Pure substances,mixtures and separations

Pure substances, mixtures and separations

Matter can be classified into **pure substances** and **mixtures**

Classification of Matter

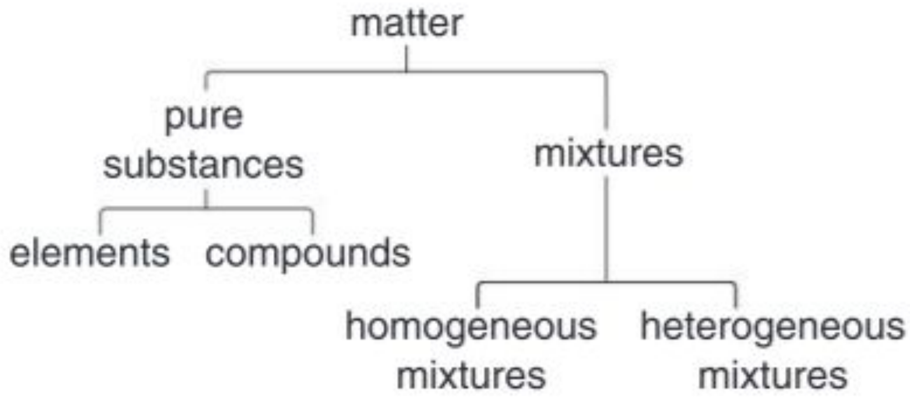

Figure 2.1.1 Classification of matter

Pure Substances

A pure substance is composed of a single type of material only.

Any pure substance possesses certain general characteristics:

- Its **composition** is fixed and constant
- Its **properties** are fixed and constant, for example, its melting point, boiling point and density.

Pure Substances

- The **component parts** cannot be separated by any physical process.

To find out if a substance is **pure**, its melting point or boiling point can be measured. If any impurities are present they will usually **lower** its melting point and **raise** its boiling point.

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Elements

Elements are the simplest form of matter.

An **element** is a pure substance that cannot be broken down into simpler substances by using any ordinary physical or chemical process.

Elements

An **atom** is the smallest particle in any element. Each element is composed of atoms of **one kind** only. Most elements are made up of **individual atoms**, e.g. silver (Ag) is made up of individual silver atoms. A few elements are made up of molecules, e.g. nitrogen (N_2) is made up of nitrogen **molecules**, each molecule being composed of two nitrogen atoms.

Elements

There are at least 118 known elements and they can be classified as

metals , **metalloids** or **non-metals**.

Compounds

A **compound** is a pure substance that is formed from two or more different types of elements which are chemically bonded together in fixed proportions and in a way that their properties have changed.

Compounds

The proportions, by mass, of sodium and chlorine in any pure sample of sodium chloride are always the same and the elements cannot be separated by physical means because they are **chemically bonded together**. The properties of sodium chloride are different from those of both sodium and chlorine.

Compounds

Compounds can be represented by **chemical formulae**, e.g. the chemical formula for sodium chloride is NaCl and for water it is H_2O.

Mixtures

A **mixture** consists of two or more substances (elements and/or compounds) which are physically combined together in variable proportions. Each component retains its own individual properties and is not chemically bonded to any other component of the mixture.

Mixtures

Any mixture possesses certain general characteristics:

- Its **composition** can vary.
- Its **properties** are variable because its component parts keep their individual properties.
- Its **component parts** can be separated by physical means

Mixtures

Mixtures can be classified into **homogeneous** and **heterogeneous.**

Mixtures

A **homogeneous mixture** is a **uniform** mixture; it has the same composition and properties throughout the mixture. It is not possible to distinguish the component parts from each other. All **solutions** are homogeneous mixtures.

Mixtures

A **heterogeneous mixture** is a **non-uniform** mixture; it is possible to distinguish the component parts from each other, though not always with the naked eye. Heterogeneous mixtures include **suspensions** and **colloids**.

Solution

A **solution** is a homogeneous mixture of two or more substances; one substance is usually a liquid.

Solution

A solution is composed of:

- The solvent, which is the substance that does the dissolving. The solvent is present in the higher concentration.

Solution

A solution is composed of:

- The solute, which is the substance that dissolves. The solute is present in the lower concentration. A solution may contain more than one solute.

Solution

Solutions in which the solvent is water are known as

aqueous solutions.

Solution

A **saturated solution** is a solution in which the solvent cannot dissolve any more solute at a particular temperature, in the presence of undissolved solute.

Solution

State of solute	State of solvent	Example	Components
Solid	Liquid	Sea water	Sodium chloride dissolved in water
Liquid	Liquid	White vinegar	Ethanoic acid dissolved in water
Gas	Liquid	Soda water	Carbon dioxide dissolved in water
Solid	Solid	Bronze(metal alloy)	Tin dissolved in copper
Gas	Gas	Air	Oxygen, carbon dioxide,noble gases and water vapour dissolved in nitrogen

Suspensions

A **suspension** is a heterogeneous mixture in which minute, visible particles of one substance are dispersed in another substance, which is usually a liquid.

Suspensions

Examples:

- **Mud** in **water** and **powdered chalk** in **water**. These are suspensions of solid particles in a liquid.
- **Oil shaken** in **water**. This is a suspension of liquid droplets in a liquid.
- **Dust** in the **air**. This is a suspension of solid particles in a gas.

Colloids

A **colloid** is a heterogeneous mixture in which minute particles of one substance are dispersed in another substance, which is usually a liquid. The dispersed particles are larger than those of a solution, but smaller than those of a suspension.

Colloids are **intermediate** between a solution and a suspension.

Colloids

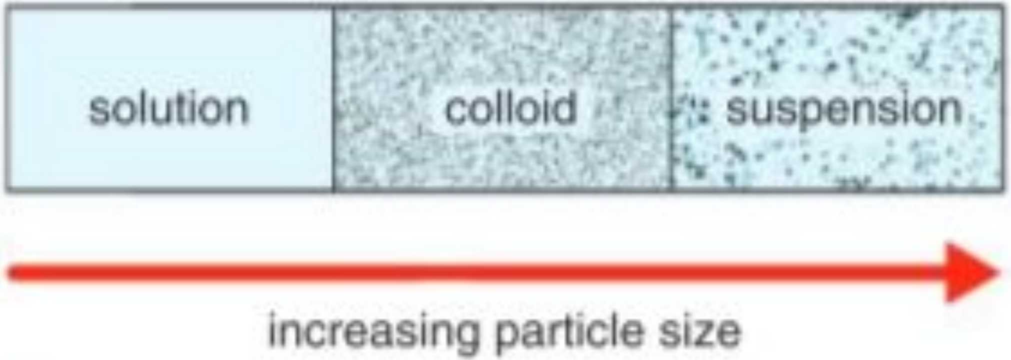
Type of Colloid	Composition	Examples
Gel	Solid particles dispersed in a liquid	Gelatin, jelly
Emulsion	Liquid droplets dispersed in a liquid	Mayonnaise,milk, hand cream
Foam	Gas bubbles dispersed in a liquid	Whipped cream, shaving cream
Solid aerosol	Solid particles dispersed in a gas	Smoke
Liquid aerosol	Liquid droplets dispersed in a gas	Fog, aerosol sprays, cloud

Types of Colloids

Comparing the properties of solutions, colloids and suspensions

Property	Solution	Colloid	Suspension
Particle size	very small (less than one nanometre in diameter)	greater than that of a solution but they are not visible to the naked eye (between 1 and 1000 nanometres in diameter)	large enough so that they are visible to the naked eye (greater than 1000 nanometres in diameter)
Type of mixture	homogeneous	heterogeneous	heterogeneous
Appearance	generally transparent	usually opaque, some are translucent	opaque
Can the components be separated by filtration?	no	no	yes
Do the components separate out after the mixture has been standing for a while?	no	no	yes
Transmission of light	transmits light appearing transparent	will scatter light	does not transmit light; it is opaque

Particles size of solutions, colloids and suspensions



▲ **Figure 2.2.4** A comparison of the size of particles in solutions, colloids and suspensions

Solubility

Solubility is the mass of solute that will saturate 100g of solvent at a specific temperature.

In general, the solubility of a **solid** solute in water **increases** as the temperature increases.

Solubility

The solubility of a solute is an indication of how much of the solute can dissolve in a fixed mass of solvent at a particular temperature. For example, we can find the solubility of sodium chloride in water by determining how much sodium chloride can dissolve in 10 cm^3 of water at a particular temperature. When no more solute can be dissolved in the solvent, the solution reaches saturation point and we say the solution is **saturated**.

Solubility Curve

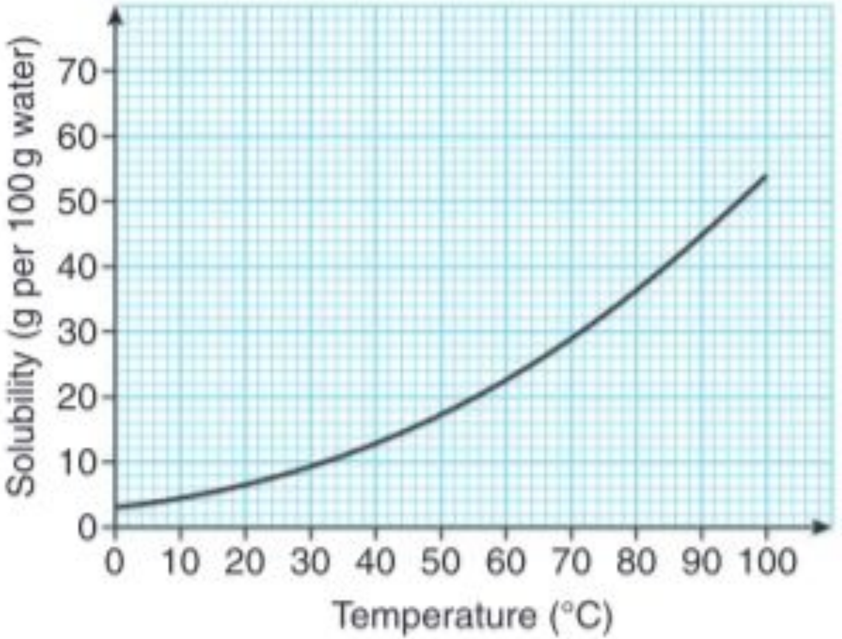


Figure 2.3.1 Graph showing the solubility of potassium chlorate(v) against temperature

Solubility: Calculations

Solubility curves are useful to obtain different pieces of information, as shown in the following examples.

Example:

- What is the solubility of potassium chlorate(V) at 78 °C?
- At what temperature would crystals just begin to form if an unsaturated solution of potassium chlorate(V) containing 20g of potassium chlorate(V) dissolved in 100 g of water is cooled from 80 °C?

Solubility: Calculations

Example:

- What mass of potassium chlorate(V) would crystallise out of a saturated solution containing 100 g of water when the temperature of the solution is decreased from 64 °C to 22 °C?

Solubility Curve

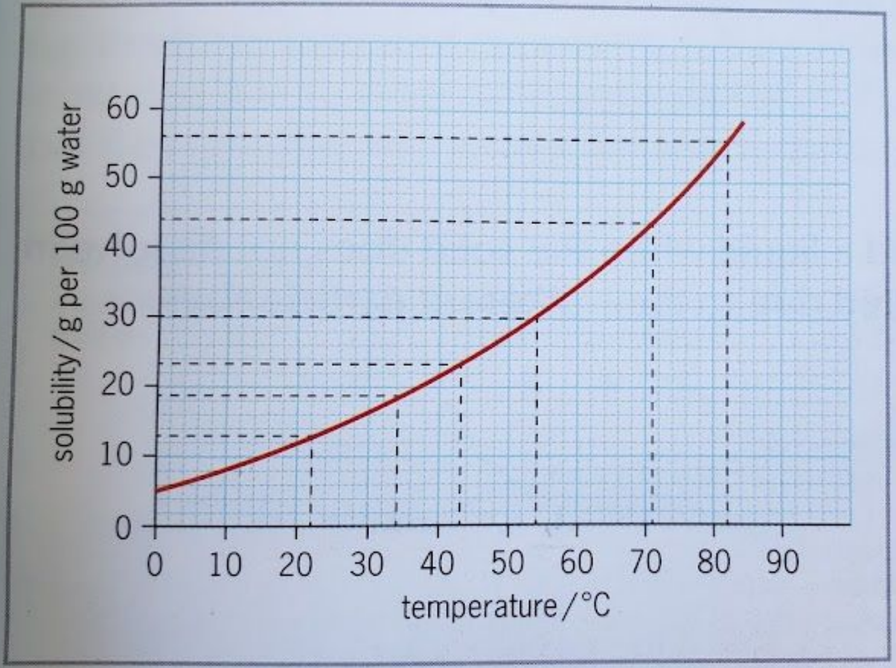


Figure 2.3 *Solubility curve for copper(II) sulfate ($CuSO_4$) in water*

Solubility: Calculations

Example:

- What is the solubility of copper(II) sulfate at 43° C?
- A copper(II) sulfate solution containing 100 g water is saturated at 34 °C. What mass of copper(II) sulfate must be added to re-saturate this solution if it is heated to 71 °C?

Solubility: Calculations

Example:

- A copper(II) sulfate solution which contains 300 g of water is saturated at 54 °C. What mass of copper(II) sulfate would crystallise out of this solution if it is cooled to 22 °C?

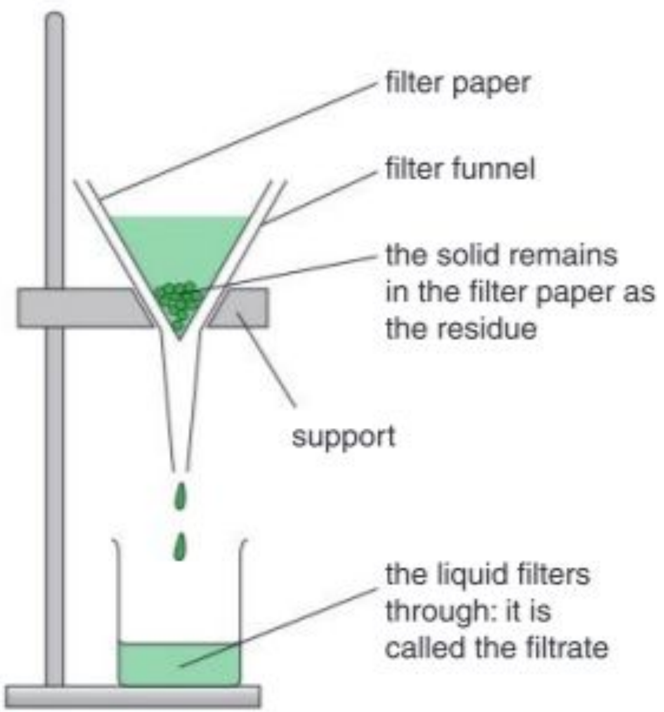
Separating Mixtures

The technique used to separate the components of a mixture depends on the physical properties of the components.

Separating Mixtures

Filtration is used to separate a suspended or settled solid and a liquid when the solid does not dissolve in the liquid, e.g. soil and water. The components are separated due to their different particle sizes.

Filtration



▲ **Figure 2.4.1** Filtration apparatus

Separating Mixtures

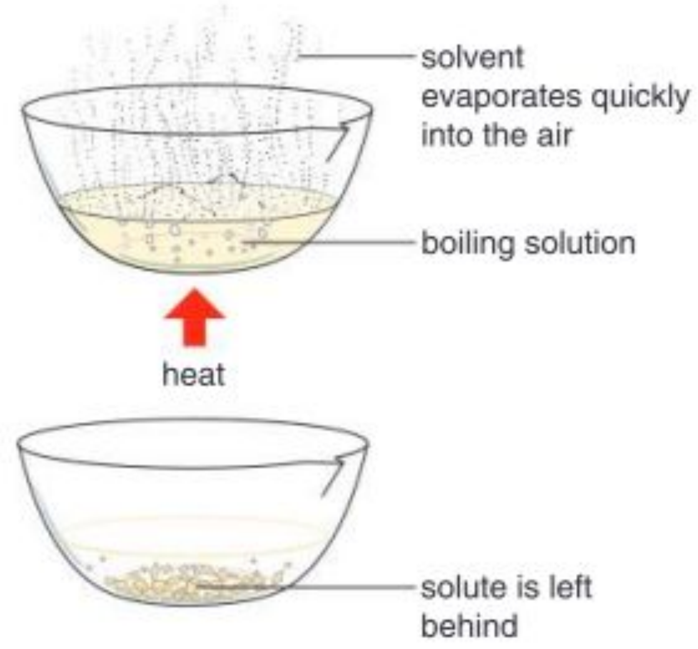
Evaporation is used to separate and retain the solid solute from the liquid solvent in a solution. It is used if the solute does not decompose on heating or if a solid without water of crystallisation is required, e.g. to obtain sodium chloride from sodium chloride solution.

Separating Mixtures

The components are separated due to their different **boiling points**.

The boiling point of the solvent must be **lower** than that of the solute so that it is converted to a gas and leaves the **solute** behind.

Evaporation



▲ **Figure 2.4.2** Evaporation

Separating Mixtures

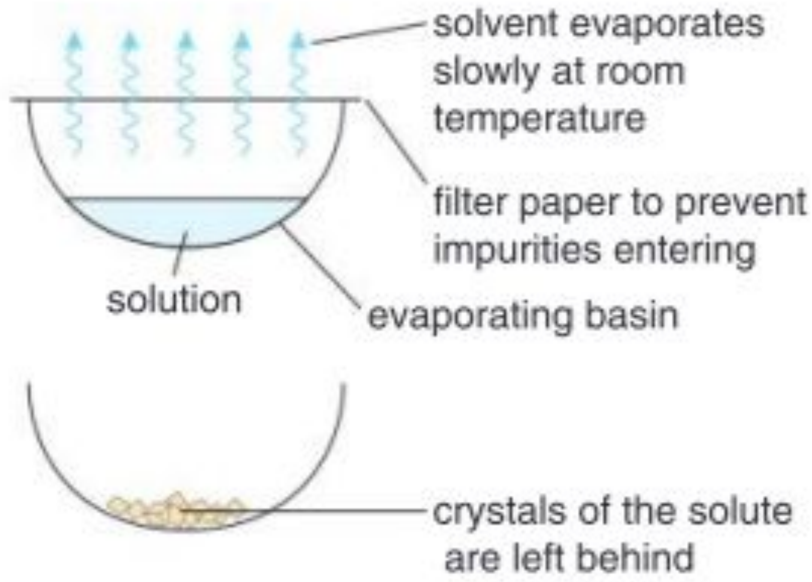
Crystallisation is used to separate and retain the solid solute from the liquid solvent in a solution. It is used if the solute decomposes on heating or if a solid containing water of crystallisation is required, e.g. to obtain hydrated copper(II) sulfate from copper(II) sulfate solution.

Separating Mixtures

The components are separated due to their different **volatilities**. The solvent must be more volatile than the solute so that it evaporates and leaves the solute behind.

Volatility- how easily a substance evaporates

Crystallisation



▲ **Figure 2.4.3** Crystallisation

Separating Mixtures

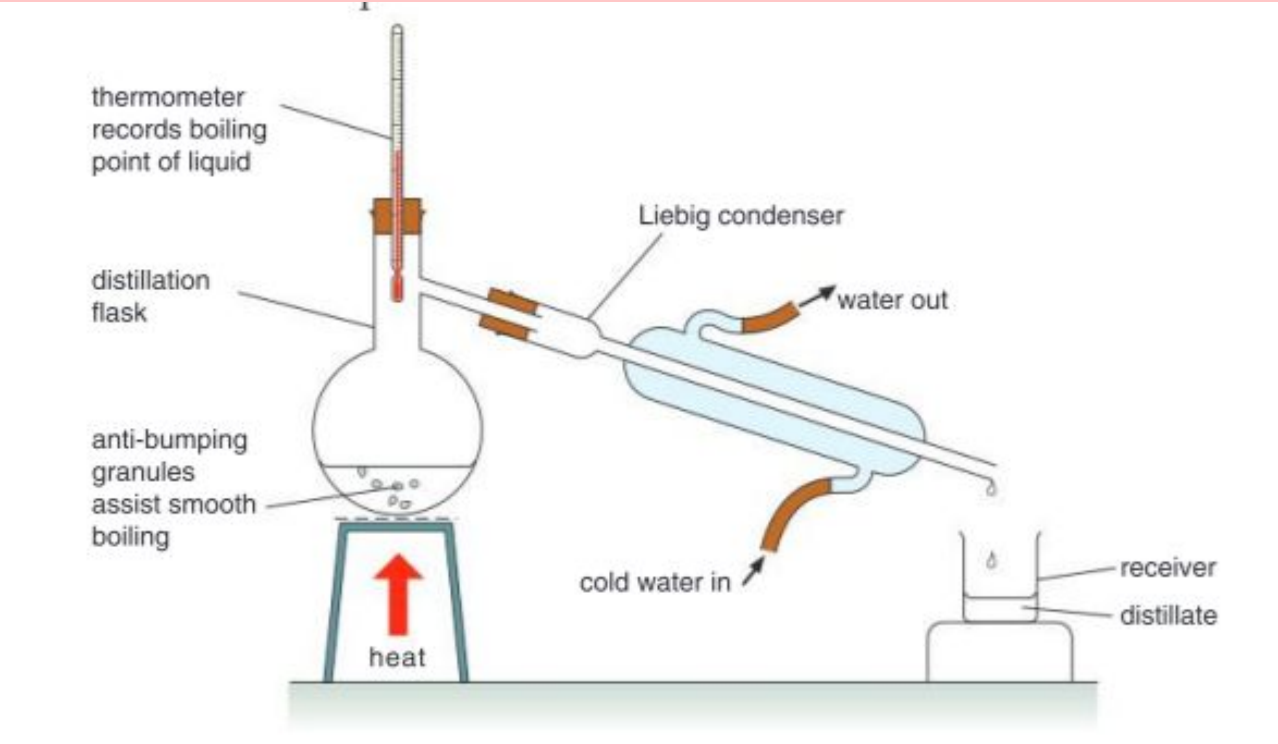
Simple distillation is used to separate and retain the **liquid solvent** from the solid solute in a **solution**, e.g. to obtain distilled water from tap water or sea water. The solute can also be obtained by **evaporation** or **crystallisation** of the concentrated solution remaining after distillation if no impurities are present.

Separating Mixtures

The components are separated due to their different **boiling points**.

The boiling point of the solvent must be **lower** than that of the solute.

Simple distillation

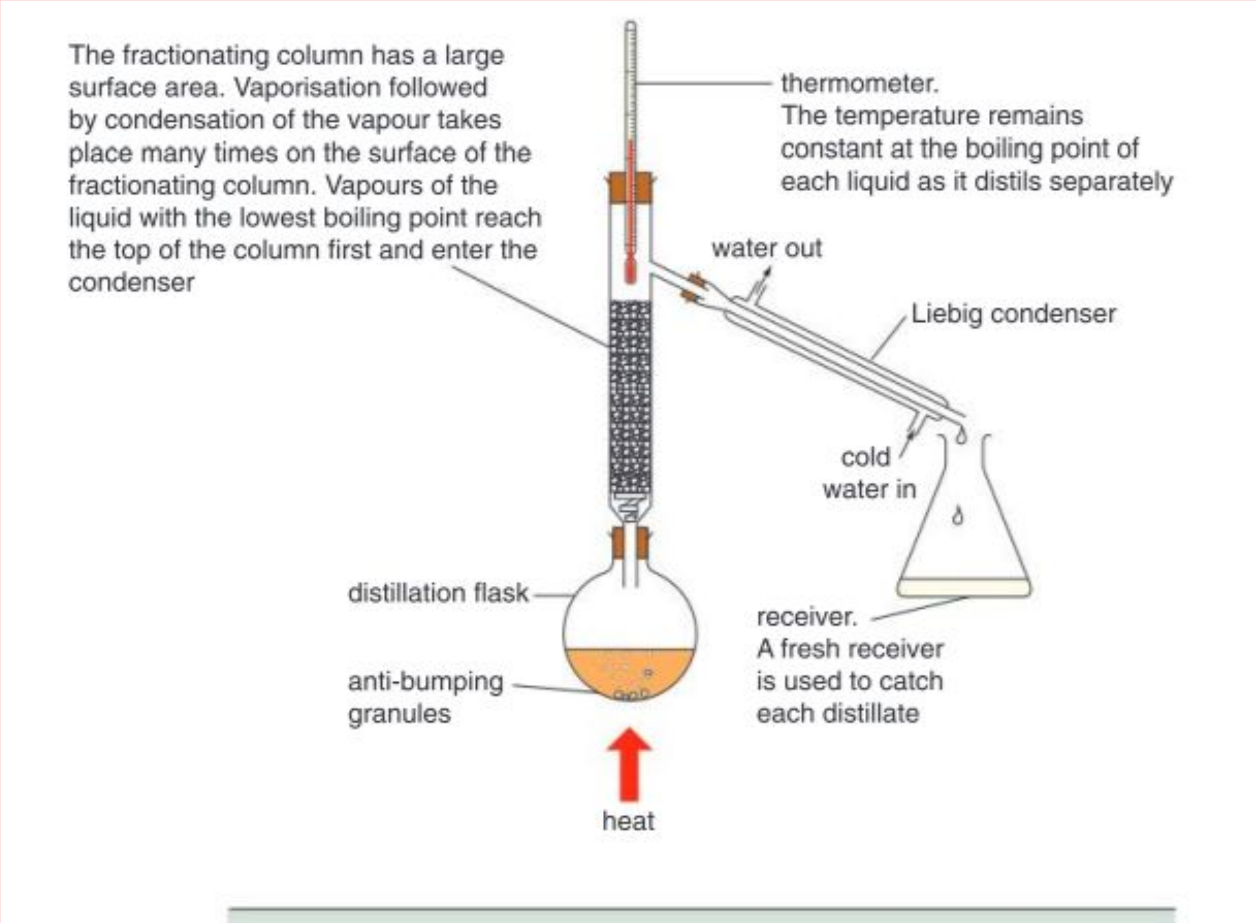


Separating Mixtures

Fractional distillation is used to separate two (or more) **miscible liquids** with boiling points that are close together, e.g. ethanol, boiling point 78 °C, and water, boiling point 100 °C. Miscible liquids mix completely and are separated due to their different **boiling points**.

Miscible liquids- a homogenous mixture of liquids

Fractional distillation



Separating Mixtures

As the mixture boils, vapours of both liquids rise up the fractionating column where they condense and evaporate repeatedly and the vapour mixture becomes progressively richer in the more volatile component (the one with the lower boiling point). The vapour reaching the top of the column and entering the condenser is composed almost entirely of the **more volatile** component and the temperature remains constant at the boiling point of this component.

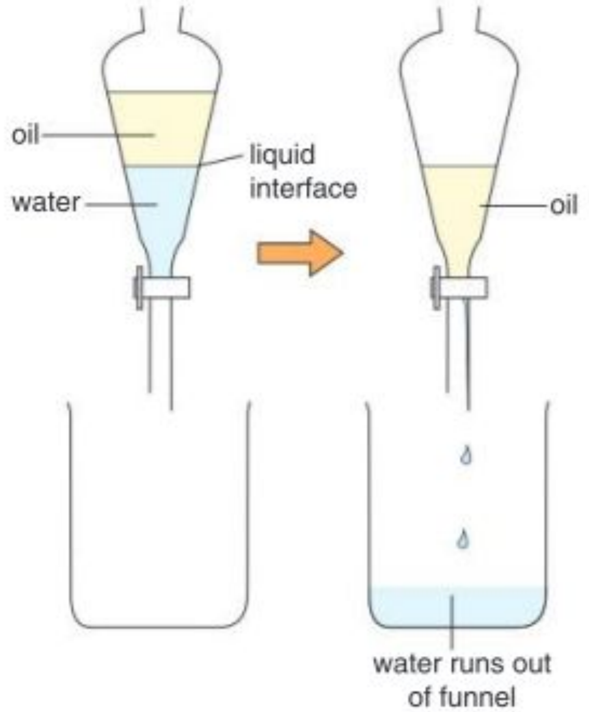
Separating Mixtures

The temperature begins to rise when almost all of the more volatile liquid has distilled over. This shows that a **mixture** of both liquids is reaching the top of the column and distilling over. This mixture is collected in a second container and discarded. When the temperature reaches the boiling point of the less volatile liquid (the one with the higher boiling point), that liquid is collected in a third container.

Separating Mixtures

A **separating funnel** is used to separate two (or more) **immiscible liquids**, e.g. oil and water. Immiscible liquids do not mix and are separated due to their **different densities**.

Separating funnel



▲ **Figure 2.4.6** Separation using a separating funnel

Separating Mixtures

Paper chromatography is used to separate **several solutes** which are present in a solution. The solutes are usually coloured and travel through absorbent paper at different speeds, e.g. the dyes in black ink or pigments in chlorophyll.

Separating Mixtures

The solutes are separated based on:

- How **soluble** each one is in the solvent used.
- How strongly each one is **attracted** to the paper used.

Paper Chromatography

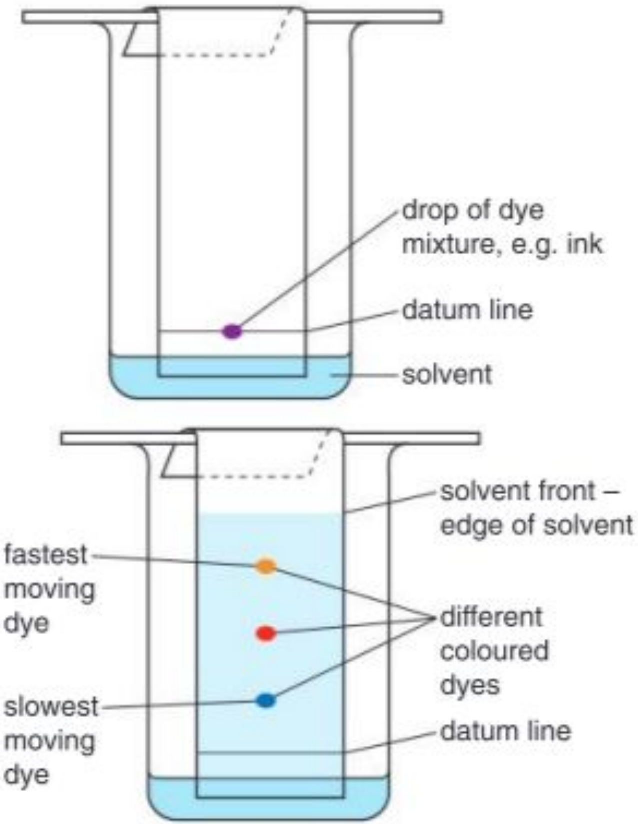


Figure 2.4.7 Separation using paper chromatography

Table 2.4.1 A summary of the methods used to separate mixtures

Separation method	Physical properties of component parts
Filtration	A mixture of a solid and a liquid where the solid does not dissolve in the liquid. The components are separated based on their different particle sizes.
Evaporation and crystallisation	A mixture of a solid which is dissolved in a liquid where the boiling point of the liquid is lower than that of the solid. The methods only allow for collection of the solid. The components are separated based on their different boiling points.
Simple distillation	A mixture of a solid which is dissolved in a liquid where the boiling point of the liquid is lower than that of the solid. Both the liquid and the solid can be collected. The components are separated based on their different boiling points.
Fractional distillation	A mixture of two (or more) miscible liquids which have different boiling points, i.e. there is a difference in volatility. Miscible liquids are ones that mix completely. The components are separated based on their different boiling points.
Separating funnel	A mixture of two (or more) immiscible liquids which have different densities. Immiscible liquids are liquids which do not mix. The components are separated based on their different densities.
Chromatography	A mixture of dissolved substances which will travel through a material. The components are separated based on their different solubilities in a solvent and attraction to the material.

Separating Mixtures: Extraction of sucrose from Sugar Cane

The production of sucrose from the sugar cane plant is an industrial process that makes use of several separation techniques.

The processes involved in the separation of sucrose from sugar cane are as follows:

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **1)** The sugar cane stalks are harvested, transported to the factory, cleaned and cut into small pieces by revolving knives in the shredder.

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **2)** The pieces are then **crushed** in the crushers as water is sprayed on them to dissolve the sugar present. This produces cane juice and cane fibre, or bagasse. The bagasse is taken to the boiler furnace where it is burnt to supply heat for the boilers.

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **3)** The cane juice, which is acidic and contains impurities, enters the clarifier where **precipitation** occurs. The juice is heated and calcium hydroxide is added which neutralises any acids in the juice and causes the impurities to precipitate out, i.e. they are converted into larger, insoluble particles.

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **4)** The juice then moves into the rotary filter where continuous **filtration** takes place to remove the insoluble impurities. This produces factory mud and clarified juice. The factory mud is returned to the fields

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **5)**The clarified juice, which is about 85% water, goes into a series of three or four boilers or evaporators where **vacuum distillation** occurs. These boilers are under successively lower pressures so that as the juice passes from one to the next it boils at successively lower temperatures.

Separating Mixtures: Extraction of sucrose from Sugar Cane

- In this way the water evaporates and the juice is concentrated but not charred or caramelised by the boiling process. The juice from the last boiler is a thick syrup containing about 35% water.

Separating Mixtures: Extraction of sucrose from Sugar Cane

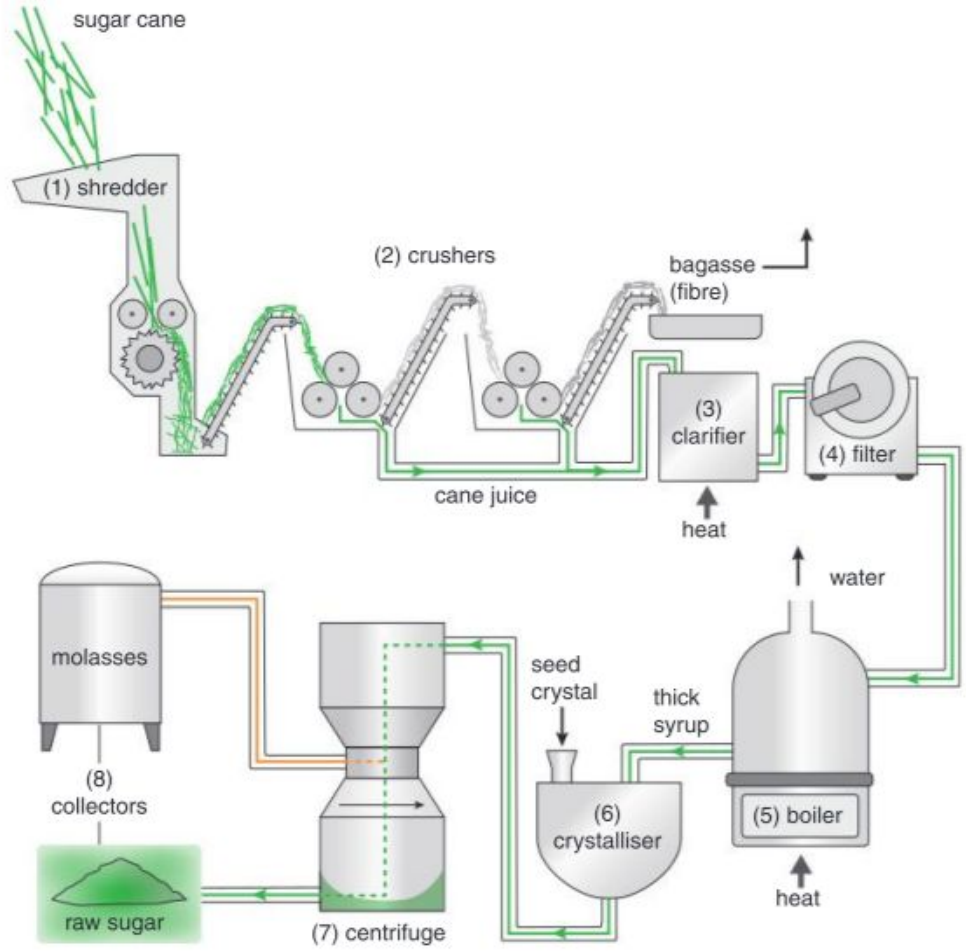
- **6)** The thick syrup moves into the crystalliser where **crystallisation** takes place. Here the syrup is evaporated until it is saturated with sugar. As soon as the saturation point is exceeded, small grains of sugar, called 'seed', are added to serve as nuclei for the formation of sugar crystals. As the crystals form, the remaining syrup becomes thick and viscous and is called molasses. The mixture of crystals and molasses forms massecuite.

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **7**) The sugar crystals and molasses in the massecuite are then separated by **centrifugation** in the centrifuges. Each centrifuge contains a perforated basket. The massecuite is placed in the basket and this revolves at high speed. The molasses are forced out through the holes in the basket and are collected in the outer drum of the centrifuge. The sugar crystals remain behind in the basket.

Separating Mixtures: Extraction of sucrose from Sugar Cane

- **8)**The damp, unrefined sugar crystals are collected and dried by being tumbled through heated air.



▲ **Figure 2.5.4** Flow diagram of the various stages in the extraction of sucrose