

‘O’ Level Chemistry

Chapter 2 – Purification of Substances

The Need for Pure Substances

- **A pure substance**
 - a **single** substance
 - not mixed with anything else
 - has **fixed melting and boiling temperatures**
 - e.g. Medicines need to be pure. Impurities can poison people.
- **A mixture**
 - contains two or more substances that are **not** chemically combined together
 - melts and boils over a **range of temperatures**
 - e.g. sugar solution, seawater
 - presence of impurities lowers the melting point and increases the boiling point of a pure substance

Identity and purity of substances can be checked by determining their **melting and boiling points**.

Separation Techniques

- To separate mixtures into pure substances
- Using **physical means** without chemical reactions

1) Filtration

- To separate **insoluble solid from a liquid**.
- To separate a **soluble solid from an insoluble solid**.

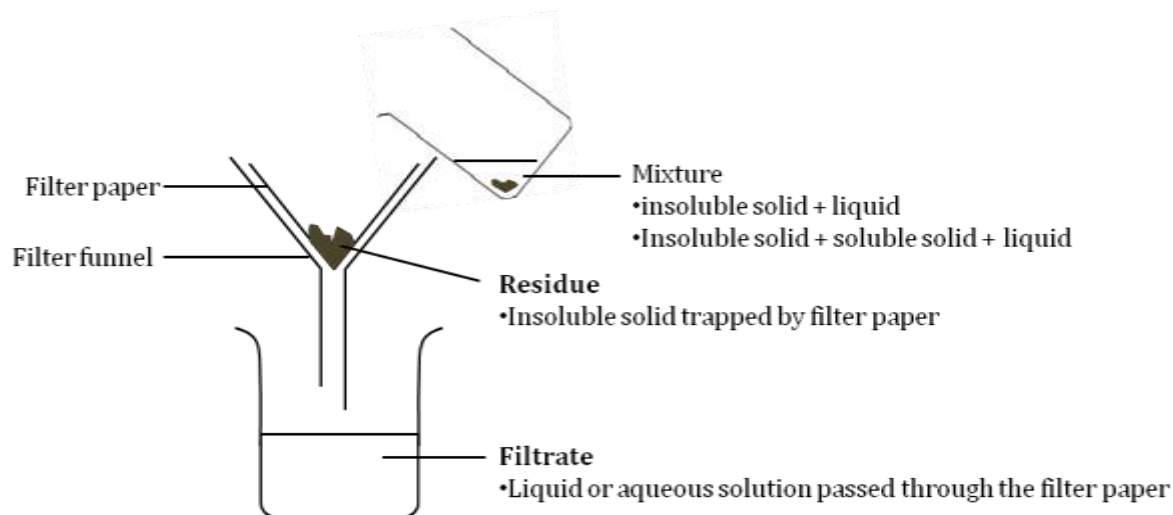


Fig. 1: Filtration Process

2) Decanting

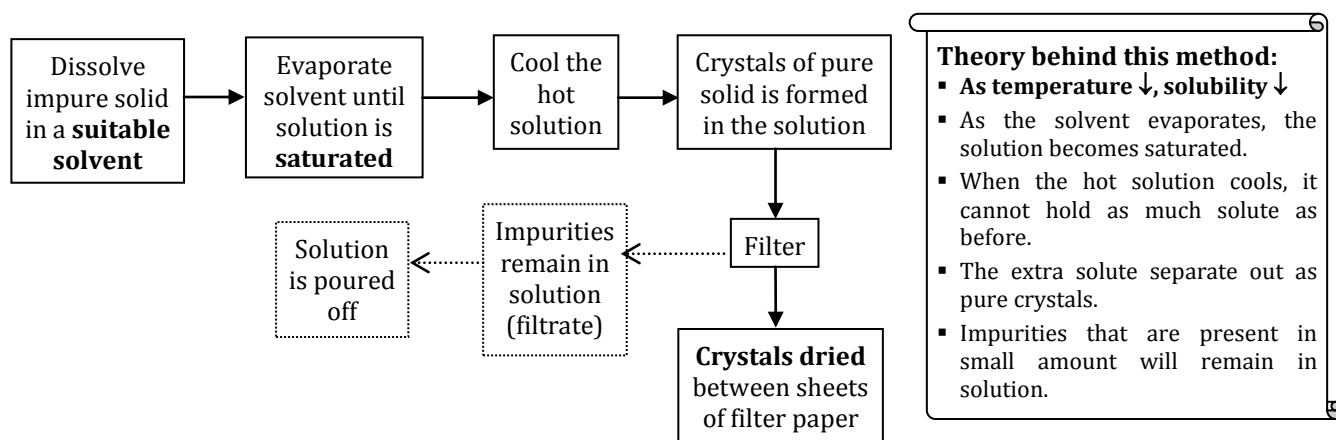
- To separate **big insoluble solid from a liquid**
- To separate **immiscible liquids** (but separating funnel is a better choice)

3) Evaporation to dryness

- To obtain a pure solid from a solution of the solid
- This method cannot be used if the solid will decompose when heated, e.g. sugar.

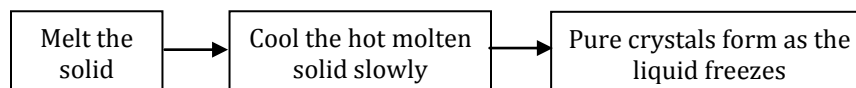
4) Crystallisation

- To obtain a **pure soluble solid from an impure solid**.
- To separate a **dissolved (soluble) solid from a solution as well-formed crystals**.



- Crystallisation without solvent

- Some solid can be purified by melting them first. (e.g. crystals of rock like quartz)



5) Sublimation

- To separate a **mixture of solids, one of which sublimes**.
- It is the process in which a substance changes **directly from solid to vapour** on heating. On cooling, the vapour changes back to solid directly.
- Substances that sublimes:
 - Iodine, dry ice (solid carbon dioxide), moth balls
 - Anhydrous iron (III) chloride, anhydrous aluminium chloride, ammonium chloride

6) Simple Distillation

- To obtain a **pure liquid from the solution of a solute**.

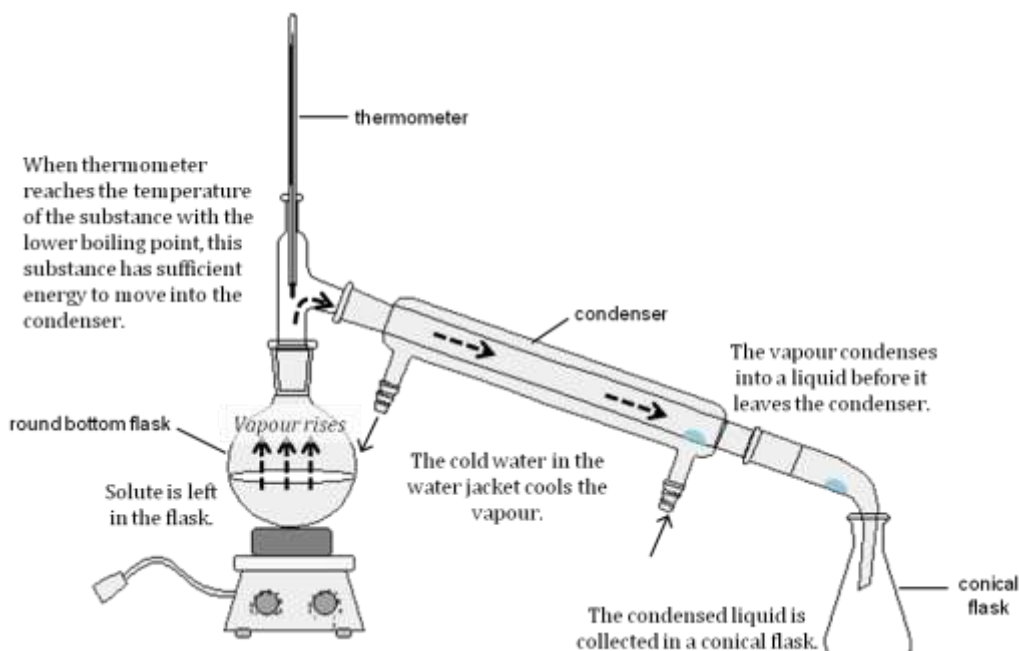


Fig. 2: Simple Distillation Process

- **Example: Desalination**
 - Pure water is obtained from distillation of seawater.
 - However, a lot of energy and fuel is required \Rightarrow high cost and maintenance

7) Fractional Distillation

- To separate a **mixture of miscible liquids** which have **different boiling points**
- Uses a **fractionating column**
 - Can be packed with glass beads.
- **Example: Separating a mixture of ethanol and water**
 - 1) Ethanol has a lower boiling point (78°C) and boils first.
 - 2) Ethanol vapour reached the top of fractionating column and cools as it passes through the condenser.
 - 3) It condensed into liquid and collected in the receiver.
 - 4) The thermometer will show a constant temperature when ethanol is boiling and distilling.
 - 5) Some water also evaporates into water vapour. However, its boiling point is higher and condenses in the fractionating column before it reaches the top. Hence, water flows back into the distilling flask.
 - 6) When all ethanol has distilled over, temperature rises to 100°C . Change the receiver before the temperature reaches 100°C . At 100°C , water begins to boil and distill over.
 - 7) The ethanol collected will still contain some water.
- **Uses of fractional distillation:**
 - Separate liquefied air
 - Separate components in petroleum/crude oil

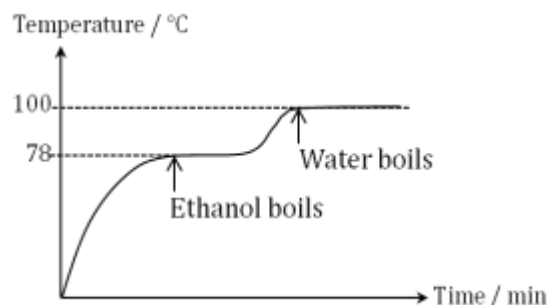


Fig. 3: Graph of temperature against time for the fractional distillation of ethanol-water mixture

- Produce alcoholic drinks

Important points for simple and fractional distillations:

- Boiling chips are added in the distilling flask for smooth boiling.
- Cold water enters the condenser from the bottom inlet
 - To ensure that the coldest part of the condenser is just before the vapour exits, so that the vapour condenses before it leaves the condenser
- A conical flask is usually used to receive the distillate.
 - It has a narrow opening which reduces evaporation of the distillate.

8) Using a Separating Funnel

- To separate **immiscible liquids**
- Uses the concept of **difference in density**

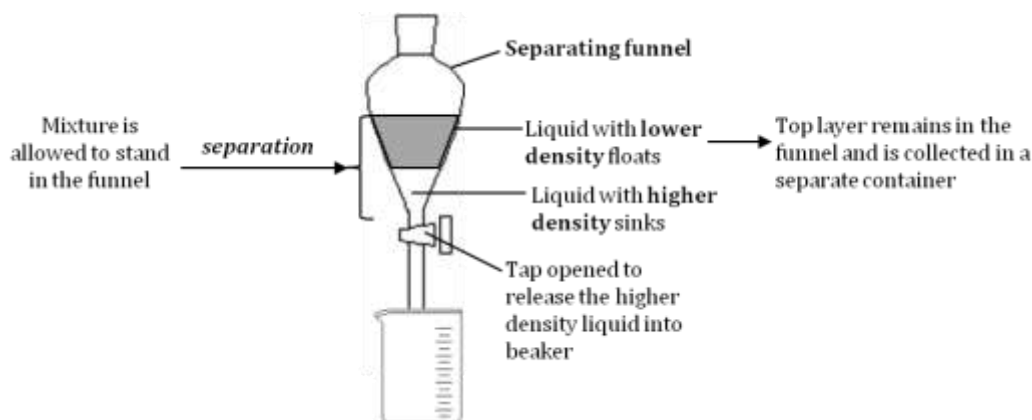


Fig. 4: The set-up for a Separating Funnel

9) Chromatography

- To **determine if a substance is pure**
- To **identify** components present in a mixture
- To **separate** the components in a mixture
- To identify the number of components in a mixture

✓ Paper chromatography

- To separate and identify
 - mixtures of coloured substances in food and dyes
 - components in drugs, urine and blood
- How it works?
 - 1) Solvent travels up the filter paper.
 - 2) Dyes dissolved in the solvent will also travel up **but at different speeds** because they have **different solubility** in the solvent.
 - **The more soluble substance will travel faster together with the solvent and will be further from the pencil line.**

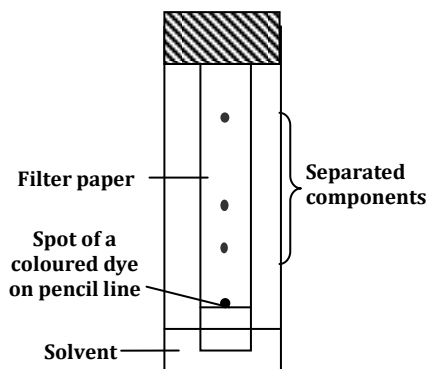


Fig. 5: The set-up for paper chromatography

- 3) Hence, the dye will be separated and the result is called a **chromatogram**.
- We can identify the mixture of coloured substances by comparing the chromatogram of the unknown dyes with that of the known dyes.
- Chromatograms of mixtures of **colourless substances** can be sprayed with a **locating agent**.
 - **Locating agent** is a substance which reacts with the substances on the paper (chromatogram) to produce a coloured product.

Important points to take note when carrying out chromatography:

- The start line must be drawn with a pencil.
 - Pen ink will dissolve in the solvent resulting in inaccurate chromatograms.
- Solvent level must be below the spot.
 - If not, the solvent will dissolve the spot before it travels up the paper which results in inaccurate chromatogram.
- The spot must be small so that the separation between the components will be distinct.

✓ **Alternative method of paper chromatography**

- Solvent travels **down** the paper ⇒ faster separation due to the pull of gravity downwards
- Uses a longer piece of paper
- Solutes which are separated will travel further ⇒ **better and greater separation** between spots

✓ **R_f Values**

- The R_f value of an unknown spot can be calculated and compared with R_f values of known substances
- $$R_f = \frac{\text{Distance moved by substance}}{\text{Distance moved by solvent}} = \frac{x}{y}$$
- The distance is measured from the start line.
- R_f values are dependent on the type of **solvent** used and **temperature**.

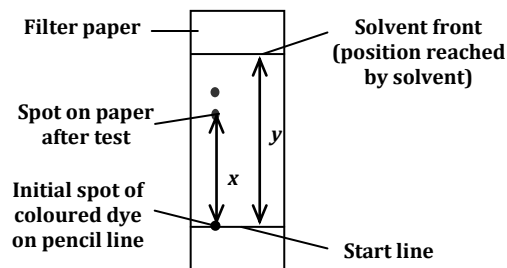


Fig. 6: A chromatogram of an unknown dye

Summary: Purification of Substances – Different Separation Techniques

Method	Substance to separate	Substance(s) obtained	Remarks
Filtration	1) Insoluble solid from a liquid. 2) A soluble solid from an insoluble solid	Filtrate. Residue.	<ul style="list-style-type: none"> Uses filter paper. Insoluble solid as the residue. Liquid as the filtrate.
Decanting	Large insoluble solid from a liquid.	-	<ul style="list-style-type: none"> By pouring most of the liquid away. Not a very effective method.
Evaporate to dryness	A solution of a dissolved solid (solute) in a liquid.	Dry salt.	<ul style="list-style-type: none"> Not for solids that decompose when heated.
Crystallisation	1) A pure solid from an impure solid. 2) A solution of a dissolved solid (solute) in a liquid. 3) Substances which decompose if heated to dryness.	Well-formed crystals of the pure solid (solute)	<ul style="list-style-type: none"> As temperature ↓, solubility ↓ Evaporate the solvent until the solution becomes saturated. When left to cool, it cannot hold anymore solute and the extra solute separates out as pure crystals. Impurities that are present in small amount will remain in solution.
Sublimation	A mixture of solids which one of them sublimes.	Pure solid which sublimes.	<ul style="list-style-type: none"> Sublimation: a process in which a substance changes directly from solid to vapour on heating. On cooling, the vapour changes back to solid directly. e.g. iodine, moth balls, dry ice.
Simple distillation	A solution of a dissolved solid (solute) in a liquid.	Pure liquid as distillate.	<ul style="list-style-type: none"> Liquid is changed into vapour by boiling. It cools and condenses into a pure liquid in the condenser and collected as distillate. e.g. Desalination
Fractional distillation	Mixture of miscible liquids.	Pure liquids as distillate.	<ul style="list-style-type: none"> The liquids have different boiling points. Liquid with the lower b.p. will be distilled out first. Uses a fractionating column.
Separating funnel	Mixture of two immiscible liquids.	Two separated liquids	<ul style="list-style-type: none"> Mixture separates into two layers. Uses the concept of difference in densities.
Paper chromatography	Solution containing mixture of small amounts of solids	Solutes which are separated in the chromatogram.	<ul style="list-style-type: none"> Identify the mixture of substances by comparing the chromatograms of unknown and known substances. Locating agent used for colourless mixtures. $R_f = \frac{\text{Distance moved by substance}}{\text{Distance moved by solvent}} = \frac{x}{y}$

• Purity of the substances can be checked by their melting and boiling points

- Pure** substances: fixed melting point and boiling point
- Impure** substances: lower melting point and higher boiling point
 - They melt and boil over a **range** of temperatures.