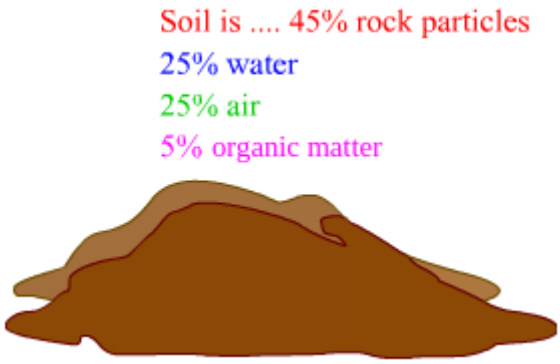
Pure Substances & Mixtures; Separation of Mixtures

Solutions-An Overview

Large amount of salt is dissolved in seawater. This makes it unfit for drinking directly. Can we say that the amount of salt in the sea is the same everywhere?

The air contains gases like oxygen, carbon dioxide and ozone along with various small particles like pollen grains and dust. Are the gases and the particles present in equal amounts in air?

Soil contains a lot of substances, e.g., clay, organic matter, minerals, pebbles, etc.



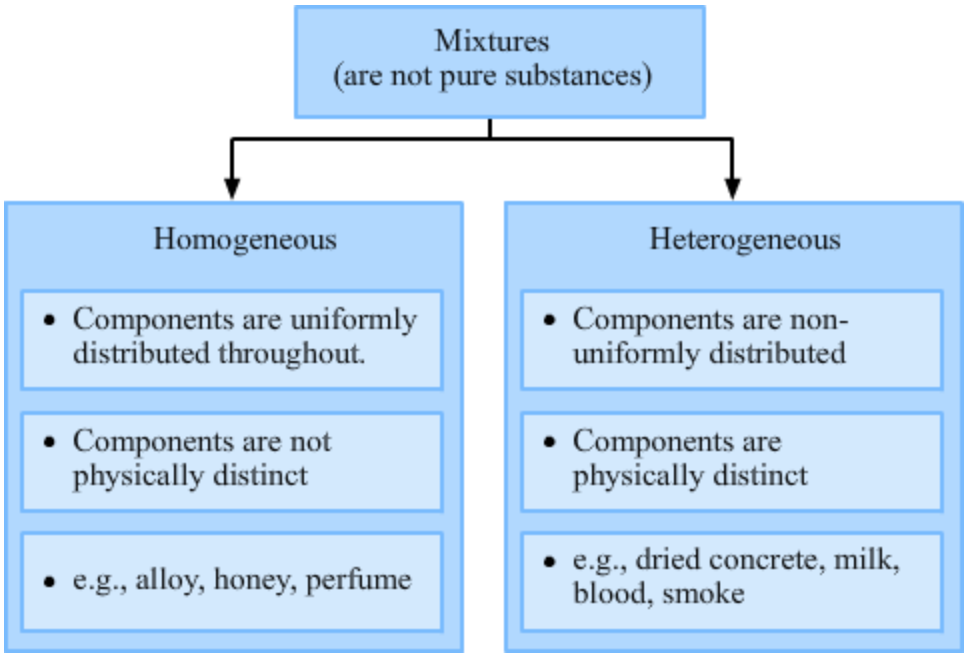
Why do the amounts of clay, organic matter, minerals, etc. in soil vary from place to place?

All of the above substances (soil, air and seawater) are examples of mixtures. Let us go through the lesson to find out what mixtures are.

Mixtures

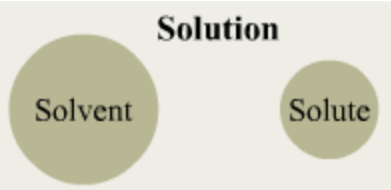
A mixture may be defined as a material having two or more types of pure forms of matter. For example, milk is a mixture as it contains a combination of water molecules, fat molecules and protein molecules. The constituents of a mixture can be separated by certain physical processes such as evaporation and boiling.

Constituents of certain mixtures can also be separated manually. For example, a mixture of stones and sand can be separated manually. On the other hand, salt cannot be manually separated from saltwater. One needs to boil the mixture to separate the salt from water.



Solutions

Now that we know what mixtures are, let us study about solutions. Whenever we talk about solutions, we instantly think of liquids. **But is it necessary for all solutions to be liquids?**



No. A solution is simply a homogeneous mixture of two or more substances. Solutions can be solid, liquid and gaseous. **Alloy** is an example of a solid solution, while air is a gaseous solution.

A mixture is called solution when it has homogeneity at the particle level. A solution is formed when a **solute** is dissolved in a **solvent**.

Examples of solutions

Solutions	Solvents	Solutes
1. Saltwater	Water	Salt
2. Solution of iodine in alcohol	Alcohol	Iodine
3. Vinegar		
4. Soda water	Water	Acetic acid

5. Air	Water Nitrogen (present in the largest amount)	Carbon dioxide Other gases (present in relatively smaller amounts)

Properties of Solutions

- They are homogeneous mixtures of solutes and solvents.
- The solute particles in a solution are extremely small in size. They are less than 1 nm (10^{-9} m) in diameter.
- The solute particles are not visible to the naked eye.
- As a result of the small size of the solute particles, a solution does not scatter a beam of light passing through it.
- Being small in size, the solute particles get dissolved in the solvent. Hence, the solute cannot be separated from the solvent by filtration.
- The solute particles do not settle down when left undisturbed.

Solved Examples

Hard

Example:

For each of the given substances, state whether or not it is a mixture. Also, if it is a mixture, then identify it as homogeneous or non-homogeneous.

Substance	**Mixture**	**Homogeneous**	**Non-homogeneous**
1.Solder 2.Soap water 3.Silver 4.Green tea			

Solution:

Substance	**Mixture**	**Homogeneous**	**Non-homogeneous**
1.Solder	✓	✓	—

2.Soap water	✓	–	✓
3.Silver	✗	–	–
4.Green tea	✓	✓	–

Know More

Further Connect

Like a gas, a liquid exerts pressure of its own due to evaporation. This pressure is known as the vapour pressure of the liquid.

When a liquid solution is formed, it exerts its own vapour pressure. This results from the individual pressures of the solute and the solvent.

In 1882, a scientist named Francois-Marie Raoult established that for a solution containing volatile liquids, the partial vapour pressure of each component of the solution is proportional to its mole fraction present in solution.

$$p_1 \propto x_1$$
$$p_1 = p_1^o \, x_1$$

where p_1^o is the vapour pressure of pure component at the same temperature.

Did You Know?

1. The addition of solutes to solvents can lower the freezing point, elevate the boiling point and lower the vapour pressure of the solvents.

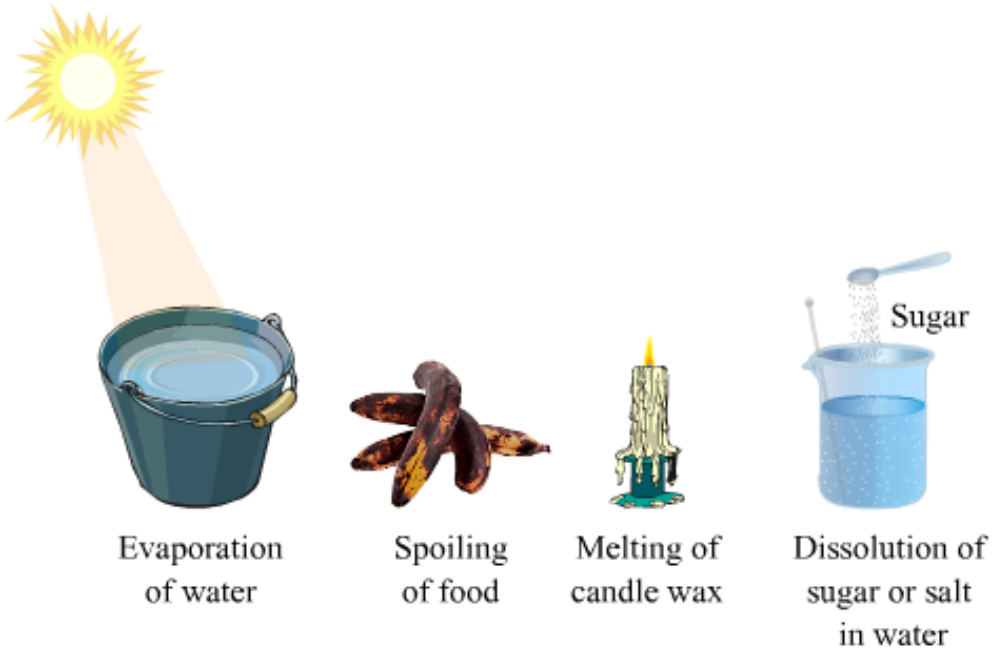
2. A solution is formed when two similar substances are mixed. For example, water and salt form a solution, but water and oil do not. This is because:

- Water and salt are polar substances (wherein the centres of positive charge and negative charge do not coincide), so they can mix with each other.
- Oil is a non-polar substance, so it does not mix with water to form a solution.

3. The solubility of a solute in a solvent is affected by temperature. Usually solubility increases with increase in temperature.

Physical and Chemical Changes: An Overview

So many changes take place around us daily. The given images show examples of such changes.



Scientists classify the various changes occurring in nature under two categories:

- **Physical changes**
- **Chemical changes**

Wondering what these categories imply? Read on to find out.

Physical and Chemical Changes

Physical changes are those changes in which only the forms of substances get modified; the chemical natures and compositions of the substances involved are not altered.

Examples: Melting of butter, boiling of water, glowing of a bulb and cutting of trees

Characteristics:

- No new substance is formed during a physical change.
- Most physical changes can be reversed easily.
- The chemical composition of a substance undergoing physical change remains the same.

Chemical changes are changes that involve reaction of substances with one another. Such reactions result in alterations in the chemical compositions of the substances involved. These changes lead to the formation of new substances.

Examples: Rusting of iron, burning of paper and cooking of food

Characteristics:

- One or more new substances are formed during a chemical change.
- Most chemical changes cannot be reversed easily.
- The chemical composition of a substance undergoing chemical change does not remain the same.
- A chemical change is always accompanied by a change in energy.

Physical and Chemical Changes

Classification of Substances as Mixtures and Compounds

On the basis of physical and chemical changes, substances are classified as mixtures and compounds.

- **Compounds** are formed when two or more elements combine together in fixed proportion. Example: water, common salt and sugar

- **Mixtures** are formed by the physical combinations of different elements and compounds. Example: air

Difference between mixtures and compounds

Mixtures	Compounds
1. They are obtained by the physical combinations of either elements or compounds or both.	1. They are obtained by the chemical combinations of elements.
2. The compositions of the constituents of mixtures are not fixed.	2. The compositions of the elements present in compounds are fixed.
3. A mixture shows the properties of all its constituents. For example, a mixture of sulphur and iron displays the properties of both sulphur and iron.	3. A compound may or may not show the properties of its constituent elements. For example, the compound obtained on heating sulphur with iron does not display the properties of iron.
4. The constituents of a mixture can be separated by physical methods. For example, in case of an	4. The constituents of a compound can be separated only by chemical and electrochemical methods.

iron–sulphur mixture, iron can be easily separated with the help of a magnet.	

Compounds

Why Do We Need to Separate Substances?

Most substances occurring in nature are mixtures. To obtain pure substances, it is necessary to separate the components of the mixtures. For example, seawater is the mixture of water and salt. If we want to use water and salt separately, then we have to separate the salt from the water.

Pure substances have great importance in chemical industries. These are used in laboratories to study their chemical properties.

Components of heterogeneous mixtures can sometimes be separated very easily as the components are physically distinct from each other. For example, methods like handpicking, filtering, sieving etc., can be used to separate the components.

However, to separate the components of a homogeneous mixture, we need to use some special separating techniques.

The commonly used techniques for separating the components of mixtures are as follows:

- **Evaporation**
- **Centrifugation**
- Separation of **immiscible liquids** by a separating funnel
- Separation of **miscible liquids** by:
- **Simple distillation**
- **Fractional distillation**
- **Sublimation**
- **Crystallization**
- **Chromatography**
- Separation of solids using solvent and filtration

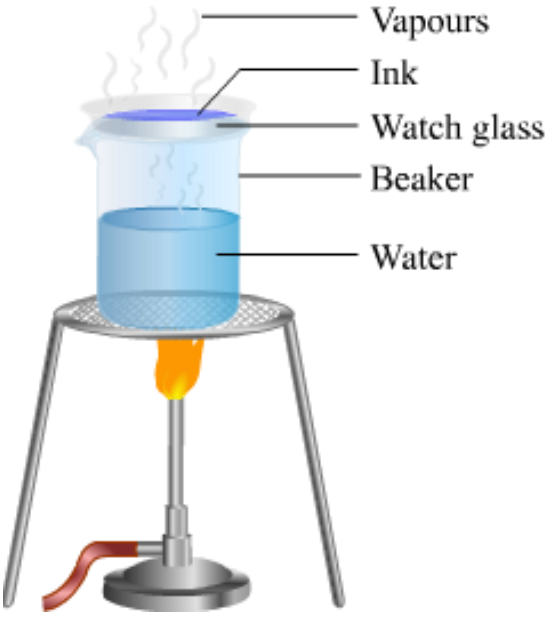
Evaporation

Evaporation is the process in which a liquid is changed into its vapour state by heating. It is used to separate solid substances dissolved in a liquid.

Separation of the coloured component (dye) from blue or black ink

Blue or black ink is prepared by dissolving blue or black dye in water. The dye can be separated from ink by evaporation. Let us perform an activity to do this.

Procedure:



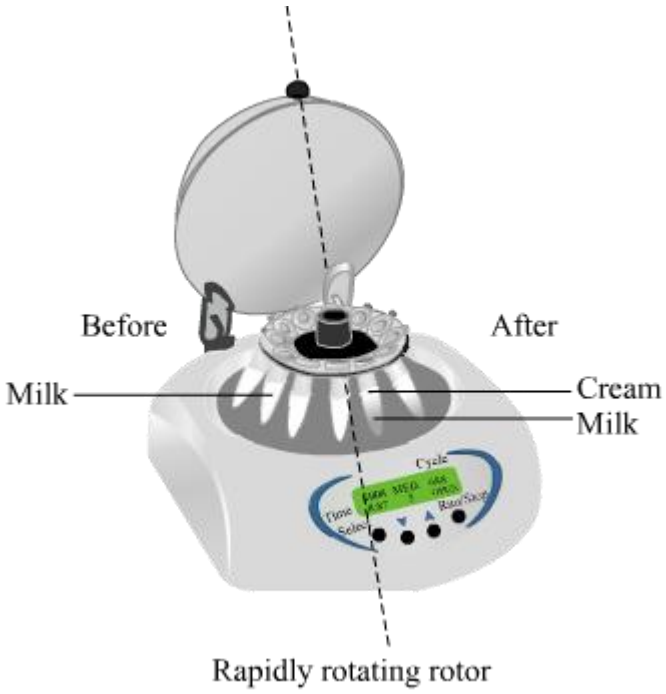
- Half fill a beaker with water.
- Put a watch glass on top of the beaker.
- Add a few drops of blue or black ink on the watch glass.
- Now, heat the beaker till a solid mass is obtained in the watch glass.

Observation:

You will observe that a solid residue of the dye is obtained in the watch glass. Ink is a colloidal solution.

It is a heterogeneous mixture of dye and water. Heating leads to the evaporation of water. This leaves behind the dye in the watch glass.

Centrifugation



Milk is a heterogeneous mixture of proteins, fats and other nutrients. Cream is separated from milk as a fat-rich substance by the process of **centrifugation**. The given figure shows this process.

It will be observed that cream collects in the upper layer of milk after centrifugation. Fat (cream) is the lightest component of milk, so it forms a layer on top.

The technique of centrifugation is used in the:

- Drying of wet clothes in the spin tub of a washing machine
- Extraction of DNA for forensic and experimental purposes
- Treatment of wastewater
- Processing of sugar and milk

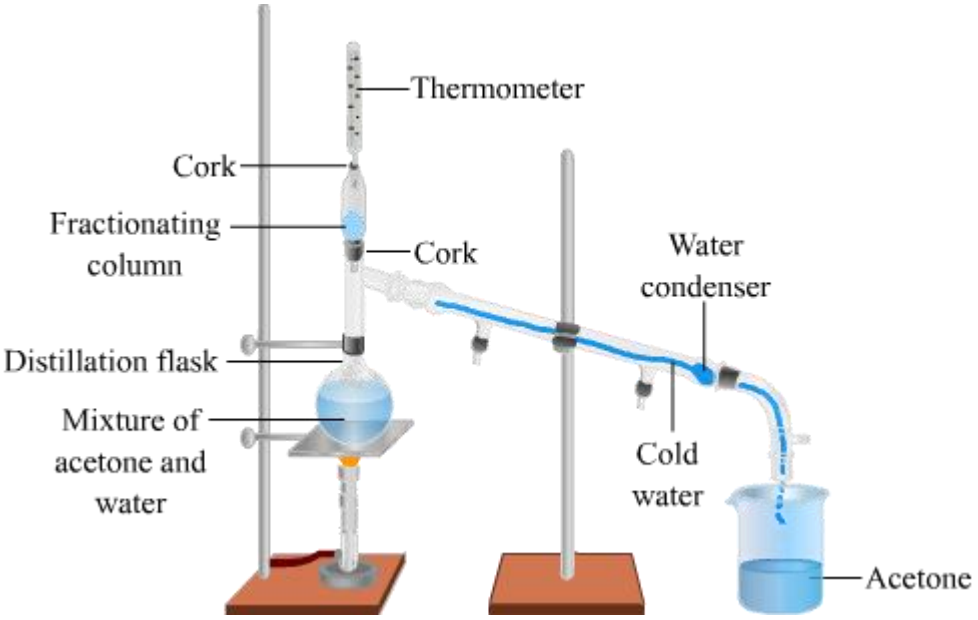
Separation of Two Immiscible Liquids

Separation of Two Miscible Liquids

They can be separated by **Simple distillation** (for liquids having at least 20–25 K difference in boiling points) and **Fractional distillation** (for liquids having very similar boiling points). Examples of miscible liquid mixtures are alcohol and water, acetone and water

Fractional Distillation

This method is used to separate miscible liquids in a mixture. The apparatus used is similar to that used in simple distillation, with the exception of a fractionating column fitted between the condenser and the distillation flask. The fractionating column is packed with glass beads. These provide a large surface area for the hot vapours to cool and condense repeatedly.



Did You Know?

Air is a homogeneous mixture of different gases such as oxygen, nitrogen and carbon dioxide. The oxygen cylinders in hospitals and cylinders of carbon dioxide in cars and buildings are prepared by separating individual gases from air.

Project Ideas

Aim: To separate a mixture of alcohol, water, salt and sand.

Apparatus required: Beaker, burner, funnel, filter paper, tripod stand, wire gauze and fractionating column

Theory: The given mixture contains alcohol, salt, water and sand. The separation of the mixture depends upon the characteristic properties of its constituents.

Alcohol and salt are soluble in water, but sand is insoluble in water. So, sand can be removed easily by filtration.

The remaining mixture now contains alcohol, salt and water. The boiling points of these are as follows:

- Alcohol = 78°C
- Salt = 108°C
- Water = 100°C

It is evident from the above information that alcohol can be separated from the mixture by simple distillation. During this process, alcohol will boil first and can then be collected in a beaker.

The remaining solution now contains salt dissolved in water which can be separated by evaporation. The water vapours can be condensed back to water, while the salt is left behind in the flask.

Procedure:

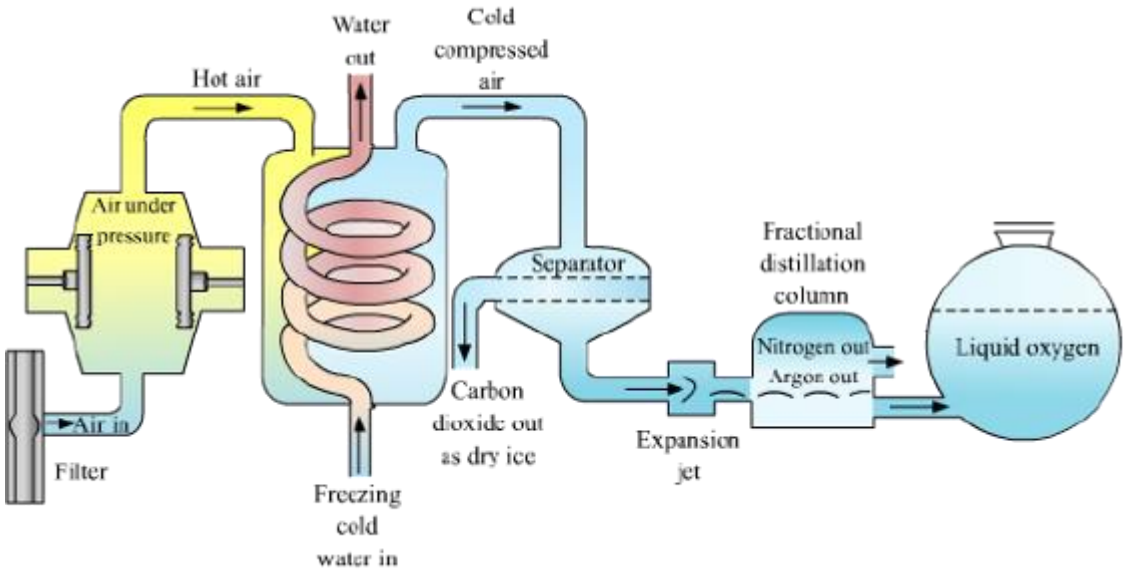
- Pour the mixture in a beaker.
- Take an empty beaker and place the funnel on it.
- Cover the inner side of the funnel with filter paper.
- Pour the mixture into the funnel, allowing sand to separate from the liquid mixture.
- Dry the sand collected on the filter paper.
- Pour the remaining solution in a distillation flask and heat to boil.
- Vapours of alcohol condense in the condenser and liquid alcohol is collected in the beaker attached to the condenser.
- Heat the remaining mixture till water starts evaporating.
- Crystals of salt will be left in the flask.

Result: Separation of the mixture is done as follows:

- Sand from the mixture: By filtration
- Alcohol from the remaining mixture: By distillation
- Salt from water: By evaporation

Real life extension: List some of the industrial uses of the separation techniques used in this experiment.

Separation of Gases by Fractional Distillation



Stages involved in separation of the components of air:

- Air is first filtered to remove dust particles. Then, it is compressed under high pressure.
- This compressed air is then passed through a water condenser to decrease its temperature.
- The cold compressed air is now passed through a separator. Here, carbon dioxide separates as **dry ice**. Due to repeated compression, air becomes cold and turns into liquid.
- The liquid air coming out of the separator is passed through an expansion jet into the distillation column. Here, it is warmed slowly. Liquid nitrogen, having the boiling point of −196°C, boils first to form liquid nitrogen gas. This gas is collected from the upper part of the column. Argon, having a boiling point of −186°C, is collected next. Oxygen, having a boiling point of −183°C, is collected last.

Sublimation

Crystals of ammonium chloride and common salt look similar. It is difficult to separate their mixture by ordinary methods. Sublimation is the best way to separate ammonium chloride from common salt. Let us understand this process with the help of an activity.

Procedure:

- Take a mixture of common salt and ammonium chloride in a china dish.
- Place the dish on a tripod stand and cover it by inverting a funnel over it (as shown in the figure).
- The funnel should be plugged on the top with cotton to prevent the vapours of ammonium chloride from escaping into the atmosphere.
- Heat the china dish using a burner.
- On heating, ammonium chloride sublimes. As a result, ammonium chloride gets separated from common salt and solidifies on the cold walls of the funnel.

Note: For any substance undergoing sublimation, the energy required to convert its solid form into liquid is greater than the energy required to convert the solid form into gas.

Did You Know?

Sublimation Printing

- It involves using dye sublimation printer to print on a substrate.
- The printer uses heat to transfer dye onto the substrate.
- Due to the heat, the dye transitions from solid to gas without passing through the intermediate liquid phase.
- The dye sublimation printer produces a continuous tone.
- The obtained prints are dry and can be used immediately.
- The process is clean since no liquid dye is formed.
- The coloured ribbons and the heating head must match the size of the substrate.
- Only specially coated papers accept sublimated dye.
- The sublimated ink is prone to diffusion, so the obtained prints are not sharp.
- Once used, the coloured ribbons cannot be used again; so, a lot of dye is wasted.
- A negative of the print appears on the coloured ribbons.

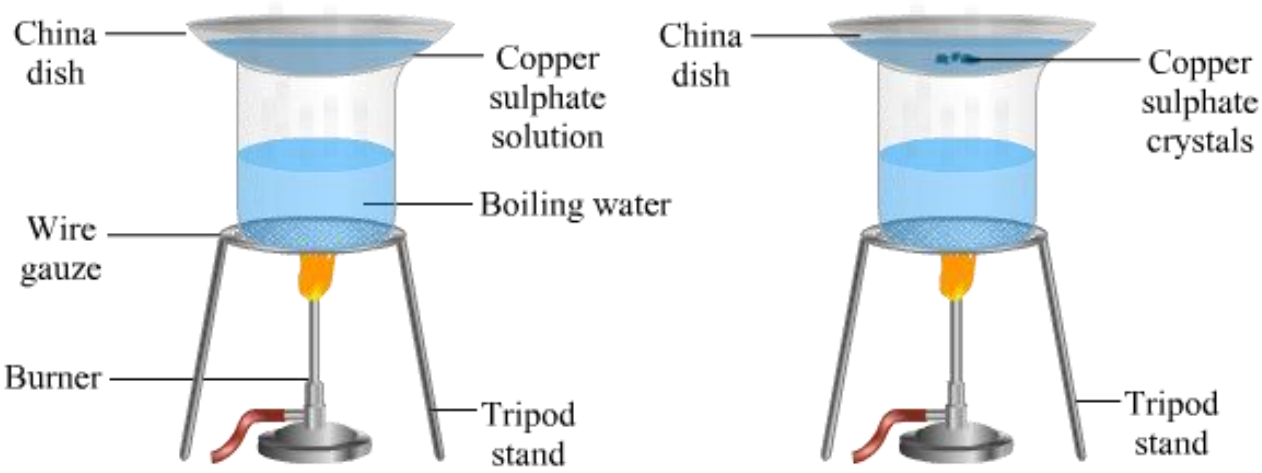
- Dye sublimation papers and ribbons are very sensitive and can be destroyed by skin oils.
- For effective prints, the ribbons need to be free from dust.

Crystallization

We can obtain pure copper sulphate from an impure sample through the process of **crystallization**. Let us understand this process with the help of an activity.

Procedure:

- Take a small amount (5 g) of impure copper sulphate in a china dish.
- Dissolve the sample in 10 mL of water.
- Filter it to remove impurities.
- Evaporate the filtered solution on a water bath till small crystals are formed, indicating that a concentrated solution has been obtained.
- Cover the solution with a filter paper and leave it undisturbed at room temperature for the rest of the day.
- It will be observed that crystals of pure copper sulphate are obtained and the impurities are left in the solution.



Sedimentation, Decantation and Filtration

Mixtures of mud in water and chalk in water can be separated by using methods such as **sedimentation**, **decantation**, and **filtration**. The definitions of these three methods are given in the following table.

SEDIMENTATION	DECANTATION	FILTRATION
It is the process of settling down of the heavier components present in a mixture.	It is the process of transferring a liquid from one container to another without disturbing the sediments that are present at its bottom.	It is the process of separating the undissolved components from a mixture. It is done by passing the mixture through a material containing fine holes that will allow only one component of the mixture to pass through.

Filtration is a better method than decantation to separate mixtures as some of the solid particles also pass along with the liquid during the process of decantation while filtration allows one to obtain a cleaner liquid. However, decantation is used in cases where recovering the solid substance from the filter paper is difficult.

Chromatography

Chromatography can be used to separate the coloured components of a mixture on the basis of the difference in the speeds of the components on chromatograph paper, when dissolved in the same solvent. The adsorbent paper acts as the stationary phase; it carries the components of the mixture on the paper.

The mixture acts as the mobile phase and the components get separated. The component which moves slowly (i.e., the less-soluble component) appears as a spot on the lower side of the paper. The component which moves faster (i.e., the more-soluble component) appears as a dot on the higher side of the paper.

Separating coloured components of ink by chromatography

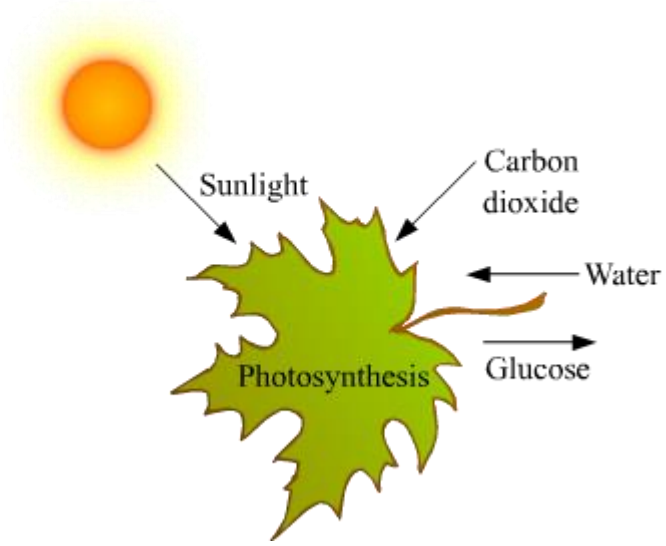
Procedure:

- On a thin strip of filter paper, make a boundary at least 3 cm above the lower portion. At the centre of the boundary, pour a drop of ink and let it dry.
- Repeat the above action two to three times, letting the drop dry each time, in order to concentrate the mixture. Pour some amount of water in a cylindrical jar.
- Place the paper in the jar in a manner that the lower end of the paper dips in water.
- Be careful not to dip the ink in water.
- Fix the upper end of the paper to the lid of the jar or on the top edge of the jar.
- Leave the apparatus undisturbed for some time.

Observation: As the water rises on the filter paper, it carries the drop of ink with itself; after some distance, the ink separates into its constituent colours.

Project Ideas

Aim: To separate the green pigment from plant leaves with the help of chromatography.



Theory: Plants survive by making their own food with the help of a green pigment known as chlorophyll. They absorb water from the ground with the help of their roots and carbon dioxide gas from the atmosphere. They use sunlight to convert the absorbed water and carbon dioxide into glucose. Glucose is a sugar which is used by plants as food to supply energy and as the building block for growth. This entire process is named photosynthesis.

Chlorophyll helps in this process of manufacturing food and provides green coloration to plants. In winters, there is often shortage of light and water for photosynthesis to be carried out. During such times, the plants rest and live off the food they stored during summers. When plants stop manufacturing food, chlorophyll starts to disappear and shades of yellow or orange become visible. This is the reason leaves change colour in autumn.

Materials required: Leaves, small beakers, covers lids for beakers, rubbing alcohol, paper coffee filters, shallow pan, hot water, tape, pen, plastic spoon, clock

Procedure:

- Collect two to three big leaves from different trees.
- Cut each leaf into tiny pieces and place them in a beaker labelled with the name or location of the tree that the leaf came from.
- Add rubbing alcohol to the beakers in order to cover the cut pieces of the leaves.
- Using a plastic spoon, carefully grind the leaves in the alcohol.
- Cover the beakers loosely with lids.
- Place the beakers in a shallow tray containing up to 1 inch of hot water.
- Keep the beakers in water for at least thirty minutes, until the alcohol is coloured (the darker the better).
- Swirl each beaker gently every five minutes. Replace the hot water if it cools off.
- Cut out a long thin strip of coffee filter paper for each beaker and label it accordingly.
- Remove the beakers from water and uncover them.
- Place a strip of filter paper into each beaker such that one end is in the alcohol. Tape the other end to the beaker after bending it around the corner.
- The alcohol will travel up the paper, dragging the colours with it.
- After thirty to ninety minutes (or longer), the colours will travel to different distances on the paper as the alcohol evaporates.
- Different shades of green, and possibly some yellow, orange or red (depending on the type of leaf) will start showing up on the paper.
- Remove the strips of filter paper, dry them and then tape them to a piece of plain paper.

Result: List the different colours into which the green pigment got separated.

Real life extension: Find out the applications and uses of chromatography in daily life.

Separation of Solids using a Solvent

Separating a mixture of sodium chloride and sand using water

Procedure:

- Place the mixture of salt and sand in a beaker.
- Add water to the mixture and stir well.
- Allow the mixture to stand for a while.
- Filter the mixture to obtain salt water and sand.
- Allow the sand to dry.
- Evaporate the salt water in china dish.

Observation: Salt being soluble in water, will get dissolved in it. The remaining sand is filtered off. Salt can be recovered from the solution by evaporation. The crystals of sodium chloride are obtained on the walls of the china dish.

Separating a mixture of carbon and sulphur using carbon tetrachloride

Procedure:

- Place the mixture of carbon and sulphur in a beaker.
- Add carbon tetrachloride to the mixture and stir well.
- Allow the mixture to stand for a while.
- Filter the mixture to obtain carbon and solution of sulphur.
- Allow the carbon to dry.
- Evaporate the solution of sulphur in china dish.

Observation: Sulphur is soluble in carbon tetrachloride solution. It gets dissolved in it leaving carbon behind. The sulphur is obtained by evaporating the solution.

Handpicking, Sieving, Threshing, Winnowing and Magnetic Separation

Mixtures are substances that are formed by the physical combination of two or more substances in any proportion. Mixtures are formed by combining different solids that have different properties.

Do you know any method that can be used for separating mixtures?

Mixtures can be separated by various methods such as handpicking, winnowing, threshing, and sieving. Here, we will discuss these methods in detail.

Handpicking

The mixtures that comprise solids of different colours, shapes, or sizes can be separated by hand. This process is known as handpicking.

You may have observed your mother separating impurities such as small stones and husk from wheat, pulses, and grains by handpicking.

1. What is the boy in the figure doing?

2. What is the name of the method that the boy is using to do the same?

Winnowing

The process of separating lighter components of a mixture from the heavier ones by using wind or moving air is known as winnowing.

Let us watch the given animation to understand the process of winnowing.

Threshing

The process of separating grains from stalks by beating them with sticks is called threshing.

After a harvest, wheat or paddy stalks are dried in the sun. Each stalk contains many grains. Hence, farmers make bundles of the stalks and then beat them with sticks to separate the grains.

Sieving

The process of separating smaller particles from bigger ones by passing them through a sieve is called sieving. **Sieving can only be used for separating the mixtures containing components of different sizes.**

Figure B: Sieving

A mixture of sand, pebbles, and stones can be separated by the process of sieving. Fine sand particles pass through the holes of the sieve, while bigger impurities such as stones and gravel remain on the sieve, as shown in figure B.

However, a mixture of chalk powder and flour cannot be separated by the process of sieving as the sizes of the two components of the mixture are almost the same.

Magnetic Separation

This process is used when one of the components of a mixture is iron. Iron shows magnetic properties because of which it gets attracted to a magnet. Any mixture containing iron and some other component can easily be separated by magnetic separation.

Which method can be used for separating the following mixtures?

1. A mixture of stones and rice

2. A mixture of dry sand and small pieces of paper