Chapter 4: Mixtures and Separation Techniques

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1 Mixtures

A mixture is composed of two or more types of matter that can be present in varying amounts and can be separated by physical changes. Mixtures can either be homogenous or heterogeneous in nature.

1.1 Homogenous Mixtures:

A homogenous mixture can be composed of two or more substances of a single phase, be it solids, liquids or gases. When salt is added to water it starts to dissolve, eventually all the salt crystals disappear into the clear liquid. This is an example of a homogeneous mixture as the salt is evenly distributed throughout the entire salt water solution.

All solutions are considered homogeneous mixtures since the dissolved substance is present in the same amount throughout the solution.

It is often easy to confuse a homogeneous mixture with a pure substance since they are both uniform in nature. The difference is that a pure substance has a constant composition while a mixture can vary in composition from one sample to another.

A **homogenous** mixture is made up of two or more substances from the same phase which are consistently composed throughout the mixture.

1.2 Heterogeneous Mixtures:

A heterogeneous mixture on the other hand, can be composed of multiple phases. Any part of a sample mixture which is of uniform composition can be described as a phase.

For example, when oil and water are combined, they form two separate layers even though they are both liquids belonging to the same phase of matter.Each of these layers is called a phase. This happens because oil has a much lower density than water and therefore rises up to the top of the mixture.

Immiscible liquids are ones which differ in density and as a result are not able to mix together to form a homogenous mixture.
Miscible Liquids are ones which can dissolve together to form a uniformly homogenous mixture, regardless of their concentration.

An example of a heterogeneous mixture made up entirely of solids is soil which is composed of a large variety of substances. Every sample of soil taken will have a different composition, the amount of rocks, dirt, grass etc. will vary in amount from one part of the soil mixture to another and can never be completely uniform.

2 Separation Techniques

As previously mentioned, mixtures can be separated using physical changes. the following are seven examples of different separation techniques.

2.1 Filtration

Filtration is the process of separating a heterogeneous *solid-liquid* mixture or *insoluble solid-soluble solid* mixture.

Apparatus: Filter paper, filter funnel, clamp and stand, beaker and stirrer.

Diagram:

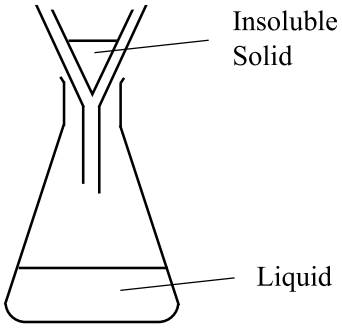

Figure 1: Apparatus diagram for filtration separation technique.

Procedure:

1. Distilled water was added to a mixture of salt and sand to dissolve the salt.
2. The contents of the beaker were stirred until the salt was completely dissolved.
3. The filter paper was folded first into two, then into four to make a cone.
4. the filter paper was placed in the filtration funnel which sat on an empty conical flask.
5. Distilled water was added to the filter paper so that it would stay in place.
6. The contents of the beaker were then poured into the filter funnel slowly as to not overflow the filter paper.
7. The beaker was washed with distilled water to flush any remaining residue. This was also passed through the filter paper.
8. The sand residue which remained on the filter paper was washed with distilled water.

Procedure steps should always be written in past tense

Conclusion: The soluble sodium chloride (salt) dissolved in the distilled water but the sand did not. A filter paper was used to separate the insoluble sand from the liquid.

The salt solution is called the **filtrate** while the sand left behind on the filter paper is called the **residue**.

In order to obtain the salt in it's original crystalline form, the following separating process can be applied.

2.2 Crystallization

Crystallization is the process separating a homogenous mixture composed of a *liquid solvent and a soluble (dissolved) solid* by evaporation.

Apparatus: Beaker, evaporating dish, Bunsen burner and tripod.

Diagram:

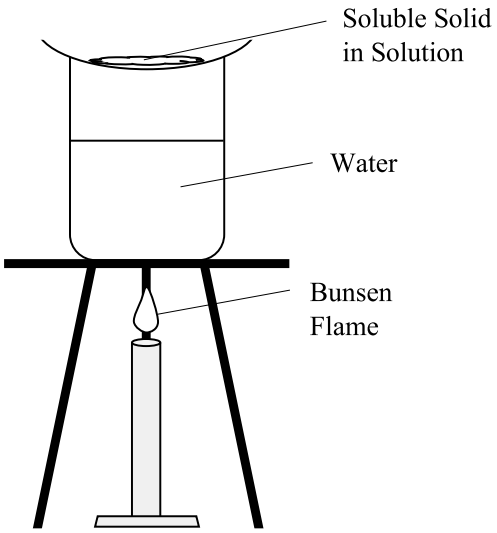

Figure 2: Apparatus diagram for crystallization separation technique.

Procedure:

1. A beaker was filled mid way with water and placed on a tripod.
2. An evaporating basin (or watch glass) was placed on top of the beaker and the crystalline solution was poured on into it.
3. The water in the beaker was heated up by the Bunsen flame until the solvent started to evaporate.

Observation: The liquid solution in the watch glass evaporated to dryness.

Conclusion: When the solvent evaporated completely, *Sodium Chloride*()salt) crystals were left behind n the evaporating basin. The crystals are irregular in shape and do not contain any water of crystallization i.e. they are **anhydrous** - *they contain no water*. This is called crystallization to dryness.

Therefore, the processes of crystallization or evaporation can both be used to recover a solute from a solution

A solute is a solid which dissolves into a liquid solvent.

In this example, the sample has been evaporated to the point of dryness and we said that the crystals are anhydrous. If this experiment were to be repeated in the same manner but the heating stopped at an earlier stage, specifically at the point of crystallization the crystals formed would be **hydrous** - *containing water*.

How do we find the point of crystallization?

This can be done by periodically inserting a cold glass rod in the mixture and removing it. The point at which the liquid on the glass rod does not remain a liquid, but turns into crystals is when you know that the point of crystallization has been reached. The heating can now be stopped and the warm solution can be left to cool down.

Even though the mixture is still in solution while it is hot, when it does cool down it will harden into crystals.

This point could also be tested by pouring a small amount of the solution into a test tube and cooling it under water.

The main differences between Anhydrous crystals and Hydrous crystals are highlighted below:

Property	**Anhydrous Crystals**	**Hydrous Crystals**
Contains Water	No	Yes, may have water of crystallization
Shape	Irregular	Regular crystalline structure
Colour	Typically White	May be coloured depending on the salt

2.3 Distillation

Distillation is the process of separating a homogenous mixture of *liquids* having *different boiling points*.

Apparatus: Round bottomed flask, condenser, thermometer, conical flask (receiver), tripod and Bunsen burner.

Diagram:

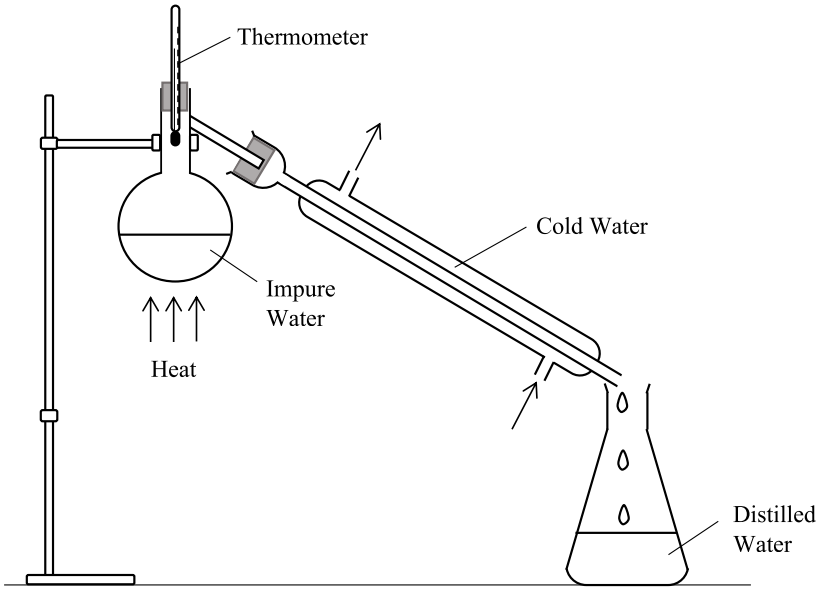

Figure 3: Apparatus diagram for distillation separation technique.

Procedure:

1. An impure water mixture was transferred to a round bottomed flask attached to a clamp and stand.
2. A thermometer was arranged at the neck of the flask close to the side arm connected to the condenser.

   The thermometer should not be immersed in, or the liquid mixture. The purpose of the thermometer is to measure the temperature of the vapour and not the liquid.

3. Heat was applied to the contents within the flask via the Bunsen flame so that the process can start.

Observation: The water started bubbling and as a result, vapour appeared at the neck of the flask and the thermometer read 100°C. The vapour passed through the condenser and eventually liquid drops were observed in the conical flask.

Conclusion: The vapour produced from the boiling of the impure water was water vapour since water has a boiling point of 100°C. the water vapour (steam) passed through the condenser where it cooled down and turned back into it's liquid form by the process of condensation. The pure water or distilled water was collected in a conical flask (preferred to a beaker as it prevents splashing) and the impure liquids remained in the round bottomed flask.

Note the water connections of the condenser. These should not be reversed so that there is always a cool supply of water surrounding the glass, allowing the vapour to condense into a liquid.

2.4 Fractional Distillation - Separation of Miscible Liquids

A homogenous mixture of two miscible liquids can be separated by the process of fractional distillation.

Apparatus: Bunsen burner, round bottomed flask, fractionating column, thermometer, clamp and stand, condenser and conical flask (receiver).

Diagram:

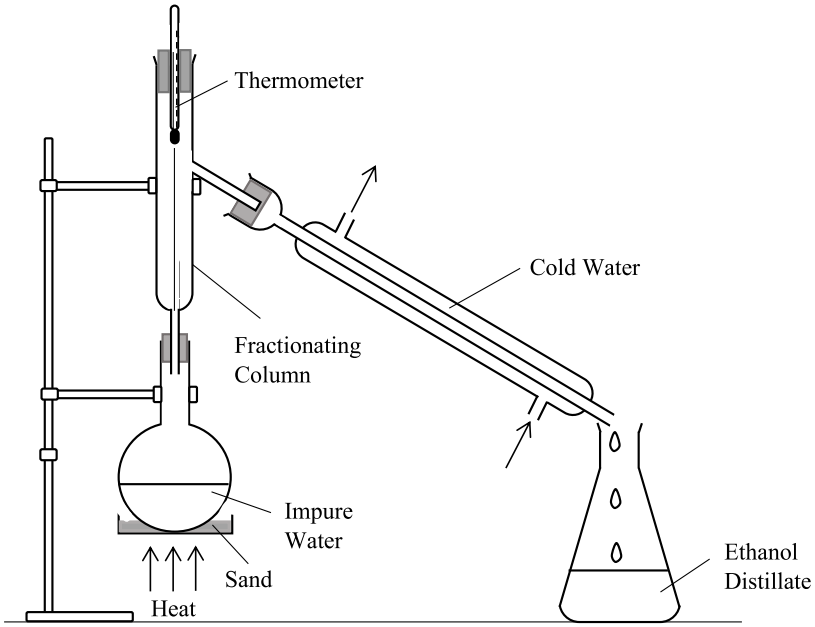

Figure 4: Apparatus diagram for the separation of Miscible liquids.

Procedure:

1. An ethanol and water mixture was transferred to a round bottomed flask attached to a clamp and stand.
2. A thermometer was arranged at the neck of the flask close to the side arm connected to the condenser.
3. Heat was applied to the contents within the flask via the Bunsen flame so that the process can start.

Conclusion and Explanation: As the heat increases gradually, the vapour of the liquid with the lowest boiling point (Ethanol: 78°C) starts to travel up the fractionating column first. As it does, the temperature of the vapour starts to decrease and the gaseous ethanol turns back into liquid and falls into the round bottomed flask.

Eventually both the temperature of the column and the flask rise and the ethanol vapour is not cooled back down into its liquid form but travels to the condenser where it is cooled down into liquid ethanol and collected in the conical flask.

Care is taken not to allow the top of the column to exceed the 78 °C temperature by monitoring the thermometer.

If the top of the fractionating column was to reach a temperature of 100°C, the water would reach it's boiling point, turn into vapour and start to mix back into the ethanol. When all the ethanol is collected in the receiver, the water can be allowed to boil and be collected into a separate receiver.

A sand bath is placed between the heating source and the bottom flask since this is a long process and the glass can crack with long-term heating.

2.5 Separation of Immiscible Liquids

This process can be used to separate two immiscible liquids from a heterogeneous mixture containing multiple phases.

Apparatus: Separating funnel, conical flask (receiver), clamp and stand.

Diagram:

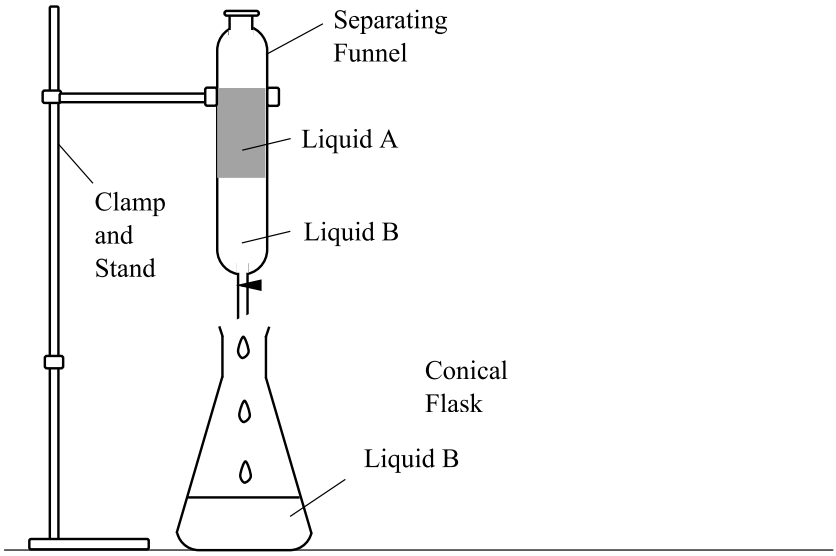

Figure 5: Apparatus diagram for the separation of two immiscible liquids.

Procedure:

1. A Toluene and water mixture was poured into the separating funnel held by a clamp and stand and left to settle into two distinct layers.

2. Once the water was completely displaced beneath the Toluene layer, the tap of the separating funnel was opened slowly until the water started to drain out into the conical flask.
3. The tap was closed when nearly all the water was drained.
4. Another container was placed under the nozzle and the last bit of water and first bit of toluene were collected and discarded accordingly.
5. Another conical flask was placed under the nozzle and the rest of the Toluene was collected.

Conclusion: The two immiscible liquids which separate due to their different densities, were separated using a separating funnel.

2.6 Sublimation

Sublimation is the process of separating a heterogeneous mixture of two solids, *when one of them sublimes*(sublimate). For the purpose of this example, sodium chloride (solid) and ammonium chloride (sublimate solid).

Apparatus: Beaker, filter funnel, tripod and Bunsen burner.

Diagram:

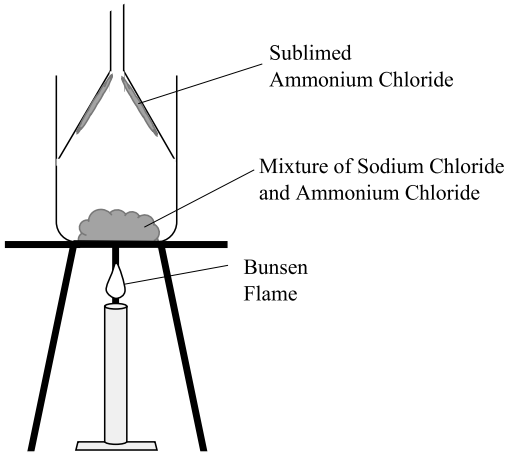

Figure 6: Apparatus diagram the process of separation through sublimation.

Procedure:

1. A mixture of sodium chloride and ammonium chloride was transferred to a beaker.
2. Heat was applied to the beaker via a Bunsen flame.
3. The sodium chloride remains unchanged by the heat and stays in the flask while the ammonium chloride sublimes directly from solid to gas.
4. The gas moves up into the inverted funnel and turns back into a solid as it meets the cool surface.
5. The heating was stopped when no more sodium chloride gas was visible.
6. A scraper was used to collect the ammonium chloride from the inner side of the filter funnel and transferred to a separate beaker.

The following are solids which sublime: all ammonium salts, iron (III) chloride and aluminium chloride, iodine and carbon dioxide.

Conclusion: Sublimation could be used as a separation process by applying heat to the mixture of solids. *This is only applicable if only one of the solids is a sublimate.*

2.7 Chromatography

Chromatography is the process of separating a mixture of pigments by using an appropriate solvent.

Apparatus: chromatography or filter paper, beaker, solvent and pigment.

Diagram:

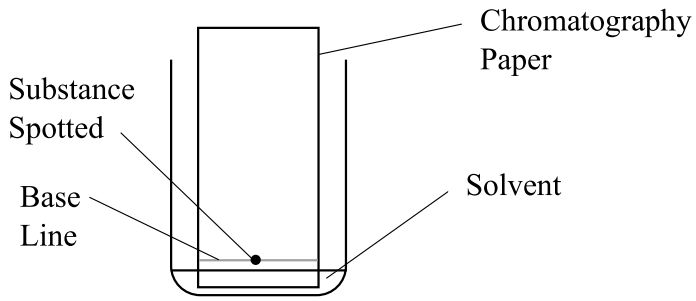

Figure 7: Apparatus diagram the process of separation through sublimation.

Procedure:

1. A line was marked 1cm from the end of a piece of chromatography paper in pencil.

   > Pencil has to be used instead of ink to draw the line so that is would not separate when placed into the solvent.

2. Two separate dots were marked onto the pencilled line equidistantly using different types of pigment (marker).
3. When the spots dried, a second application of ink was added to the previous ones.
4. This was repeated 5 more times or until the spots look concentrated.
5. A suitable solvent (ethanol) was poured into the beaker and left to settle.
6. The chromatography paper was gently placed into solvent.

   > The solvent cannot exceed the pencilled line.

7. The jar was allowed to stand until the solvent had almost risen to the top of the paper.
8. At this point, the paper was removed from the jar and was allowed to dry before it was examined and measured.

Conclusion: the original colour of the spot was separated into multiple different colours which when added together would make the original colour. *this is called chromatography.* Due to their the colours different solubilities in the common solvent, the different components present in the ink were separated by chromatography.