

4

Exploring Diversity of Matter using Separation Techniques

Many substances around us are mixed together with other substances. In order to obtain substances that are useful, we will need to use suitable separation techniques based on our understanding of both chemical and physical properties of the substances present in these mixtures.



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The separation of mixtures can be carried out via physical methods such as:

- magnetic attraction (4.1)
- filtration (4.2)
- evaporation (4.3)
- distillation (4.4)
- reverse osmosis (4.5) Optional for N(A)
- paper chromatography (4.6)

The following are some key separation techniques.

4.1 Magnetic Attraction

In the recycling industries, magnets such as electromagnets are often used to separate magnetic metals such as iron from other non-magnetic metals and substances.

1. Magnetic attraction is a separation technique used to separate components of mixtures by using magnets to attract magnetic materials. This technique will detach non-magnetic materials from those which are magnetic.
2. This technique can be used only if one of the components is magnetic.
3. Metals like iron, nickel and cobalt are magnetic. However, there are metals such as aluminium, gold and silver which are non-magnetic. **Hence, magnets can be used to separate iron filings from a mixture of gold powder and iron filings.**

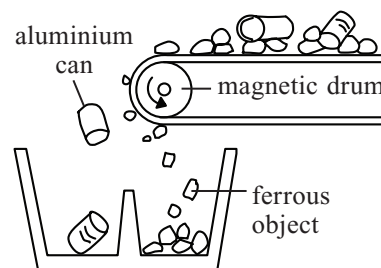


Fig 4.1 Magnetic separator

- A mixture of iron and sulfur can be separated using a magnet. The magnet will attract the iron filings which are magnetic and leave the sulfur powder behind.

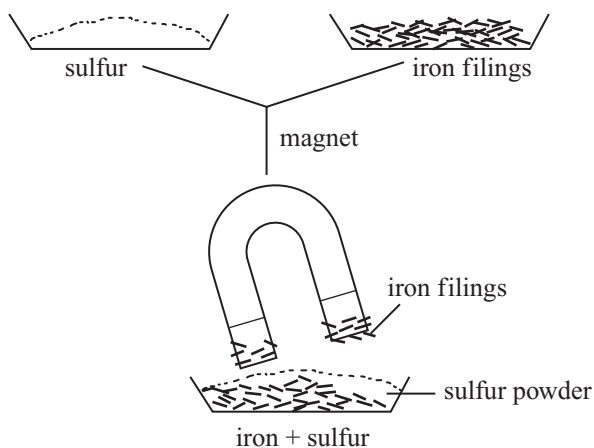


Fig 4.2 Separating iron filings and sulfur powder

4.2 Filtration

In water treatment plants all over the world, sand filters are often deployed in the water purification process. There are three main filters which are used in the water industry namely rapid sand filters, upward flow sand filters and slow sand filters. These filters ensure that large solid particles can be removed from the impure water before further steps are taken to purify the water.

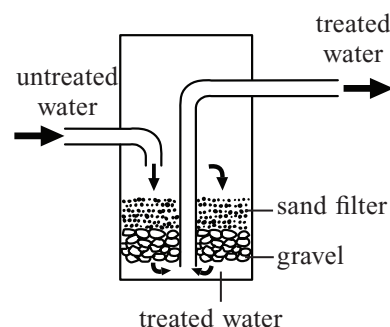


Fig 4.3 Rapid sand filter

- Filtration is a separation technique used to separate an insoluble solid from a suspension.

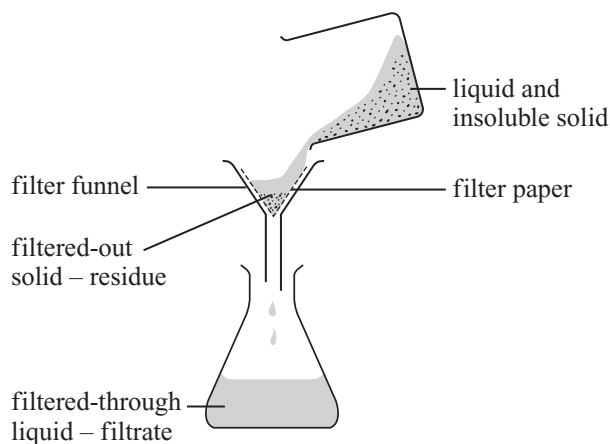


Fig 4.4 Filtration technique

Note

- Take note of the terms residue and filtrate.
- To 'filter out' means to remove from a liquid or gas.
- To 'filter through' means to pass through a filter. The filter paper is one example of a filter.

- The pores in the filter paper will only permit the smaller liquid molecules to pass through but not the larger solid particles. As a result, the solid particles in the suspension are trapped by the filter paper as **residue**. The liquid is able to pass through the filter paper and is collected as **filtrate**.

SCIENCE AROUND US

In a laboratory, a technician accidentally toppled a bottle of iron filings into a bag of sodium carbonate. Describe two ways of separating the mixture of iron filings and sodium carbonate given that sodium carbonate is soluble in water while iron filings are not.

ANSWER

Method 1: Use a magnet to attract the iron filings, leaving behind the sodium carbonate.

Method 2: Stir the mixture in a beaker of water to dissolve the sodium carbonate. Filter the suspension to obtain the iron filings as the residue on the filter paper. The sodium carbonate solution is collected as the filtrate.

4.3 Evaporation

In the food and fermentation industries, evaporation is often done to concentrate so as to recover targeted products. In most laboratories, evaporation is used to obtain saturated solutions. From these saturated solutions, crystallisation will then be carried out to obtain the salts present in the solutions.

- Evaporation, as a separation technique, is the heating of a solution to dryness in order to retrieve the solute.

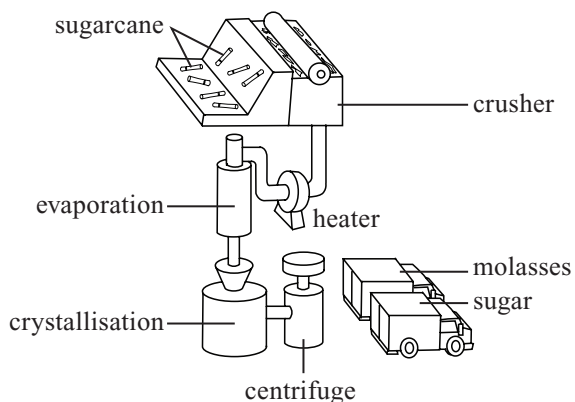


Fig 4.5 The process of obtaining molasses and sugar from sugarcane involves evaporation and crystallisation.

- When salt water in an evaporating basin is strongly heated, the water is boiled off and sodium chloride, a white solid, is left behind in the evaporating basin.

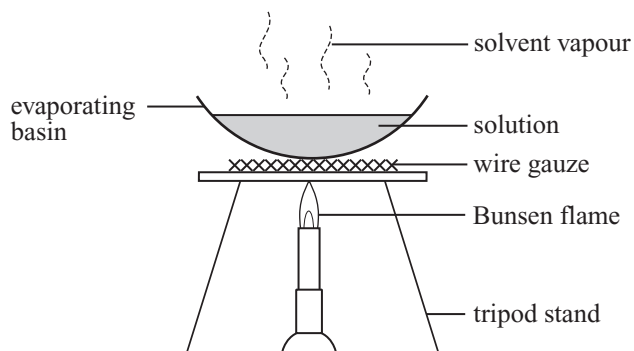


Fig 4.6 Evaporation to dryness by direct heating

- To use strong heating to evaporate a solution, the solute must be stable to heat. Generally, the solute should have a relatively high melting point (higher than the boiling point of water) and it should not decompose on strong heating.
- Sodium chloride (table salt) can be obtained from its solution by the above evaporation set-up because it is able to withstand the strong heating.
- Sugar will decompose to carbon and water vapour if it is strongly heated. The thermal decomposition of sugar is also known as caramelisation. To avoid strong heating which would decompose the solid sugar, we use steam to provide gentler heating to evaporate the sugar solution.

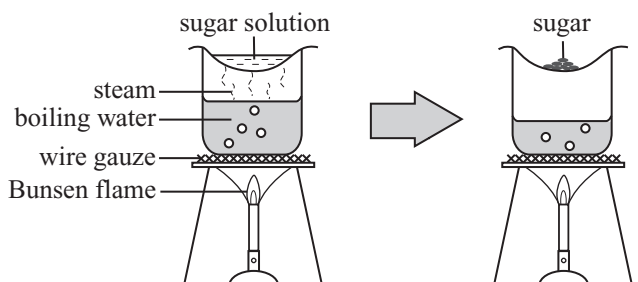


Fig 4.7 Evaporation to dryness by steam

- Hydrated copper(II) sulfate is blue in colour. Upon strong heating, it would lose water and turn into white anhydrous copper(II) sulfate. To obtain blue copper(II) sulfate from its solution, steam should be used to gently evaporate the copper(II) sulfate solution to form a saturated solution. Crystallisation is then used to obtain the hydrated copper(II) sulfate.

4.4 Distillation

Steam distillation is often used to extract aromatic compounds (essential oils) from a plant. During the steam distillation process, the heated steam will pass through the plant material and cause the essential oils to be released. When the vapour mixture flows through a condenser and cools, it will yield a layer of oil on top of a layer of water. The essential oil can then be separated from the water and collected.

- Distillation**, as a separating technique, can be used on a mixture containing two or more liquids with different boiling points.
- Two processes are involved in distillation: evaporation or boiling and condensation.
- Heat is supplied to evaporate or boil the mixture. The liquid with the lower/lowest boiling point will be vaporised first and the hot vapour of this liquid will travel into the condenser.
- The thermometer will indicate the temperature (boiling point) of this liquid as the hot vapour travels into the condenser. A further rise in the temperature will indicate that all of the liquid has been distilled from the solution.
- The **condenser** provides a cool surface for the hot vapour to condense to form the pure liquid.
- The liquid that is collected from the condenser is the **distillate**.

Extra

Copper(II) sulfate can be used to test for the presence of water. Anhydrous copper(II) sulfate will turn from white to blue (hydrated copper(II) sulfate) when it comes in contact with moisture.

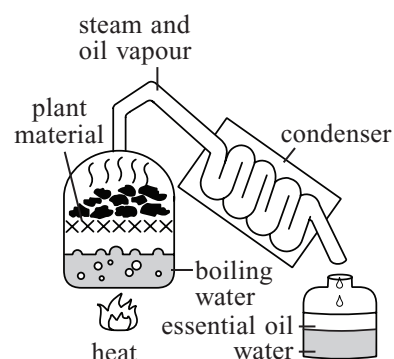


Fig 4.8 Steam distillation to obtain essential oils from plant material

7. Distillation can be used to obtain pure water from sea water or muddy water. The following set-up shows how pure water (distillate) can be obtained from sea water through distillation.

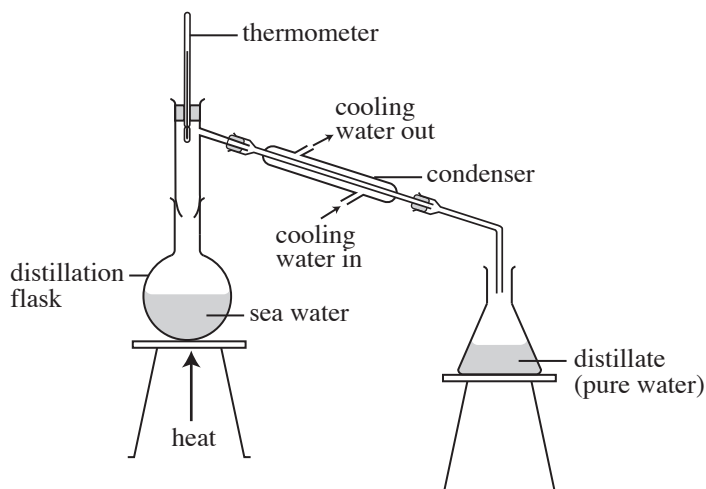


Fig 4.9 Simple distillation technique

Note

The bulb of the thermometer should be at the entry of the condenser so as to record accurately the temperature of the vapour entering the condenser.

SCIENCE AROUND US

A boat transporting salt sunk off the coast of an island. The salt was mixed with the sea water and sand to form a suspension. Describe how you would obtain sand, water and salt (sodium chloride) from this suspension.

ANSWER

Filter the suspension to obtain the sand as the residue. The filtrate is sodium chloride solution. Distillation is performed on the sodium chloride solution to obtain the water as the distillate. The sodium chloride is left behind in the boiling flask.

4.5 Reverse Osmosis

Optional for N(A)

Desalination is the removal of salt and impurities from seawater to produce fresh water. Many countries use reverse osmosis for the desalination process so as to make seawater drinkable. However, desalination is an energy-intensive process. As a result, many countries are exploring ways to reduce the energy requirement for desalination so as to make the process more energy-efficient.

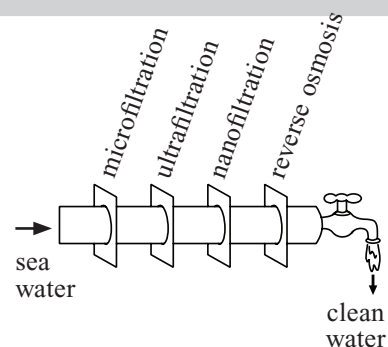


Fig 4.10 From microfiltration to reverse osmosis, the size of the pores decreases to remove smaller and smaller particles.

1. Reverse osmosis, as a separation technique, is a technology that forces pure water out of undrinkable water (e.g. sea water) through a partially permeable membrane.
2. High pressure is applied to the sea water against the partially permeable membrane.
Salt minerals, bacteria and viruses are unable to pass through the partially permeable membrane.

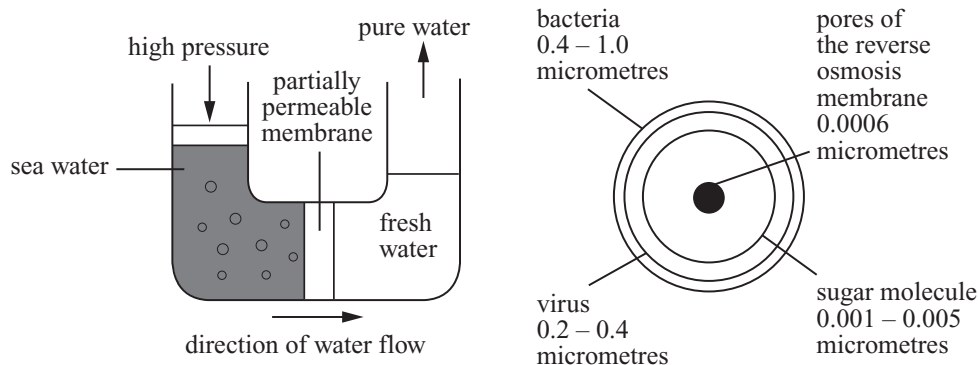


Fig 4.11 Reverse osmosis

3. Unlike distillation, no heating and therefore no fuel is needed in reverse osmosis.
4. Reverse osmosis can also be used to recycle water from sewage water.
5. In 2010, Singapore set up a reverse osmosis plant which can meet 30% of the country's water demand.

4.6 Paper Chromatography

Chromatography is often used in forensic science for the separation of compounds. At a crime scene, for example, chromatography can be used to determine if the deceased has alcohol or drugs or poisons within his/her body and the information can be used to determine the cause of death.

1. Paper chromatography, as a separation technique, involves the separation of a small amount of a mixture based on the different solubilities of the components in a solvent and the different affinities (attraction) of the components for the paper.

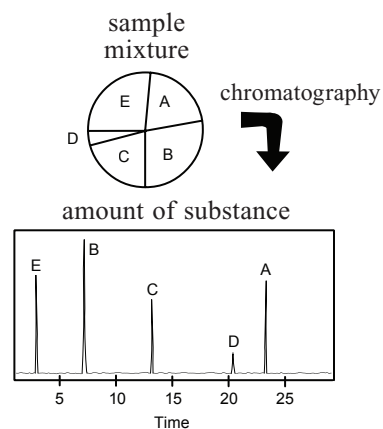


Fig 4.12 Chromatography

2. A suitable solvent (e.g. water, alcohol) must be chosen to dissolve all the components in the mixture (e.g. ink). The components should be known to be soluble in the solvent used.
3. Steps in setting up the paper chromatography:
 - Step 1: Prepare a strip of paper by cutting it out from the filter paper.
 - Step 2: Draw a pencil line a short distance from the edge of the strip to indicate the starting point of the mixture.
 - Step 3: Place a small and dense spot of the mixture on the pencil line. Air-dry the spot.
 - Step 4: Pour some solvent into a beaker. The height of the solvent in the beaker should be between the pencil line and the edge of the paper.
 - Step 5: Dip the end of the paper strip into the solvent. The spot of mixture should be above the solvent.
 - Step 6: Allow the solvent to move up the paper. Cover the set-up to slow down the evaporation of the solvent.

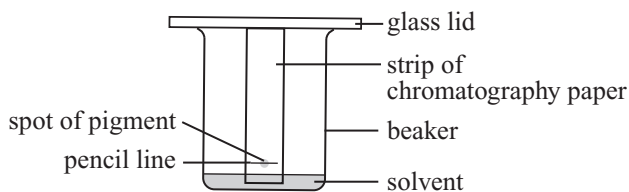


Fig 4.13 Paper chromatography technique

4. The paper absorbs the solvent. The solvent then dissolves the components present in the mixture (spot of pigment) and carries the components along as it moves up the paper.
5. The components that are more soluble in the solvent and have less affinity for the paper move over a greater distance on the paper.

6. The components that are less soluble in the solvent and have more affinity for the paper move over a shorter distance on the paper.

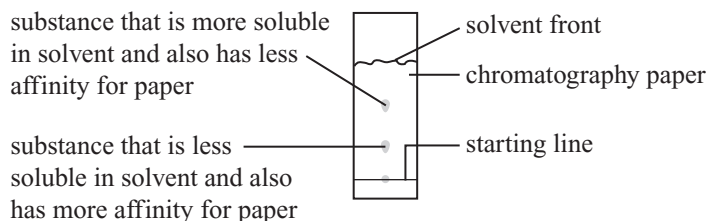
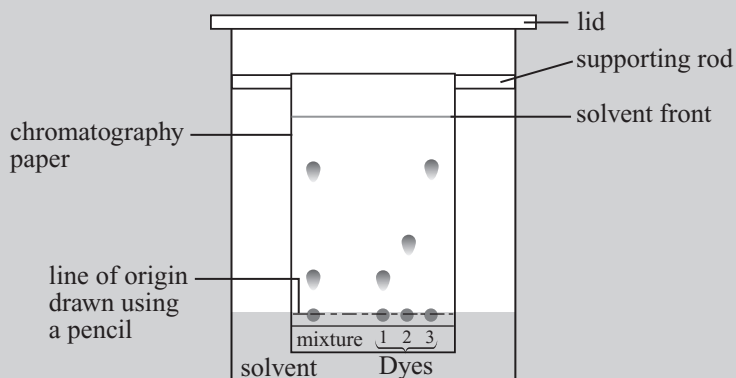


Fig 4.14 A paper chromatogram

SCIENCE AROUND US

In some countries, banknotes are usually printed with special dyes, Dye 1, Dye 2 and Dye 3 only. All three dyes must be present in order to pass the first test. Subsequent tests will then be conducted after a banknote clears the first test. Ink from a banknote which was suspected to be fake was dissolved and a paper chromatography test was carried out. The following chromatogram was obtained. Is this banknote real or fake?



ANSWER

The note is fake as dye 2 is missing from the mixture as shown in the chromatogram.