6 Separation of mixtures

Content

Learning Outcomes

Candidate should be able to:

Knowledge, Understanding and Application

(a) Show an awareness of basic principles involved in some separation techniques such as filtration, distillation and paper chromatography

(b) Explain how the properties of constituents are used to separate them from a mixture:
- Magnetic attraction
- Filtration
- Evaporation
- Distillation
- Paper chromatography

(c) Show an awareness of the applications of the various separation techniques in everyday life and industries Explain why most food must be digested

(d) Show an awareness of the techniques involved in obtaining pure water from sea water in desalination plants (e.g. distillation and reverse osmosis)

Skills and Processes

(e) Use separation techniques such as filtration, distillation and paper chromatography

Separation techniques

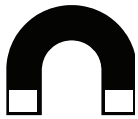
- The **physical combination** of two or more **pure** substances forms a **mixture**.
  - Substances constituting a mixture can be separated by applying different separation techniques.
  - These techniques are termed "**physical methods**".
  - With these methods, the substances in the mixture are just separated; they **do not change** into other substances
- Magnetic attraction, filtration, evaporation, crystallisation, distillation and chromatography are methods used for the separation of substances within the mixtures.

Magnetic attraction

- The method of magnetic attraction uses the basic principle of **magnetism** to separate a mixture of magnetic and non-magnetic substances.

- Bringing a magnet near such a mixture allows the magnetic substances to be attracted to the magnet.

- For instance, a magnet can be used to separate iron from a mixture of iron and non-magnetic substances.



  - A mixture of sulphur and iron fillings can be separated using a strong magnet.

- Commercially, iron is separated from scrap metal with the help of an **electromagnet**.
  - The electromagnet moves over the scrap metal, which contains a mixture of metals such as iron, copper and aluminium.
  - The pieces of iron from the pile of scrap metal cling to the electromagnet.
  - This is extremely useful in scrap yards where iron is remove from scrap materials such as cars.

- The technique of magnetic attraction is also used in **sewage treatment**.
  - Magnetic materials mixed with sewage are removed and cleaned to be reused again.

Filtration

- Filtration can be applied to separate **insoluble solids** from **liquids** as well as **solids** from **solids**.

- Materials required for separating solids from liquids include: a large beaker, a funnel, a piece of **filter paper** and a container filled with the mixture.

  ❶ Fix the funnel over the beaker.

  ❷ Fold the piece of filter paper into the shape of a cone and place it inside the funnel.

  ❸ Moisten the filter paper with a little distilled water.

  ❹ Slowly pour the mixture into the funnel.

  ❺ You will observe that the solid remains in the filter paper, while the liquid passes through the filter paper and is collected in the beaker below.

- A liquid containing solid particles is called a **suspension**.

- When a suspension is **filtered**, the **solid** that **remains** on the filter paper is called the **residue**.

- The **liquid** that passes through the filter paper is known as the **filtrate**.

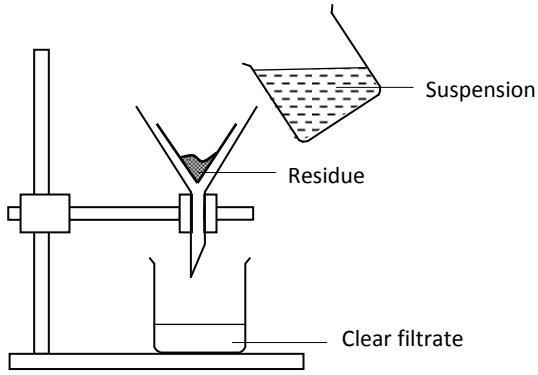
- **Solid particles** are **too big** to pass through the fine holes of the filter paper.

- On the other hand, the **liquid particles** are **much smaller** than the holes in the filter paper, so they can pass through it easily and be collected in the beaker.

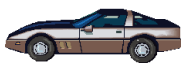
- A mixture of **two solids** can also be separated by filtration **only if one of them is soluble** in a particular solvent while **the other is not**.

  Example

  ① An example of such a mixture would be a salt-sand mixture, in which salt is soluble in distilled water while sand is not.



- Filtration using a filter paper is time-consuming.
- An electronic instrument called a **centrifuge** can carry out filtration **quickly** for commercial purposes.
- Filtration is employed in **vehicles** in the form of **air** filters and **oil** filters.
  - An air filter **traps dirt particles** entering the engine, thus protecting engine cylinders, walls, pistons and piston rings from damage.
  - Each moving part in an engine requires clean oil for proper lubrication and lasting life.



  - An oil filter cleans the oil as it passes through the filter element.
  - This prevents abrasive contaminants in the engine lubrication system from damaging the engine parts.
- The **human nose** also acts as a filter.
- The small hair strands in the nose trap dust and other small solid particles in the air to prevent them from entering the lungs.
- **Common household items** such as coffee sock and the strainer also make use of filtration concepts.
- Strainers are used to separate tea leaves from the tea we drink.

Evaporation

- Evaporation refers to the process in which there is a **gradual change of state** from **liquid to gas** that occurs at the liquid's surface.

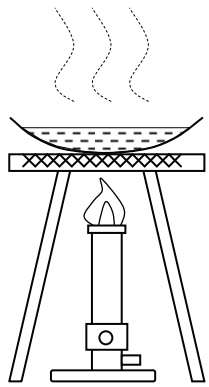
- Some examples of evaporation are rainwater evaporating from a warm pavement after a thunderstorm and wet paint drying as solvents in the paint evaporate.

- The method of evaporation is used to **separate dissolved solids from a solution**.

- When the solution containing dissolved solids is heated, the liquid (solvent) **evaporates gradually**, with the **solid** (solute) remaining in the evaporating dish. This is called the **residue**.

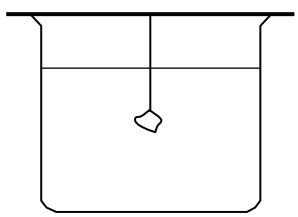
- In some countries, salt is obtained by evaporating seawater trapped in large open areas called "salt pans".

- The water slowly gets evaporated by the heat of the sun, leaving behind solid salt in the pans.



Crystallisation

- Crystallisation is used to **separate soluble solids** that tend to decompose upon heating, from its solution.
- In crystallisation, the solute becomes the solid crystals, separated from the solution.
- The **solubility of solids increases** with **temperature**.
- Hence, when the solution is heated and more solid is dissolved in it, the solution becomes saturated.
- Heating is stopped at the point when a **hot saturated solution** is formed.
- A saturated solution is one that contains the **maximum amount of solute** at a given temperature.
- If the resulting solution is allowed to **cool** to room temperature, the excess dissolved solid will precipitate out as **pure crystals**.
- The excess solid particles are “forced” to deposit as crystals around a “seed” object tied to a string.
- More crystals will start appearing on the **seed crystal** as the solution cools.
- An example of use of crystallisation is to obtain pure white sugar crystals.



Distillation

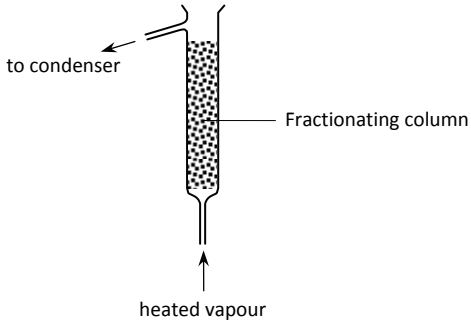
- Distillation involves separating a liquid (solvent) from a solution.
- Two processes are involved in distillation: **boiling** and **condensation**.
- The solution is **heated** in the distillation flaks so that the **solvent evaporates** and becomes **vapour**.
- The vapour then rises, and is directed to the **condenser** and where it is being **cooled**.
- The vapour then **condenses** into a liquid called the **distillate**.
- Distillation can also be used to separate **miscible liquids** with **different boiling points** (that is, liquids that dissolve in each other).
- When separating two miscible liquids, the liquid with the **lower** boiling point will vaporise and is **collected first**.
- While this happens, the temperature **remains constant** at the boiling point of the liquid.
- The conical flask will be removed once the temperature starts increasing again. This is to prevent the other liquid from contaminating the first liquid that has been collected.
- The other liquid will remain in the distillation flask.

Example

① Distillation may be used to obtain pure water from seawater. Seawater is evaporated and the water vapour that escapes condenses into pure water.

This is however a very **expensive** process, and it requires a lot of **fuel** as a huge amount of water has to be heated.

- Liquids that **do not mix** are said to be **immiscible**.
- Liquids that **mix completely** are said to be **miscible**.
- Two miscible liquids with different boiling points can be separated by a method called **fractional distillation**.
- An additional apparatus called a **fractionating column**, is required for fractional distillation as compared to simple distillation. It is attached to the distillation flask and the condenser.



- The fractionating column contains **glass beads**.
- This is to provide a **large surface area** for vapour condensation.
- During fractional distillation, only the vapour that has the **lowest boiling point** will **distil over** the condenser **first.**
- As boiling proceeds, the mixture of vapours rises up the fractionating column.
- In the fractionating column, both condensation and vapourisation take place.
- As the vapours rise up the column, liquid vapour condenses and drops back into the distillation flask.
- Eventually, the liquid vapour with the lower boiling point reaches the upper part of the column and distils over the condenser first.
- Inside the condenser, the hot vapour is **cooled by running water**, allowing it to condense slowly.
- The liquid formed flows down the inner tube of the condenser and into the receiver (conical flask).

Fractional distillation has many **industrial applications**.

- It is used to **separate the constituents of air**, to obtain liquid nitrogen, liquid oxygen and high-purity argon.
- The second industrial application of fractional distillation is to **obtain petroleum fractions from crude oil** in oil refineries.
- Another industrial application of fractional distillation is in the **making of alcoholic beverages**. These beverages contain alcohol, which is produced by the fermentation of glucose and collected by fractional distillation.

Chromatography

- Chromatography is an analytical method of isolating the coloured components of a mixture.

- Chromatography comes in many forms: paper chromatography, liquid chromatography, gas chromatography and ion-exchange chromatography.

- **Paper chromatography** is used to separate the components of a mixture by treating the mixture with a **solvent.**

- When a **spot of ink** is applied to the chromatography paper, the dyes in the ink are **adsorbed** onto the paper surface.

  - As the solvent is soaked up by the paper, it **dissolves** the dyes.
  - A dye that is **not very soluble** and is **strongly adsorbed** onto the paper travels the **slowest**, while a dye that is **highly soluble** and **weakly adsorbed** is carried the **furthest** through the paper.
  - A chromatography paper with the separated components of a mixture is known as a **chromatogram**.

Examples

① Paper chromatography is commonly used to find colours in dyes and coloured substances used in food products such as sweets and canned vegetables.

② It can also be used to identify poisons or drugs, detecting traces of banned additives in foodstuffs.

Desalination

- Desalination is the **removal of salt from water.**
- Desalination and reverse osmosis have been used to produce desalinated water.
- The distillate collected is pure water.
- In solar desalination, solar heat is used to remove the water from seawater.
  - Solar heat evaporates the water and the water vapour condenses on a sloping glass roof.
  - The disadvantage of this method is that large areas of land are needed for desalination units.
- Desalination by **reverse osmosis** involves a **partially-permeable** membrane, which allows only water molecules to pass through but not others.
- In reverse osmosis, the membrane acts like an **extremely fine filter** to create drinkable water from seawater by removing dissolved impurities.
  - Seawater is pumped under pressure into a closed container.
  - The seawater is held on one side of the membrane and pressure is applied to force the seawater against the membrane.
  - Water, but not salt passes through the membrane.
  - In this way, water can be transformed into highly-purified water for industrial use at microelectronics, power and pharmaceutical facilities.

6.9 Worked Examples

Example 1

How would you know if a solution is saturated?

(A) When a sample is taken out and cooled, it forms small crystals rapidly.
(B) When the sample starts to evaporate.
(C) When more solid is added, they continue to dissolve in the solution.
(D) When solution changes colour.

Solution:

(A) When a sample is taken out and cooled, it forms small crystals rapidly.

(At a given temperature, a solution can only hold a certain amount of solute. A saturated solution is one that contains the maximum amount of solute at a given temperature.)

Example 2

Which of the following is an industrial application of fractional distillation?

(A) Identifying poisons or drugs, detecting traces of banned additives in foodstuffs.
(B) An air filter trapping dirt particles entering the engine, thus protecting engine cylinders, walls, pistons and piston rings from damage.
(C) Sewage treatment.
(D) Making of alcoholic beverages.

Solution:

(D) Making of alcoholic beverages.

(These beverages contain alcohol, which is produced by the fermentation of glucose, and collected by fractional distillation)

Example 3

Crystals can be grown by_____.

(A) cooling a saturated solution
(B) heating a saturated solution
(C) stirring a saturated solution
(D) planting in a well watered fertile soil

Solution:

(A) cooling a saturated solution

(Heating is stopped at the point when a hot saturated solution is formed. If the resulting solution is allowed to cool to room temperature, the dissolved solid will precipitate out as pure crystals.)

Example 4

A student used a pen to draw a line across a piece of chromatography paper. He then placed a sample of dye on the drawn line for analysis. Is the student doing the right thing? Why?

Solution:

The student is not doing the right thing. The components present in the ink of the pen will be separated upon being dissolved by the solvent. The chromatogram obtained eventually will contain a mixture of spots that include both the components of ink from the pen and the dye. Thus, the accuracy of the analysis of the sample of dye is affected.

Example 5

Describe the method you would use to obtain:

(a) Pure water from a mixture of ink and water.
(b) Petrol (boiling point 20 ~ 60°C) from a mixture of petrol and kerosene (boiling point 180 ~ 220°C)

Solution:

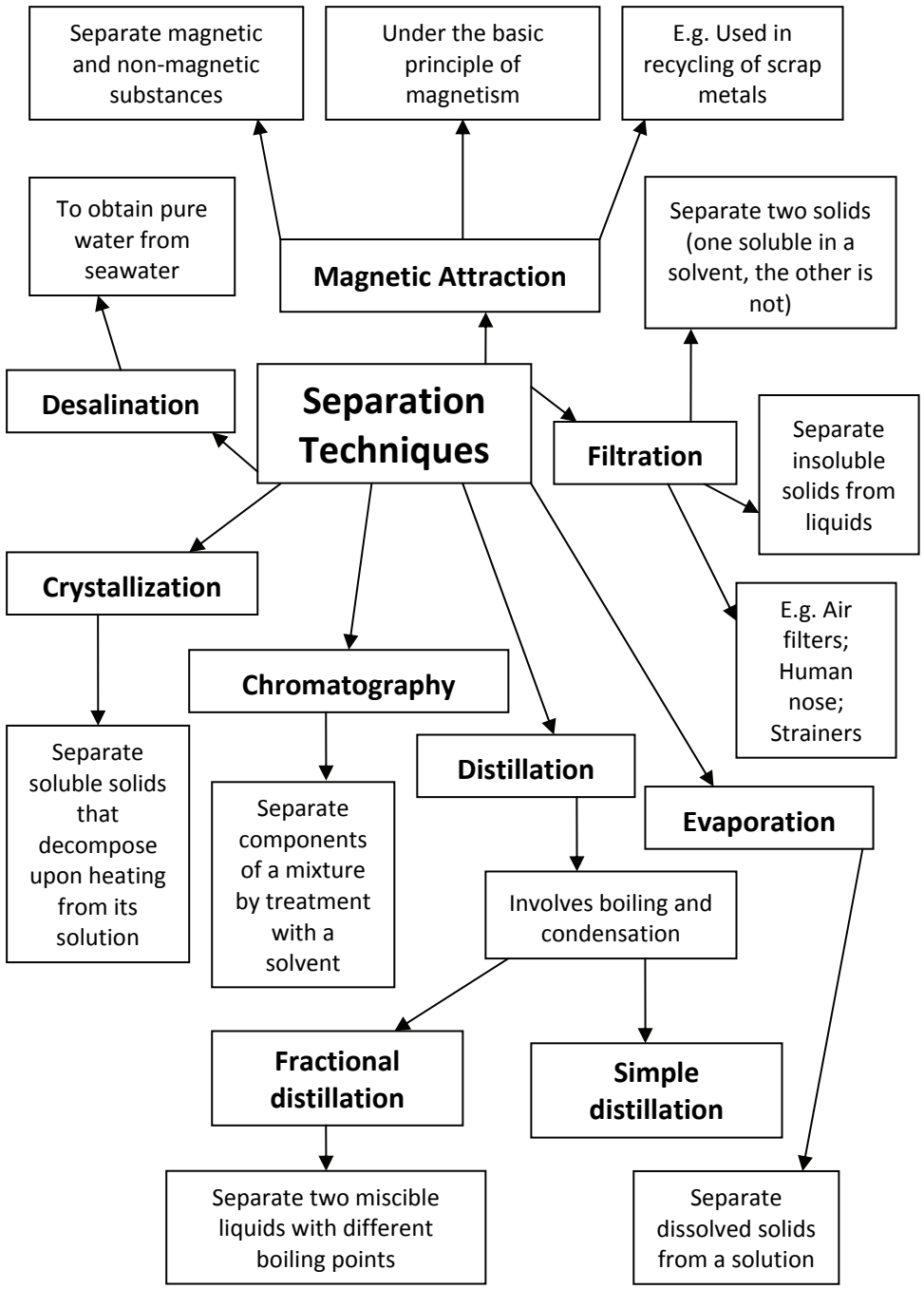
(a) Simple distillation.

Water changes into steam as it vapourises. It rises and enters the condenser, where the steam condenses and changes back into pure water.

(b) Fractional distillation.

Fractional distillation can be used to separate a mixture of two miscible liquids (petrol and kerosene), which are of different boiling points. The one with the lower boiling point; petrol, will be distilled over first.

6.10 Concept Map



6.11 Practice Questions

Multiple-Choice Questions

1. Which of the following methods is most suitable for separating a mixture of dissolved solid and water?

   (A) Filtration

   (B) Crystallisation

   (C) Sublimation

   (D) Simple Distillation

   ( )

2. To separate mud from muddy water we can use filtration. The mud collected in the filter paper is known as _____.

   (A) Filtrate

   (B) Residue

   (C) Crystals

   (D) Mixture

   ( )

3. Which of the following statement is **true**?

   (A) During distillation, water vapourises and changes into steam.

   (B) During distillation, in the condenser, water evaporates.

   (C) During distillation, hot water is used to run along the condenser.

   (D) During distillation, the thermometer is not necessary.

   ( )

4. A pupil accidentally poured a blue liquid into a beaker of water in the laboratory. The blue liquid is immiscible in water and is denser than water. What must he use to separate the 2 liquids?

   (A) Filter funnel

   (B) Displacement can

   (C) Separating funnel

   (D) Distilling flask

   ( )

Structured Questions

1. State <u>three</u> precautions that should be taken when carrying out distillation.

   _____

   _____

2. What is the limitation of separating mixtures of liquids with different boiling points by simple distillation?

   _____

   _____

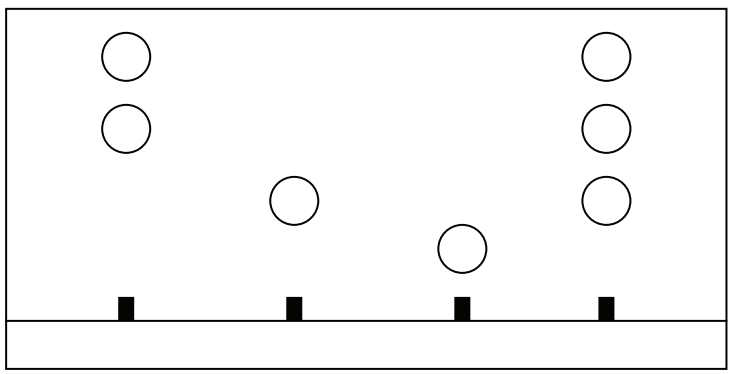
3. How can paper chromatography be used to analyse a sample, such as food?

   _____

   _____

   _____

4. The figure below shows the chromatogram produced by three dyes and a food colouring. What colour would you expect the food colouring to be?



Answers

Multiple-Choice Questions

1. Answer: (D)

   Explanation: Simple distillation can be used to separate dissolved solid and water.

2. Answer: (B)

   Explanation: Residue is the solid left behind on the filter paper.

3. Answer: (A)

   Explanation: In the distillation flask, the solution boils. Water vapourises and changes into steam, which rises and enters the condenser. In the condenser, steam condenses and changes back into the pure water.

4. Answer: (C)

   Explanation: Filter funnel is used to separate solids and liquids. Displacement can is used for displacing water. Distilling flask is used to separate miscible liquids with different boiling points.

Structured Questions

1. The thermometer should be placed at the side arm of the flask, and should not dip into the solution as it measures the boiling point of the solvent that is being distilled over.

   The condenser slopes downwards so that the pure solvent formed can run into the receiver.

   If the distillate is volatile, the receiver can be put in a large container filled with ice as this helps to keep the temperature of the distillate low; allowing it to remain at liquid state.

2. It is difficult to separate mixtures of liquids whose boiling points differ by less than 20°C. This problem can be overcome by using fractional distillation as the separation technique.

3. Paper chromatography can be used to separate dyes in food. Each dye can be identified by comparing its position in the chromatogram with that of the known dye. Chemists can then check whether or not these dyes are permitted for use in food.

4. Green colour, as it contains both blue and yellow dyes.

Notes: