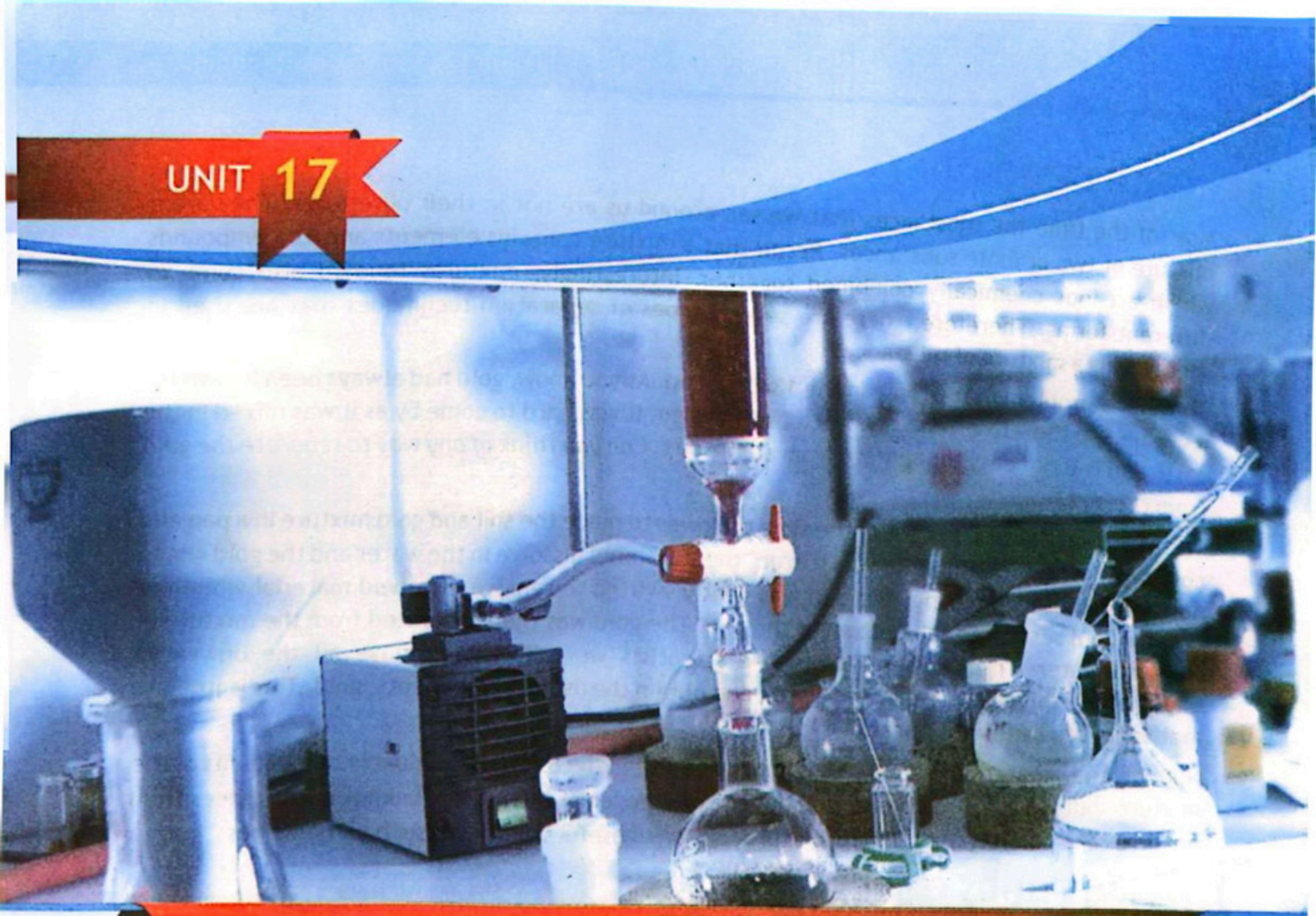


UNIT 17

SEPARATION TECHNIQUES

Student Learning Outcomes (SLOs)

After completing this lesson, the student will be able to:

- Define important terms associated with creating chemical solutions. (some example include: a) solvent as a substance that dissolves a solute. b) solute as a substance that is dissolved in a solvent. c) solution as a mixture of one or more solutes dissolved in a solvent. d) saturated solution as a solution containing the maximum concentration of a solute dissolved in the solvent at a specific temperature. e) residue as a substance that remains after evaporation, distillation, filtration, or any similar process. f) filtrate as a liquid or solution that has passed through a filter.
- Explain methods of separation and purification (some examples includes: a) using a suitable solvent. b) filtration. c) crystallization d) simple distillation e) fractional distillation.
- Suggest suitable separation and purification techniques, given information about the substances involved, and their usage in daily life.
- Identify substances and assess their purity using melting point and boiling point information.

INTRODUCTION

Most of the time the substances that we see around us are not in their pure form. They are a mixture of two or more substances. *Recall* that a mixture contains elements and/or compounds which are not chemically combined together. Interestingly, mixtures tend to also come in different forms. Therefore, there are several types of separation techniques that are used in segregating a mixture of substances.

Consider a problem that people in the 1840's faced. As you know, gold had always been known for its value and therefore was very precious. However, it was hard to come by as it was mixed in the earth and was not easy to separate from all the dirt. *Can you think of any way to separate the gold from the dirt?*

The approach that the people of the time took was to place the soil and gold mixture in a pan and cover with water. The mixture was stirred, the soil would dissolve in the water and the gold would not. After thorough mixing, the pan was gently swirled to remove dissolved material while the heavier gold settled to the bottom of the pan. The gold was then separated from the mixture of soil and water. Through separation, the scientists were able to remove all the unwanted materials, in this case the dirt and water, and obtain the useful components, gold. This is just one method of separating mixtures.

Not only the separation of mixtures is helpful to obtain the useful and valuable components of the mixture, but we are also able to find out the properties of the known/unknown substances from mixtures and possibly use them for the production of useful substances such as medicines.

17.1 METHODS OF SEPARATION

The mixture is composed of two or more substances that can be present in varying amounts and can be physically separated by using methods that use physical properties to separate the components of the mixture. The appropriate method to use for separating the components in a mixture depends on the physical states. Separations exploit differences in chemical properties or their physical properties. For instance, size, shape, mass, density, or chemical affinity between the constituents of a mixture. Some of the common methods of the separation are filtration, evaporation, distillation, sedimentation and decantation, magnetic separation, centrifugation.

A solution is a mixture that consists of a solute and a solvent. The solute is a solid that is dissolved in the solvent (which is a liquid) and together they make up a solution. Ask yourself, in a brine solution consisting of salt and water, which is the solute and which is the solvent?

The idea behind the separation techniques of mixtures is to separate the solute and the solvent from each other as they may be much more useful independently. Like in the example above, we separated gold from the dirt and the gold was useful for us.

17.2 EVAPORATION

Evaporation is a separation method use to separate components of a mixture in which a solid is dissolved in a liquid, where the liquid changes into the gaseous phase and solid is left behind. The application is based on the fact that solids do not vaporize easily, whereas liquids do. Can you think of any mixture that can be separated through this technique?

In an enclosed space, a liquid will continue to vaporize until air saturation is achieved. In

practically, only a small fraction of the total molecules possess enough heat energy required to vaporize the liquid.

Mixture of a solid dissolved in a liquid

Only a solid remains

17.2.1 Factors affecting rate of evaporation

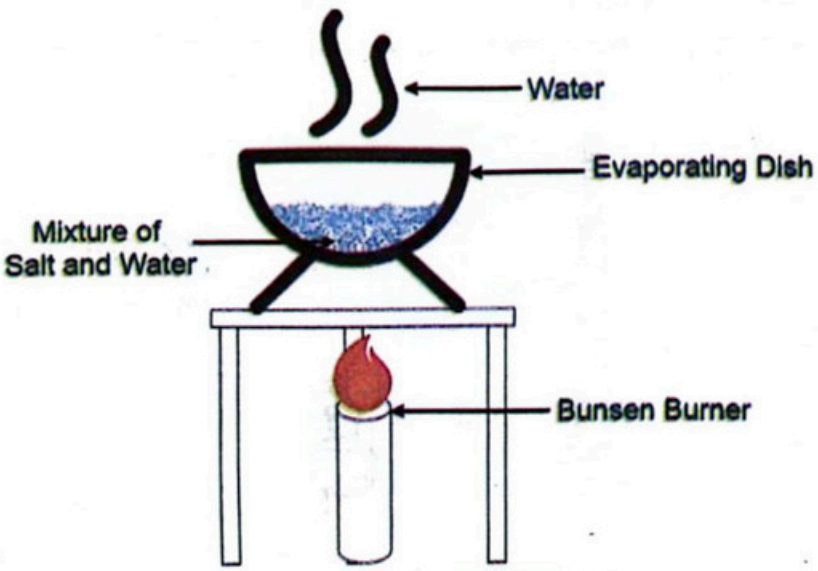
Pressure: An increase in pressure pushes gas particles close together. The force between the particles increases making it difficult for the liquid to convert to gaseous form.

Temperature: On increasing the temperature of the substance, the material heats up and the constituent particles begin moving with greater kinetic energy. This leads to an increase in the rate of evaporation. For example, warm water boils faster than cold water.

Surface area of the substance: A substance with a larger surface area will contain more surface molecules per unit of volume, it triggers the potential of the particles to escape, thereby increasing the rate of evaporation.

Inter-molecular forces: Stronger inter-molecular forces between the molecules of the liquid require greater amounts of energy to break and turn into a gas. Therefore, substances with stronger intermolecular forces have lower rate of evaporation. An indicator of the intermolecular forces is provided by the enthalpy of vaporization.

Flow rate of the atmosphere: Increase in the flow of air which is unsaturated, for instance, fresh air, will lead to the increase in the rate of evaporation.



17.2.2 Applications of Evaporation

From the explanation above, we can deduce that evaporation helps to separate a volatile component from a non-volatile one.

Can you think of any examples?

- seawater can be evaporated to produce drinking water
- Dye from ink: ink is mixture of water and dye
- Dairy producers also use the technique of evaporation to use it to dry lactose into powders.
- Beverage producers can create concentrates, for instance, juice concentrators by reducing water content through evaporation.
- Water containing minerals can be evaporated to extract the metals and minerals which simulates the chemical processes.

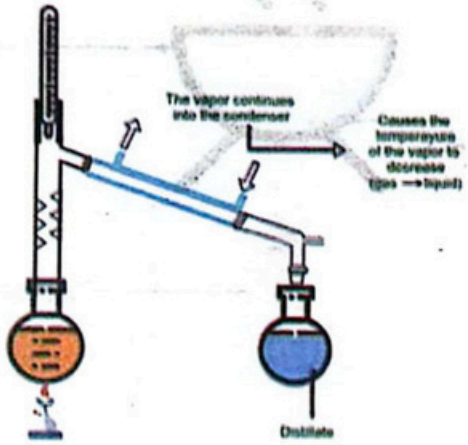
17.3 DISTILLATION

Distillation is a separation technique used to separate components of a liquid mixture by a process of heating and cooling, which exploits the differences in the volatility of each of the components. The liquid that is obtained by performing the condensation of vapor is called the distillate. Distillation is carried out at the solvent's boiling points. Boiling takes place when the vapor pressure is equivalent to the atmospheric pressure.

Separation of the components of the mixture takes place better in case of the higher relative volatility of a liquid. On supplying heat to the liquid, the vapor boils and then condensation takes place.

17.3.1 Distillation procedure:

1. The round bottom flask contains the liquid mixture which is heated to a vigorous boil.
2. The component with the lower boiling point will change into its gaseous state.
3. On coming in contact with the water-cooled condenser, the gas will condense.
4. The condensed gas will trickle down into the graduated cylinder where the chemist can collect the final distilled liquid.
5. The other liquid component remains in the round bottom flask.



17.3.2 Types of Distillation

1. Simple distillation.
2. Fractional distillation.
3. Steam distillation.

Fractional distillation.

This technique works in a very similar way to simple distillation, but fractionating column is used to get a temperature gradient, cooler at the top and hotter at the bottom. This allows careful control of the temperature at which the distillate is being collected, allowing different liquids in a mixture to be separated, each turning into a vapor and being cooled and condensed in the condenser at their own individual boiling points.

Steam distillation.

Steam distillation is a separation process that consists in distilling water together with other volatile and non-volatile components.

Vacuum distillation.

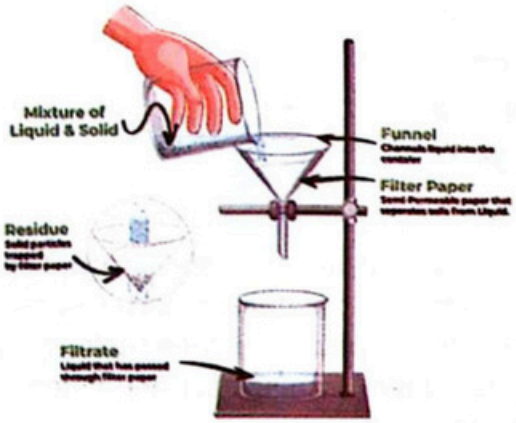
Vacuum distillation or Distillation under reduced pressure is a type of distillation performed under reduced pressure, which allows the purification of compounds which are not readily distilled at ambient pressures or simply to save time or energy. This technique separates compounds based on differences in their boiling points

17.3.3 Application:

- There is a piece of evidence that humans were using the distillation process since 3000 BC (approximately). This process is used to make distilled water.
- Distillation plays an important role in many water purification techniques. Many desalination plants incorporate this method in order to obtain drinking water from seawater.
- This process is also used to refine the crude oil and to purify the alcohol.
- The process of steam distillation is used to obtain essential oils and herbal distillates from several aromatic flowers/herbs.
- Distilled water has numerous applications, such as in lead-acid batteries and low-volume humidifiers.
- Many fermented products such as alcoholic beverages are purified with the help of this method.
- Many perfumes and food flavorings are obtained from herbs and plants via distillation.
- Air can be separated into nitrogen, oxygen, and argon by employing the process of cryogenic distillation.
- Distillation is also employed on an industrial scale to purify the liquid products obtained from chemical synthesis.

17.4 FILTRATION

Filtration is a separation technique used to separate the components of a mixture containing an undissolved solid in a liquid. The exact method used depends on the purpose of the filtration, whether it is for the isolation of a solid from a mixture or removal of impurities from a mixture.



17.4.1 Filtration Process

The principle of filtration is based on the difference in sizes between the particles. Filtration separates the solid matter from a liquid mixture using a filter medium for example filter paper or filtration membrane that allows the liquid to pass through it and block the solid particles on the other side of it. The pores of the filter medium are bigger as compared to the solvent particle but are smaller compared to the solute particle, so they allow only solvent particles to pass through them the solute particle is left on the other side making the solution free from the insoluble solute. The mechanism of "filtration" can be mechanical, biological, or physical. Filtration may be done cold or hot, using gravity or applying vacuum, using a Buchner or Hirsch funnel or a simple glass funnel.

As the process of filtration uses the concept of difference in the particles. We have two types of mixtures

- Heterogenous Mixture
- Homogenous Mixture

We define a heterogeneous mixture as a mixture in which the solute particle is not evenly distributed in the solvent phase. Such as sand in the water is an example of a heterogeneous mixture. On the other hand, a homogeneous mixture is a mixture in which the solute particles are evenly distributed in the solvent. A brine solution is an example of a homogenous mixture. Homogenous mixtures are also called solutions.

Solution

A homogeneous mixture of two or more components is called a solution. Basically, solution has two components

a) Solute: The component of solution which is present in smaller quantity is called solute for example salt, in salt solution.

b) Solvent: The component of solution which is present in larger quantity is called solvent for example water, in salt solution.

Various types of processes are used for filtration. In general, the filtration process uses the filtration membrane that allows only a specific size particle to move through it making the solution at one end free from the insoluble solute particle. Insoluble solid substances left behind are called residues. We can understand this by using the example, suppose we have to filter sand

and water then we use a muslin cloth at the mouth of the container containing the sand in water. We allow the solution to pass through the muslin cloth which only allows water may pass through it separating the sand from the sand and water solution. We can also use filtration paper in place of muslin cloth as the filtration membrane.

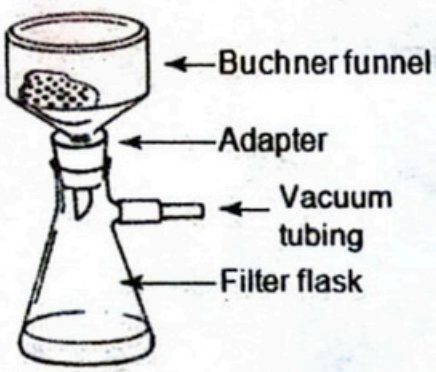
7.4.2 Filtration by filter paper

Filtration by filter paper is also called gravity filtration. Filter paper is a semi-permeable barrier placed perpendicular to a liquid or air flow. Filter paper can have pore sizes ranging from small to large to permit slow to fast filtering

17.4.3 Filtration by vacuum (or Suction) Filtration

Vacuum filtration uses a Buchner funnel. A Buchner funnel is a flat bottomed, porous, circular porcelain bowl with a short stem. The stem is fitted with a rubber stopper and inserted in the mouth of a side arm filter flask. Circular filter paper, the same diameter as the bowl, is placed on the flat bottom and wetted with the appropriate solvent to create a seal before starting the filtration.

Can you think of some examples of filtration in your daily life? Some are listed below.



17.4.4 Filtration in daily life:

- When making coffee, hot water is filtered through the ground coffee and a coffee bean. The filtrate is the coffee in liquid form. Using a tea ball or a tea bag (paper filter) for tea is also an example of filtration.
- A kidney is a biological filter that is used to filter the human blood. Blood filtering in kidneys is another application of the filtration technique.
- HEPA filters are used by various vacuum cleaners and air conditioners to filter out dust and pollen from the air.
- Filters with particulate-capturing fibers are commonly used in aquariums.
- During mining, belt filters extract precious metals. Filtration techniques are used in the metallurgical process to remove the slag.
- Sand and permeable rock in the ground filtered the water which is then stored in the aquifer and

then used as groundwater.

- The wastewater treatment plant uses the filtration technique to filter the sewage.
- Air filters are used in automobiles and in factories to remove harmful particles from the smoke.
- The treatment of water uses filtration techniques.

17.5 CRYSTALLIZATION

Crystallization is a technique for purification of the substances. It is a technique that separates a solid from its solution. **The process in which the solid dissolves in the liquid arranges itself into well-defined 3-D structure is called crystallization. When any substance undergoes crystallization its molecule arranges itself in a fixed structure at an angle to form a 3-D structure called the crystal and then the crystal is removed from the solution. The crystal is a pure substance and thus the process of crystallization is widely used in the purification of material from its impure solution.**

What is the principle of crystallization?

The principle of crystallization is based on the limited solubility of a compound in a solvent at a certain temperature and pressure. A change of these conditions to a state where the solubility is lower will lead to the formation of a crystalline solid.

Crystallization is a purification technique that involves the following steps:

- When a small amount of solute at a given temperature is added in a solvent, solute dissolves very easily in the solvent.
- If the addition of solute is kept on, a stage is reached when solvent cannot dissolve any more solute.
- At this stage, further added solute remains undissolved and it settles down at the bottom of the container. On the particle level, a saturated solution is the one, in which undissolved solute is in equilibrium with dissolved solute.
- At this stage, dynamic equilibrium is established. Although dissolution and crystallization continue at any temperature, the net amount of dissolved solute remains constant.
- The solution is heated until enough of the solvent (water) has evaporated to make the solution saturated.

- We can tell when the solution is saturated by dipping a glass rod into the solution to remove a drop and seeing if the drop goes cloudy and crystals start to form as it cools.
- Once the solution is saturated, the Bunsen is turned off and the solution is allowed to cool - solubility decreases with temperature, and the solute that can't remain dissolved forms crystals.
- The crystals are removed from the remaining solution by filtering.
- The crystals are dried (in a warm oven, or just left to dry in air)

Science Titbits:

The size of the crystals formed during this process depends on the speed of cooling.
Rapid cooling of the solution will cause a large number of tiny crystals to form.
Slow cooling rates lead to the formation of large crystals.

17.5.1 Application of Crystallization

Crystallization is primarily employed as a separation technique in order to obtain pure crystals of a substance from an impure mixture.

Another important application of crystallization is its use to obtain pure salt from seawater.

Crystallization can also be used to obtain pure alum crystals from an impure alum. In such scenarios, crystallization is known to be more effective than evaporation since it also removes the soluble impurities

17.5.2 Application of separation and purification techniques

Filtration, Crystallization, distillation are suitable separation and purification techniques Filtration can be a physical process or a biological process. The physical application of filtration can be seen routinely all around our daily life–

- Human kidneys are responsible for filtering both the blood and other waste materials that may enter the body, whether through food, drink or medicine. The waste leaves the body as urine.
- coffee filters, automotive filters are commonly used in daily routine.
- Tea staining or coffee filters are examples of filtration Common example of crystallization for separation and purification the salt we get from seawater can have many impurities in it. Hence, the process of crystallization is in use to remove these impurities.
- The crystallization of water to form ice cubes and snow is commonly observed in daily life.
- The crystallization of honey when it is placed in a jar and exposed to suitable conditions.
- The formation of stalagmites and stalactites (especially in caves).
- Have you ever observed as the sugar syrup cools, sugar crystals can begin to form. This is crystallization.

17.5.3 Identification and purity of substances

Melting Point and Boiling point are characteristic parameters of substances which help to identify

them. Pure substances have a fixed boiling and melting point. For example, pure water boils at a 100°C and melts at 0°C. Impure substances have no fixed melting and boiling points. They can melt and boil at a range of temperatures.

To determine if a substance is pure in school laboratories, we can check the substance's melting or boiling points. Impure substances tend to have a slightly lower melting point and higher boiling point than the pure substance, and a broader range.

Have you ever noticed that in chocolate - milk chocolate melts really easily in your mouth whereas dark chocolate which is usually 70% takes much longer to melt. When water contains dissolved impurity (for example, table salt), it boils at a slightly higher temperature (around 100.5°C).

KEY POINTS

- The change of a liquid into its vapours is called evaporation.
- Distillation is a separation technique used to separate components of a liquid mixture by a process of heating and cooling.
- Distillation under reduced pressure is called vacuum distillation.
- Filtration separates the solid matter from a liquid mixture using a filter medium.
- The principle of crystallization is based on the limited solubility of a compound in a solvent at a certain temperature and pressure.

REVIEW QUESTIONS

1. Give short answer.
   - (i) Why is it important to separate materials from a mixture?
   - (ii) What is distillation
   - (iii) What is filtration?
   - (iv) What is evaporation?
2. What technique would you use to separate sand from water? There are two possibilities. Mention their names.
3. What technique would you use to separate alcohol from water?
4. What are mixtures?
5. How separation of mixtures of two or more liquids is done. Name the separation technique.
6. How to separate a mixture of two solids?
7. What method will you use to separate a sand and sugar mixture?