \frac{1}{\frac{\text{weight of solution}}{\text{volume of solution}}} = \frac{1}{d_{\text{solution}}}\left(\text{density} = \frac{\text{mass}}{\text{volume}}\right)$$

$\Rightarrow$ % by volume weight of solution $(d_{\text{solution}}) \times$ % by weight

## Relation between Solubility (S) and Weight Percentage (% w)

Let $w_i$ and $w_2$ be the weight of solute and solvent respectively. We know that

Solubility (S)

$$= \frac{\text{weight of solute}}{\text{weight of solvent}} \times 100 = \frac{W_{\text{solute}}}{W_{\text{solvent}}} \times 100 \text{ ...(i)}$$

Percentage by weight (% w)

$$= \frac{\text{weight of solute}}{\text{weight of solvent}} \times 100 = \frac{W_{\text{solute}}}{W_{\text{solution}}} \times 100 \text{ ...(ii)}$$

$$\frac{\text{(ii)}}{\text{(i)}} = \frac{\%w}{S} \frac{\frac{W_{\text{solute}}}{W_{\text{solution}}} \times 100}{\frac{W_{\text{solute}}}{W_{\text{solvent}}} \times 100} \Rightarrow \frac{\%w}{S} = \frac{W_{\text{solvent}}}{W_{\text{solution}}} = \frac{W_2}{W_1 + W_2}$$

$$\Rightarrow \%w = S \times \frac{W_2}{W_1 + W_2}$$

$\therefore$ w = solubility $\times \frac{W_{\text{solvent}}}{W_{\text{solution}}}$, where $w_1$ and $w_2$ are the weight of solute and solvent in grams respectively.