# Edexcel GCSE Chemistry

Your notes

## Methods of Separating & Purifying Substances

### Contents

Your notes

## Pure Substances & Mixtures

# Pure Substance vs Mixture

- In everyday language we use the word pure to describe when something is **natural** or **clean** and to which nothing else has been added
- In chemistry a pure substance may consist of a single element or compound which contains no other substances
- For example a beaker of a sample of pure water contains only $H_2O$ molecules and nothing else
- If salt were added to the beaker then a mixture is produced
- A mixture consists of two or more elements or compounds that are **physically mixed** together, they are **not** chemically combined
- The chemical properties of the substances in a mixture remain **unchanged**
- Substances in mixtures can be separated by physical means
- Air for example is a mixture of nitrogen, oxygen and some other gases such as carbon dioxide and argon

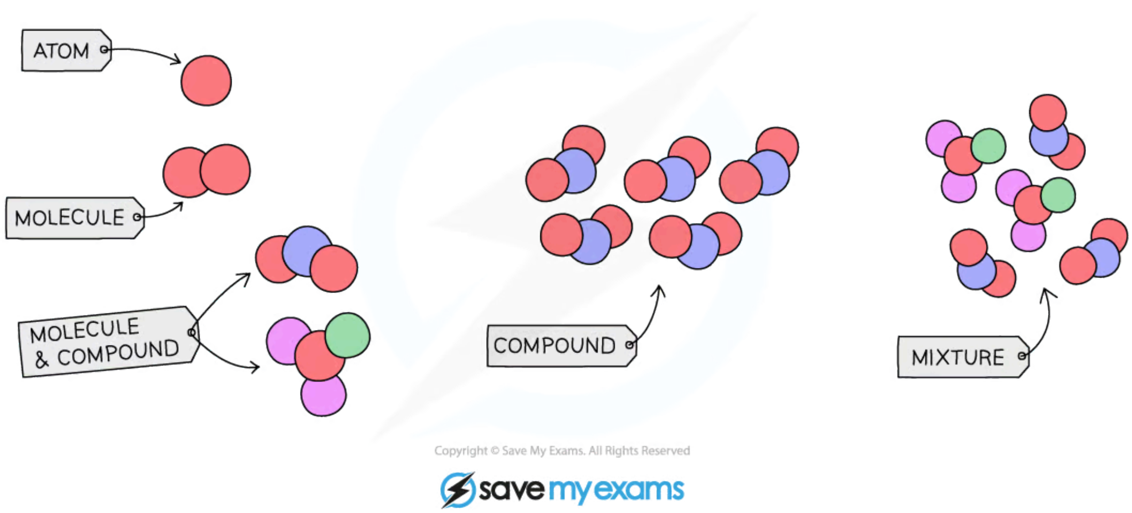


*Diagram showing how to represent elements, compounds and mixtures using particle diagrams*

## Distinguishing Purity

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- Pure substances melt and boil at **specific** and **sharp** temperatures e.g. pure water has a boiling point of 100°C and a melting point of 0°C
- Mixtures have a **range** of melting and boiling points as they consist of **different** substances that tend to lower the melting point and broaden the melting point range
- **Melting** and **boiling** points data can therefore be used to distinguish pure substances from mixtures
- Melting point analysis is routinely used to assess the purity of drugs
- This is done using a melting point apparatus which allows you to **slowly** heat up a small amount of the sample, making it easier to observe the **exact** melting point
- This is then compared to data tables
- The closer the measured value is to the actual melting or boiling point then the purer the sample is

## Cooling Curves

- The influence of impurities can be more clearly seen on a **heating / cooling curve**
- If the temperature of a liquid is measured as it cools and freezes the data can be used to produce a graph
- The following graph shows the cooling curve for a sample of a compound
- The horizontal part of the graph shows that the compound has a **sharp melting point**, so the compound is pure

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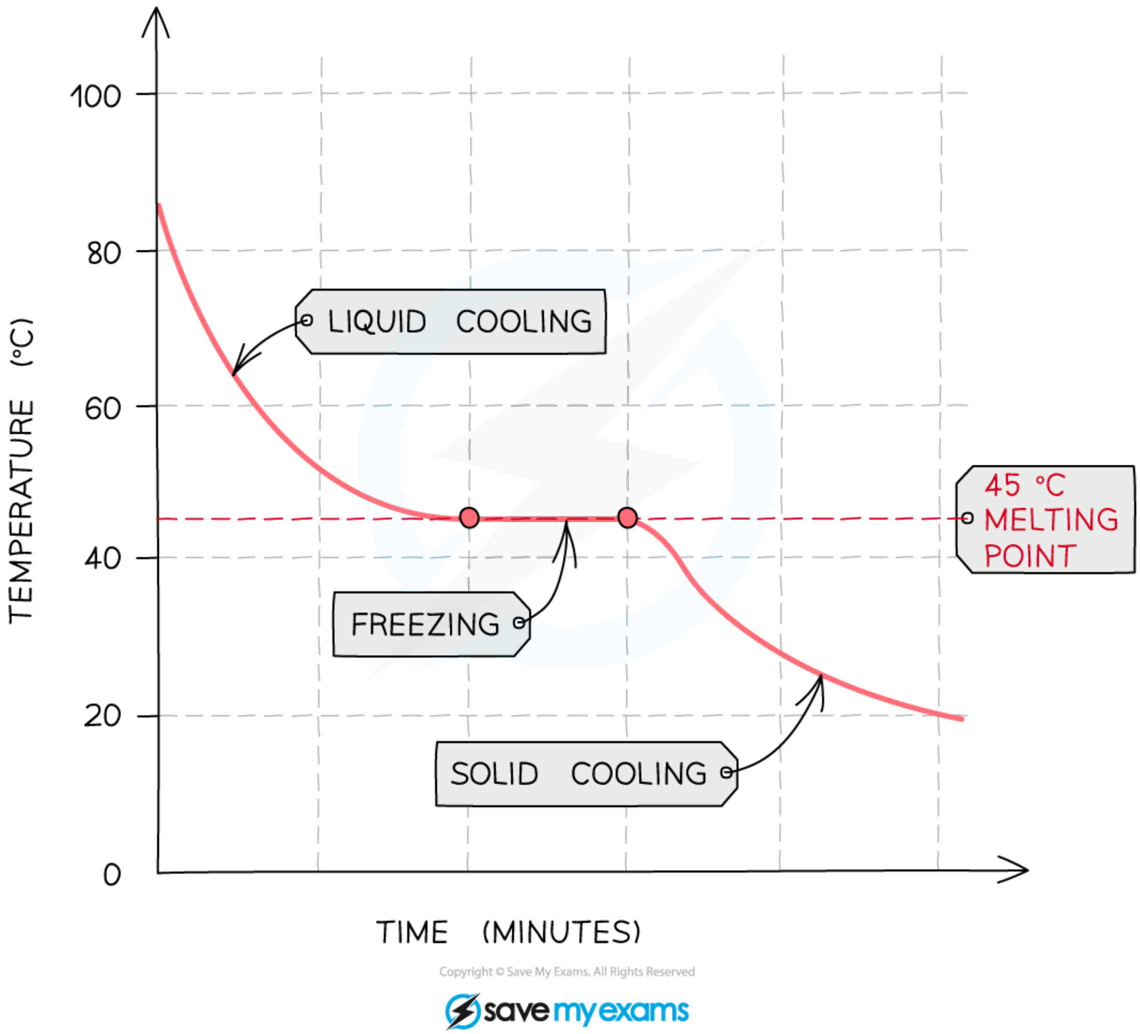


*Cooling curve for a pure substance*

- An impure sample of the compound would produce a **gradual decrease** in temperature as it freezes as shown in the graph below

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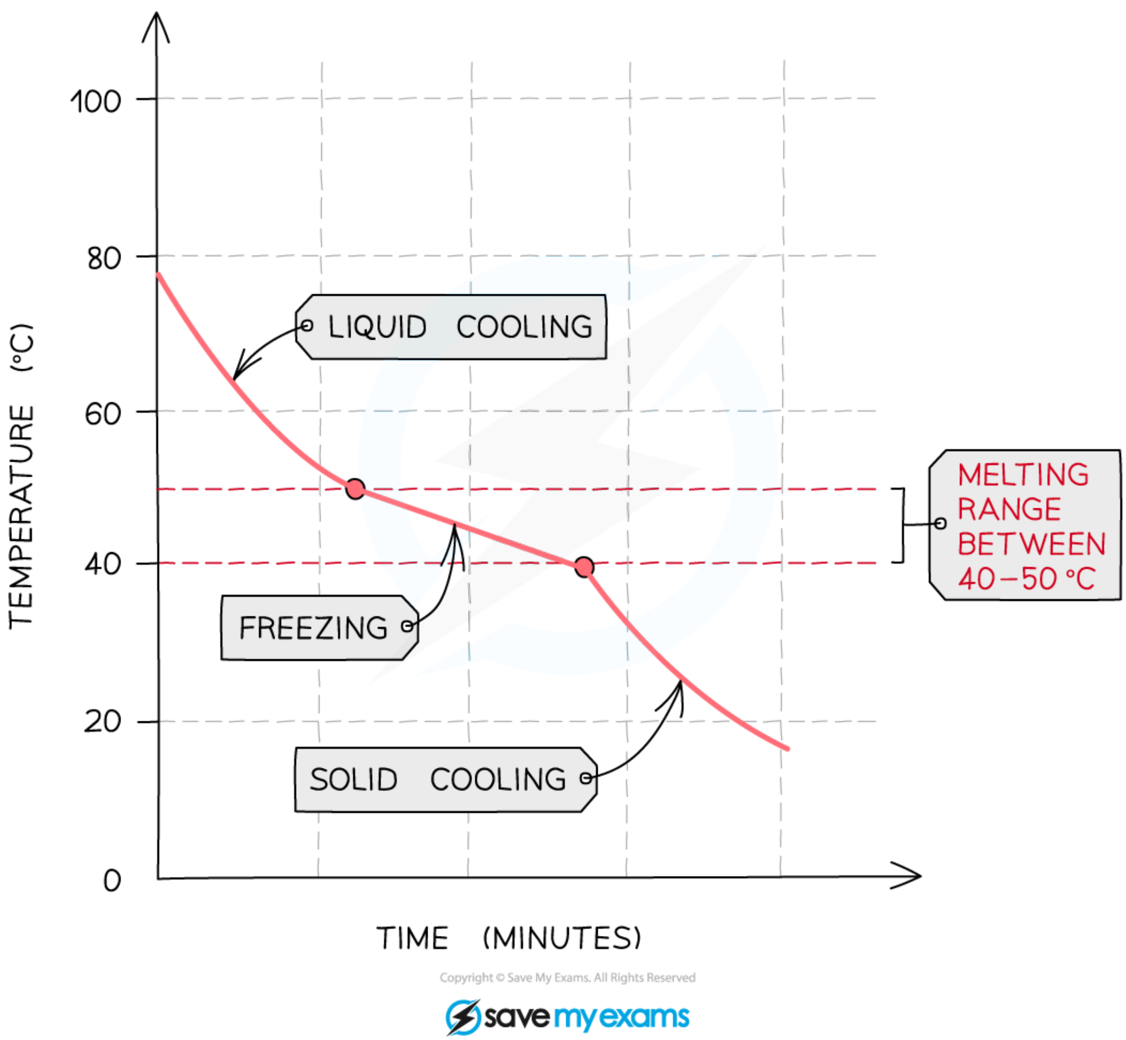


*Cooling curve for an impure substance*

## Separation Techniques

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# Simple Distillation

## Methods of purification

- The choice of the method of separation depends on the nature of the substances being separated.
- All methods rely on there being a **difference** of some sort, usually in a physical property such as boiling point, between the substances being separated
- Five common techniques are **distillation, fractional distillation, filtration, crystallisation** and **chromatography**

## Simple Distillation

- This is used to separate a liquid and **soluble solid** from a solution (e.g., water from a solution of salt water) or a pure liquid from a mixture of liquids
- The solution is heated, and pure water evaporates producing a vapour which rises through the neck of the round bottomed flask
- The vapour passes through the condenser, where it cools and condenses, turning into the pure liquid that is collected in a beaker
- After all the water is evaporated from the solution, only the solid solute will be left behind

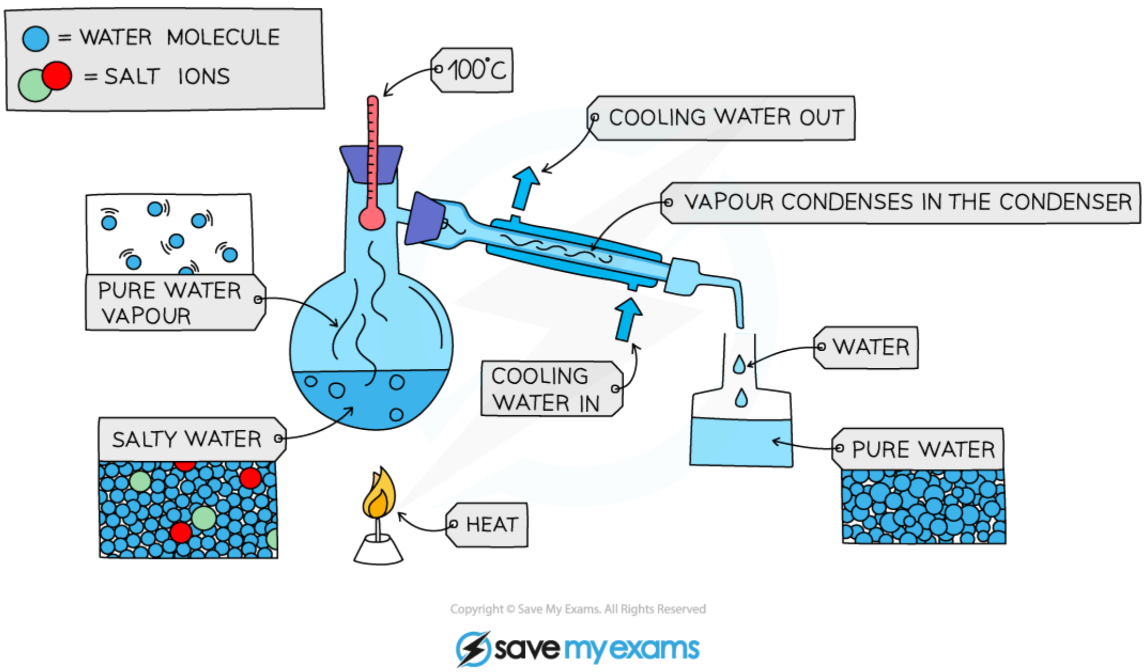


*Diagram showing the distillation of a mixture of salt and water*

### Examiner Tips and Tricks

If asked to draw or label a diagram of simple distillation, make sure that the water goes in at the bottom of the condenser near the collecting beaker, and comes out at the top near the column.

# Fractional Distillation

- This is used to separate two or more liquids that are **miscible** with one another (e.g., ethanol and water from a mixture of the two)
- The solution is heated to the temperature of the substance with the lowest boiling point
- This substance will rise and evaporate first, and vapours will pass through a condenser, where they cool and condense, turning into a liquid that will be collected in a beaker
- All of the substance is evaporated and collected, leaving behind the other components(s) of the mixture
- For water and ethanol

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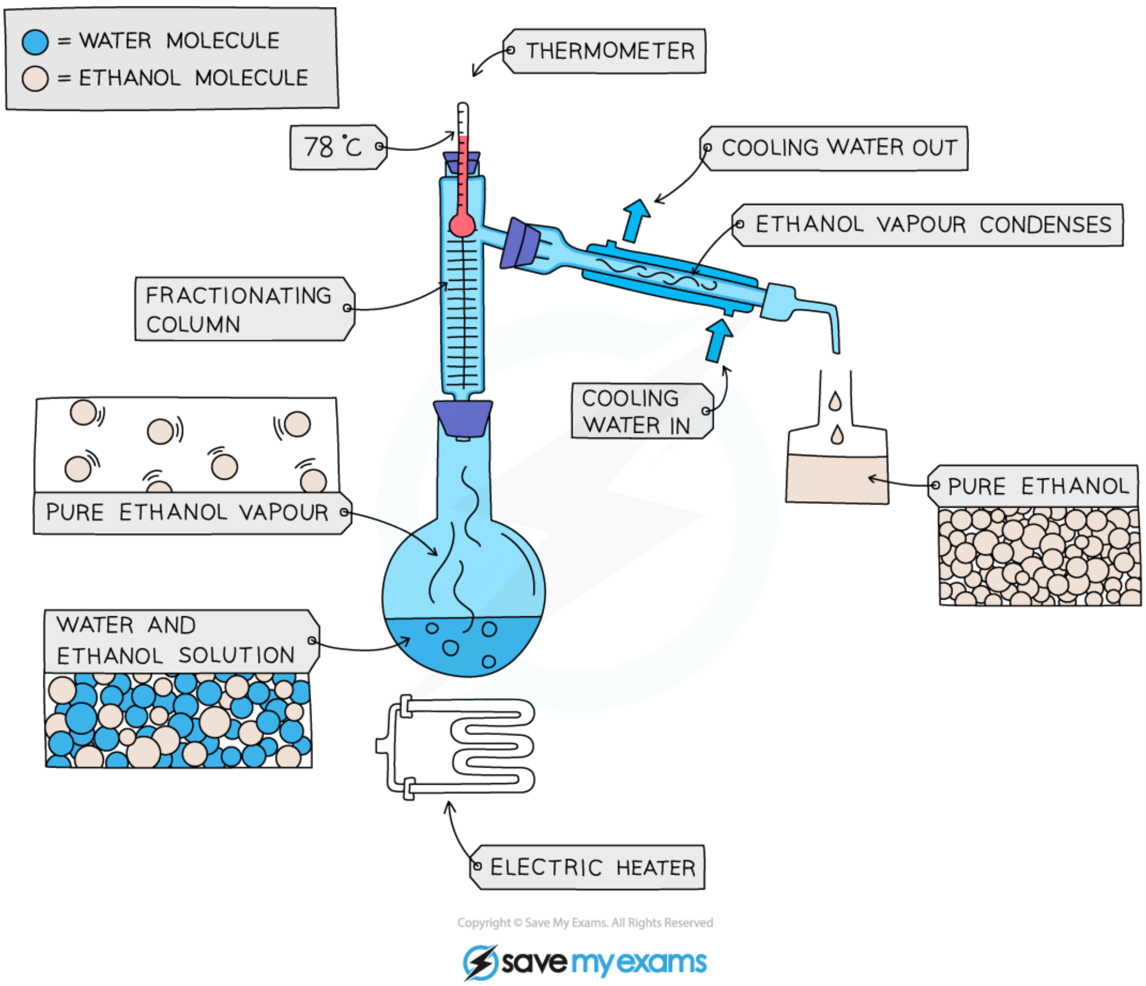
- Ethanol has a boiling point of 78 °C and water of 100 °C
- The mixture is heated until it reaches 78 °C, at which point the ethanol boils and distills out of the mixture and condenses into the beaker
- When the temperature starts to increase to 100 °C heating should be stopped. Water and ethanol are now separated




*Fractional distillation of a mixture of ethanol and water*

# Filtration

- Used to separate an **undissolved solid** from a mixture of the solid and a liquid / solution ( e.g., sand from a mixture of sand and water)
    - Centrifugation can also be used for this mixture

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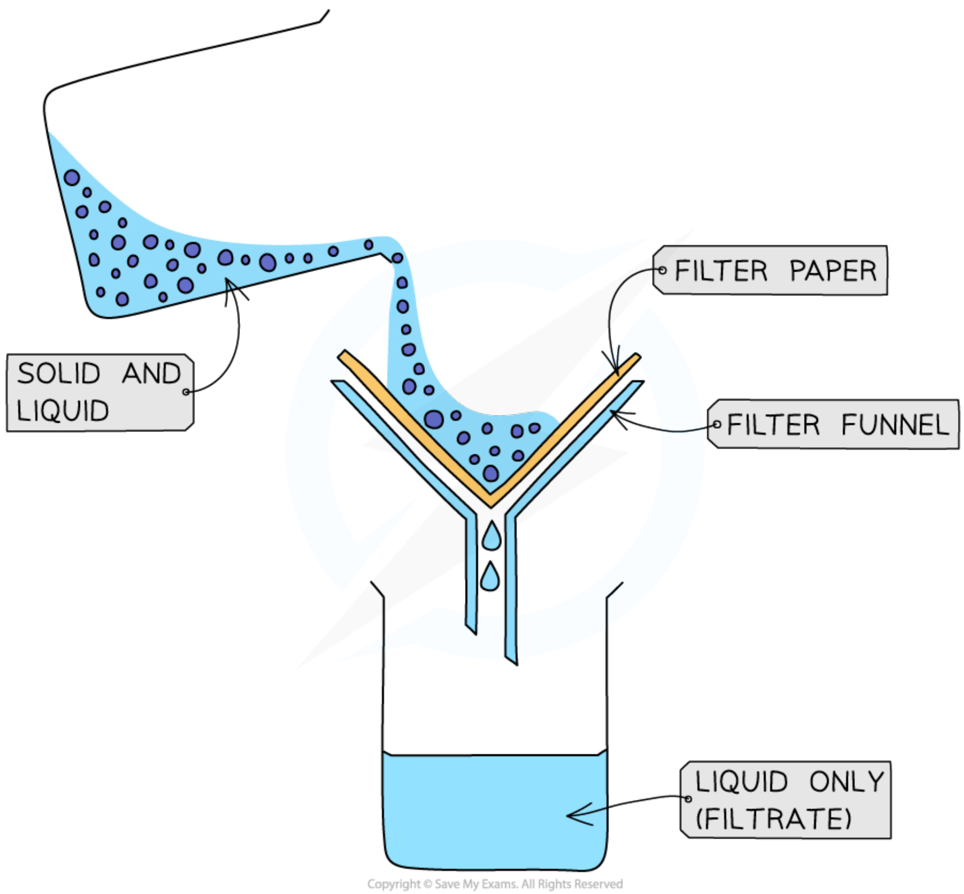
- A piece of filter paper is placed in a filter funnel above a beaker
- A mixture of insoluble solid and liquid is poured into the filter funnel
- The filter paper will only allow small liquid particles to pass through as filtrate
- Solid particles are too large to pass through the filter paper so will stay behind as a residue




***Filtration of a mixture of sand and water***

# Crystallisation

- Used to separate a **dissolved solid** from a solution, when the solid is much more soluble in hot solvent than in cold (e.g., copper sulphate from a solution of copper (II) sulphate in water)
- The solution is heated, allowing the solvent to evaporate, leaving a saturated solution behind
- Test if the solution is saturated by dipping a clean, dry, cold glass rod into the solution
    - If the solution is saturated, crystals will form on the glass rod

- The saturated solution is allowed to cool slowly
- Crystals begin to grow as solids will come out of solution due to decreasing solubility
- The crystals are collected by filtering the solution, they are washed with cold distilled water to remove impurities and are then allowed to dry

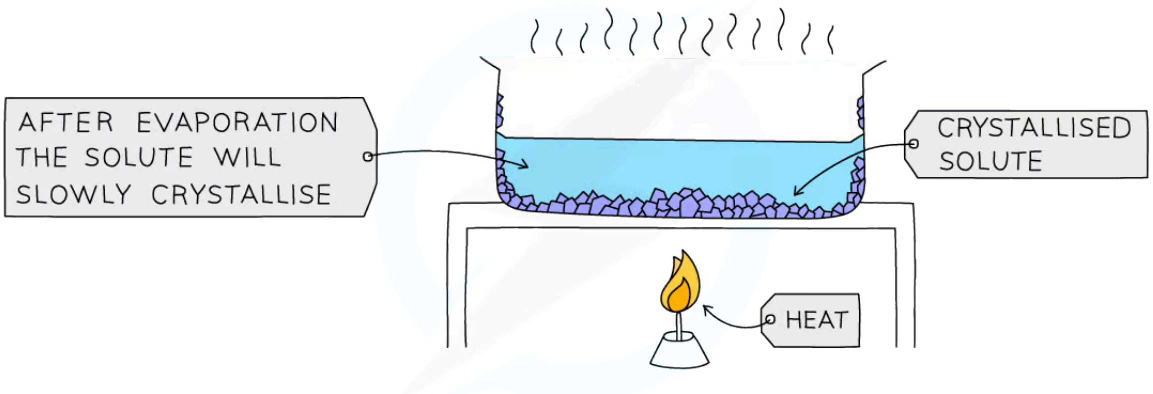



*Diagram showing the process of crystallisation*

## Paper Chromatography

- This technique is used to separate substances that have **different solubilities** in a given solvent (e.g., different coloured inks that have been mixed to make black ink)
- A **pencil line** is drawn on chromatography paper and spots of the sample are placed on it. Pencil is used for this as ink would run into the chromatogram along with the samples
- The paper is then lowered into the solvent container, making sure that the pencil line sits **above** the level of the solvent, so the samples don't wash into the solvent container
- The solvent travels up the paper by **capillary action**, taking some of the coloured substances with it
- Different substances have different solubilities so will travel at different rates, causing the substances to spread apart
  - Those substances with higher solubility will travel further than the others
- This will show the different components of the ink / dye
- If two or more substances are the same, they will produce identical chromatograms

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- If the substance is a mixture, it will separate on the paper to show all the different components as separate spots
- An impure substance will show up with more than one spot, a pure substance should only show up with one spot

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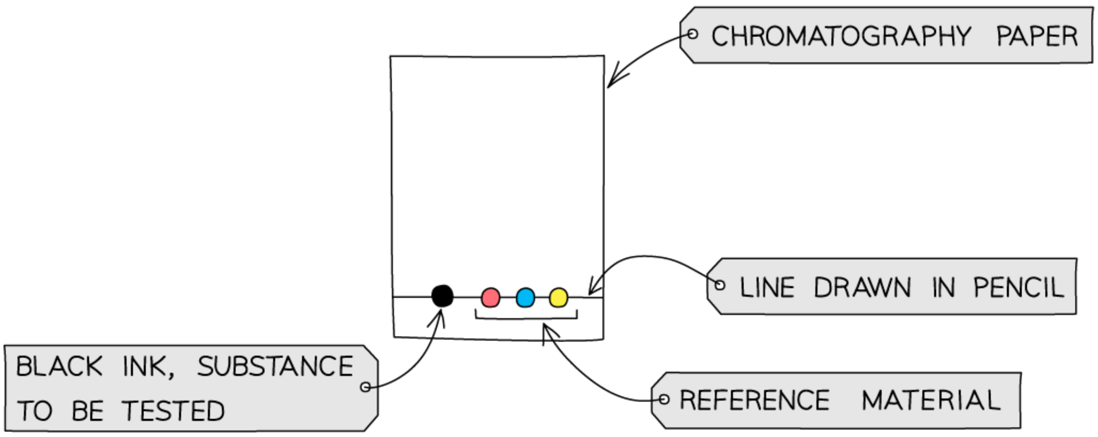
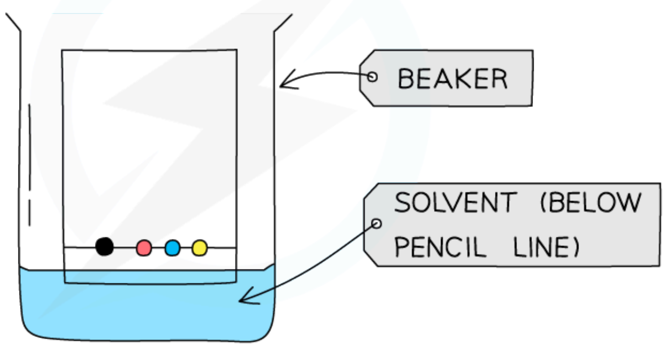
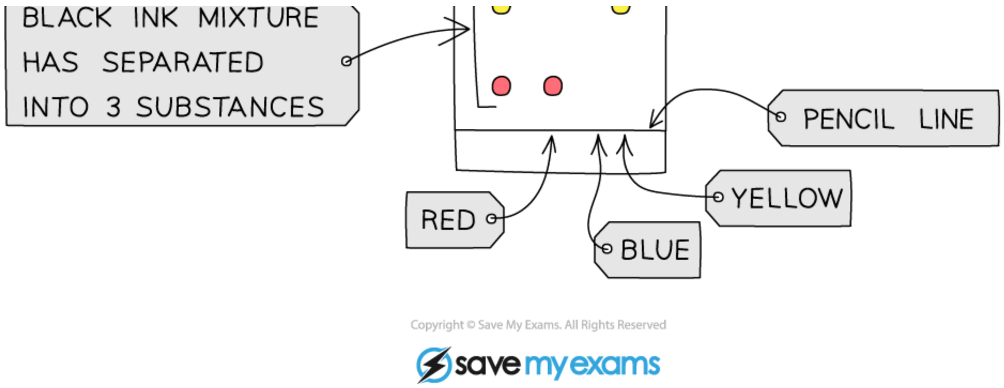
**1** SET UP CHROMATOGRAPHY PAPER AS SHOWN




**2** LOWER PAPER INTO A BEAKER WITH APPROPRIATE SOLVENT. WAIT FOR SOLVENT TO TRAVEL UP THE PAPER.




**3** ANALYSE CHROMATAGRAM




*Analysis of the composition of ink using paper chromatography*

### Examiner Tips and Tricks

Paper chromatography is the name given to the **overall** separation technique while a **chromatogram** is the name given to the **visual output** of a chromatography run. This is the piece of chromatography paper with the visibly separated components after the run has finished.

The initial line must be drawn in pencil because if you used ink this would smudge or run in the water!

The solvent level must not start above the pencil line, or this will ruin the chromatogram.

Your notes

Your notes

## Interpreting Chromatograms

# Interpreting Chromatograms

## Identifying Mixtures

- Pure substances will produce only **one spot** on the chromatogram
- If two or more substances are the same, they will produce identical chromatograms
- If the substance is a **mixture**, it will separate on the paper to show all the **different components** as **separate** spots
- An impure substance therefore will produce a chromatogram with more than one spot

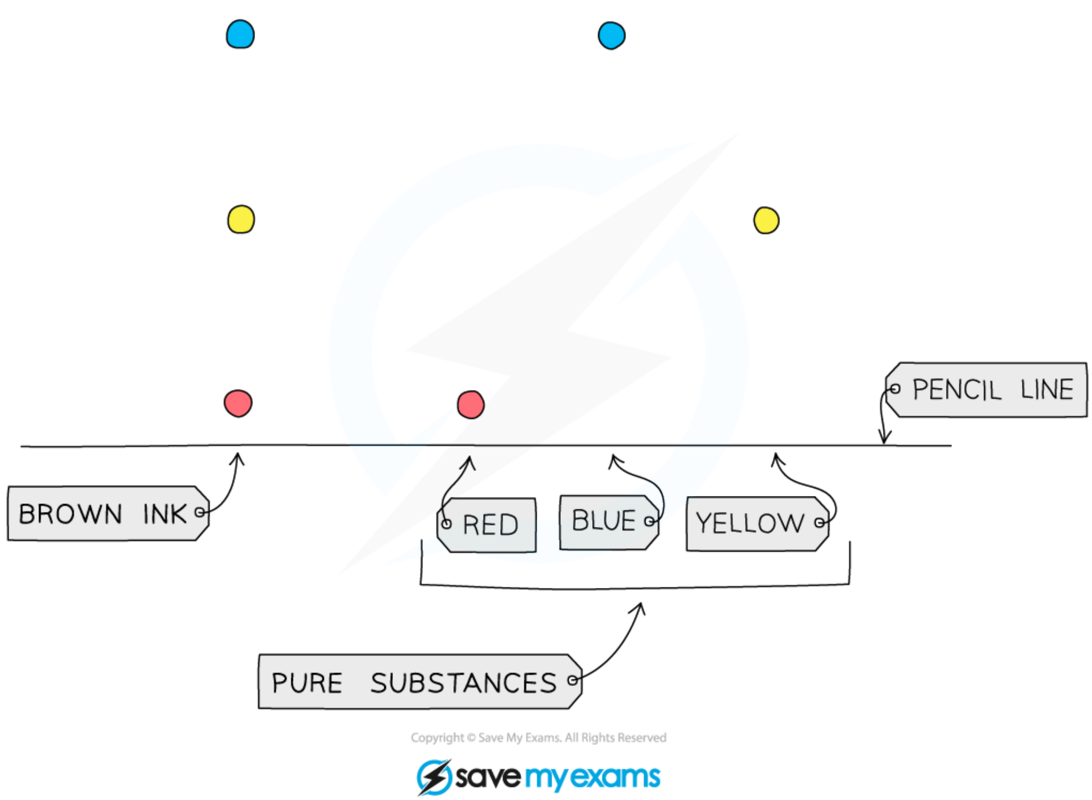



*Diagram showing the analysis of a mixture and pure substances using chromatography*

## $R_f$ Values

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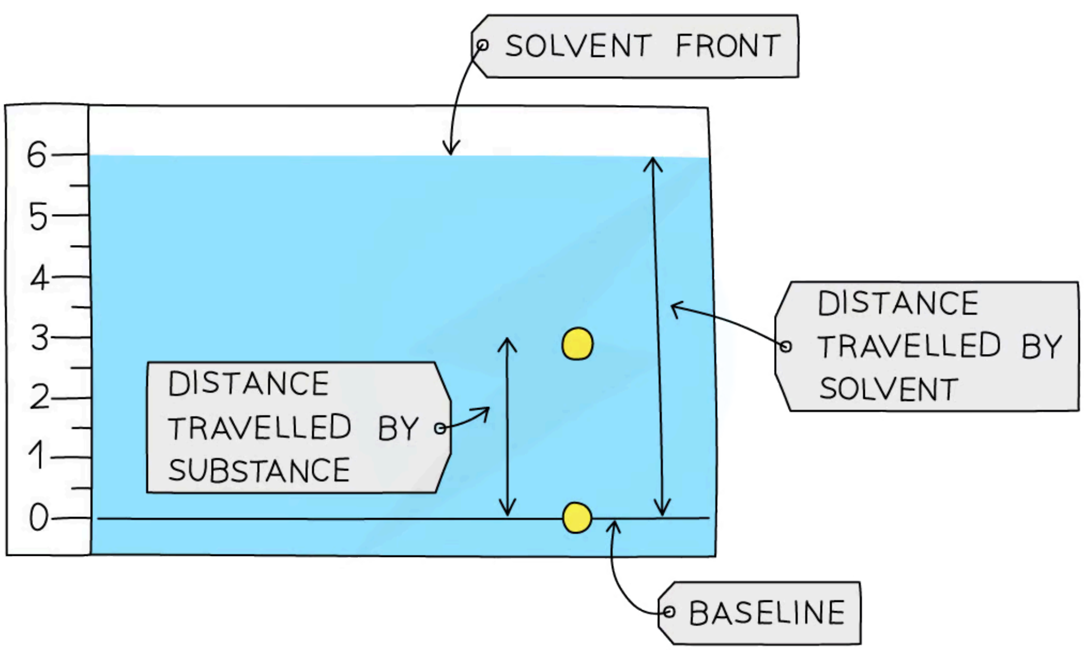
- These values are used to **identify** the components of mixtures
- $R_f$ stands for **retention factor**
- The $R_f$ value of a particular compound is always the **same** but it is dependent, however, on the solvent used
- If the solvent is changed then the value changes
- Calculating the $R_f$ value allows chemists to **identify unknown substances** because it can be compared with $R_f$ values of known substances under the same conditions
- These values are known as **reference values**

**Calculation**

- The Retention factor is found using the following calculation:

**$R_f$ = distance travelled by substance ÷ distance travelled by solvent**

- The $R_f$ value will always lie between 0 and 1; the closer it is to 1, the more soluble is that component in the solvent
- The $R_f$ value is a ratio and therefore has no units



*Using $R_f$ values to identify components of a mixture*

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## Examiner Tips and Tricks

For the $R_f$ calculations, both distances are measured from the baseline.

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# Core Practical: Investigating Inks

**Aim:**

Investigate how simple distillation and paper chromatography can be used to separate and identify a mixture of food colourings

**Part 1– Simple Distillation**

- Ink consists of a **solvent** which has different **dyes** dissolved in it
- The investigation must thus include analysis of **both** the solvent and the dyes used
- The solvent must first be **separated** which can be done by simple distillation
- Solvents tend to have **low** boiling points than the dyes which tend to be more **viscous** so it will evaporate first.
- Add anti-bumping granules and heat **gently** so as not to go past the boiling point
- Record the temperature of boiling point

**Part 2– Paper ChromatographyMaterials:**

- A 250 $cm^3$ beaker
- A wooden spill
- A rectangle of chromatography paper
- Four known food colourings labelled A–D
- An unknown mixture of food colourings labelled U
- Five glass capillary tubes
- Paper clip
- Ruler & pencil

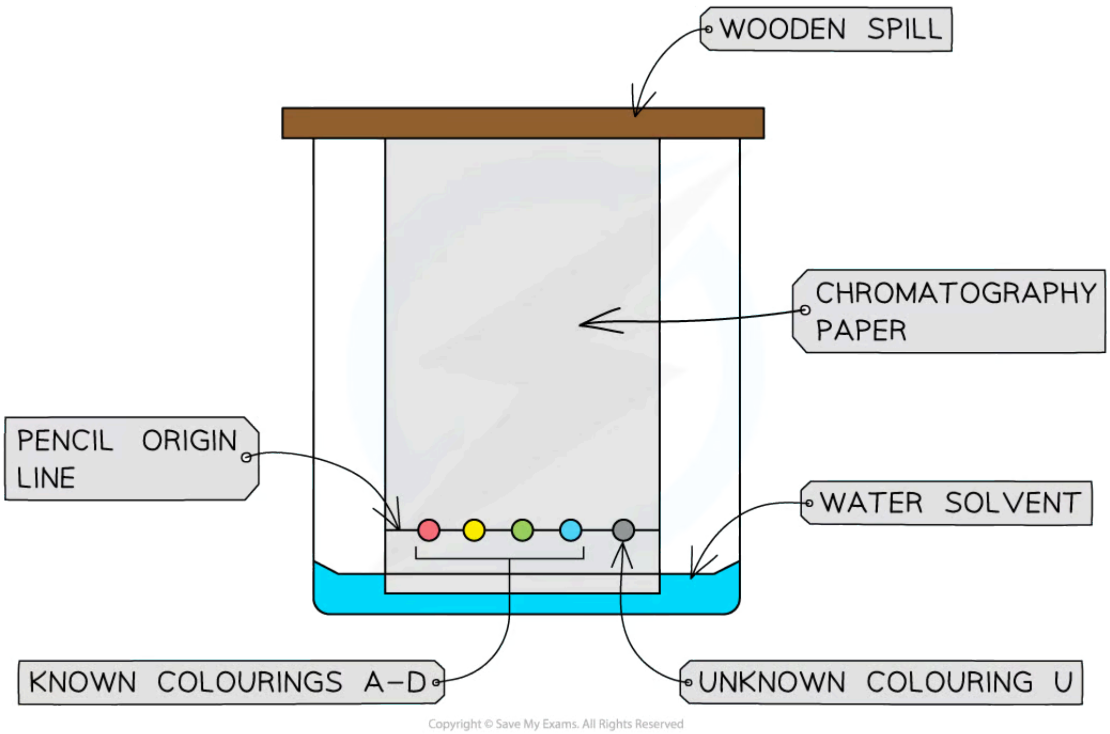


***Diagram of the apparatus needed for paper chromatography***

**Practical Tip:**

The pencil line must never be below the level of the solvent as the samples will be washed away

**Method:**

1. Use a ruler to draw a horizontal pencil line 2 cm from the end of the chromatography paper
2. Use a different capillary tube to put a tiny spot of each colouring A, B, C and D on the line
3. Use the fifth tube to put a small spot of the unknown mixture U on the line
4. Make sure each spot is no more than 2–3 mm in diameter and label each spot in pencil
5. Pour water into the beaker to a depth of no more than 1 cm and clip the top of the chromatography paper to the wooden spill. The top end is the furthest from the spots
6. Carefully rest the wooden spill on the top edge of the beaker. The bottom edge of the paper should dip into the solvent
7. Allow the solvent to travel undisturbed at least three quarters of the way up the paper

8. Remove the paper and draw another pencil line on the dry part of the paper as close to the wet edge as possible. This is called the solvent front line
9. Measure the distance in mm between the two pencil lines. This is the distance travelled by the water solvent
10. For each of food colour A, B, C and D measure the distance in mm from the start line to the middle of the spot

**Results:**

Record your results in a suitable table

| Food colouring | Distance in mm | | $R_f$ value |
|---|---|---|---|
| | Solvent | Spot | |
| A | 5 | 2.5 | 0.5 |
| B | 5 | 1.8 | 0.36 |



**Evaluation:**

The $R_f$ values of food colours A, B, C and D should be compared to that for the unknown sample as well as a visual comparison being made

**Conclusion:**

The use of chromatography and $R_f$ values is a viable method of identifying unknown mixtures given reference material

## Hazards, risks and precautions

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***Hazard symbols to show substances that are flammable and harmful to health***

- The solvents used in chromatography are often flammable and harmful to health, e.g. ethanol, propan-2-ol or propanone
- The solvents should be kept away from naked flames, e.g. a Bunsen burner
- Avoid contact with the skin and breathing in the vapour
- A fume cupboard can be used for harmful solvents

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## Purifying Water

# Purifying Water

## Making Water Potable

- Ground water from aquifers is relatively clean but surface water (from rivers & lakes) and waste water need significant treatment in order to be fit for human consumption
- Untreated water contains **soluble** and **insoluble** impurities
- Insoluble impurities include **soil**, pieces of **plants** and other **organic** matter and soluble impurities include **calcium**, **metallic** compounds and **inorganic** pollutants
- Unclean water also contains **microbes** which can cause illness
- **Potable water** means water that is clean enough for human consumption

## Filtration

- This process removes large insoluble particles by passing the water through layers of sand and gravel filters that trap larger particles
- Wire mesh filters are sometimes used, depending on the level of impurities in the water

## Sedimentation

- Large insoluble particles sink to the bottom of a tank of water that has been left still for some time
- Iron sulfate or aluminium sulfate is sometimes added to help the fine particles clump together

## Chlorination

- This process is used to kill bacteria and microorganisms which are too small to be trapped by the filters
- Cholera and typhoid are examples of bacterial diseases which can arise by the consumption of untreated water

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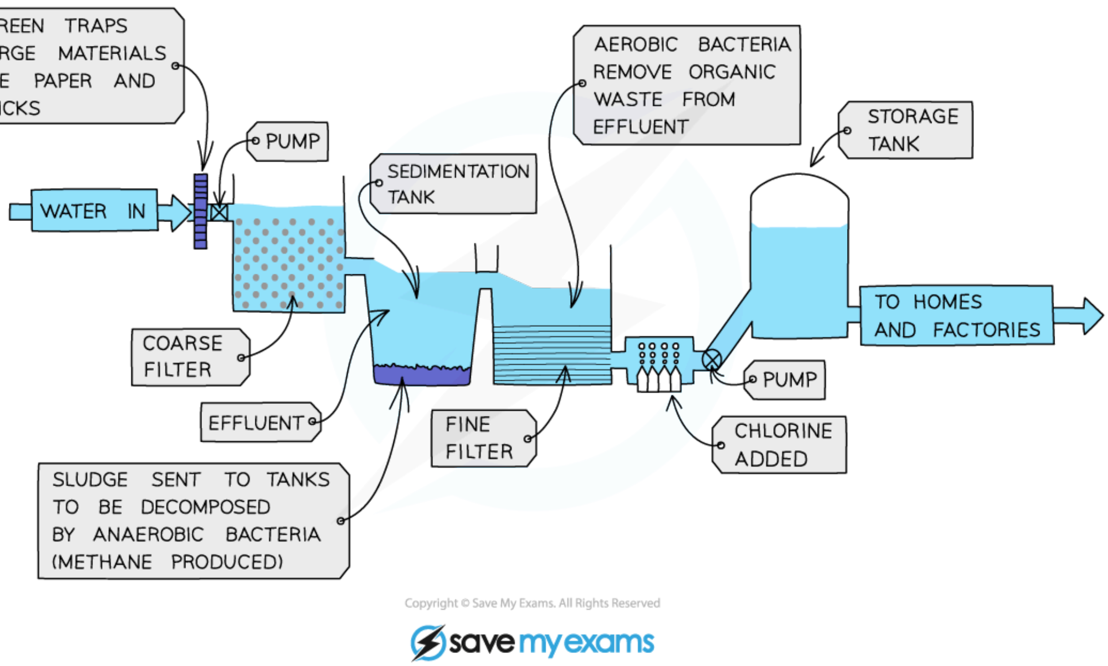
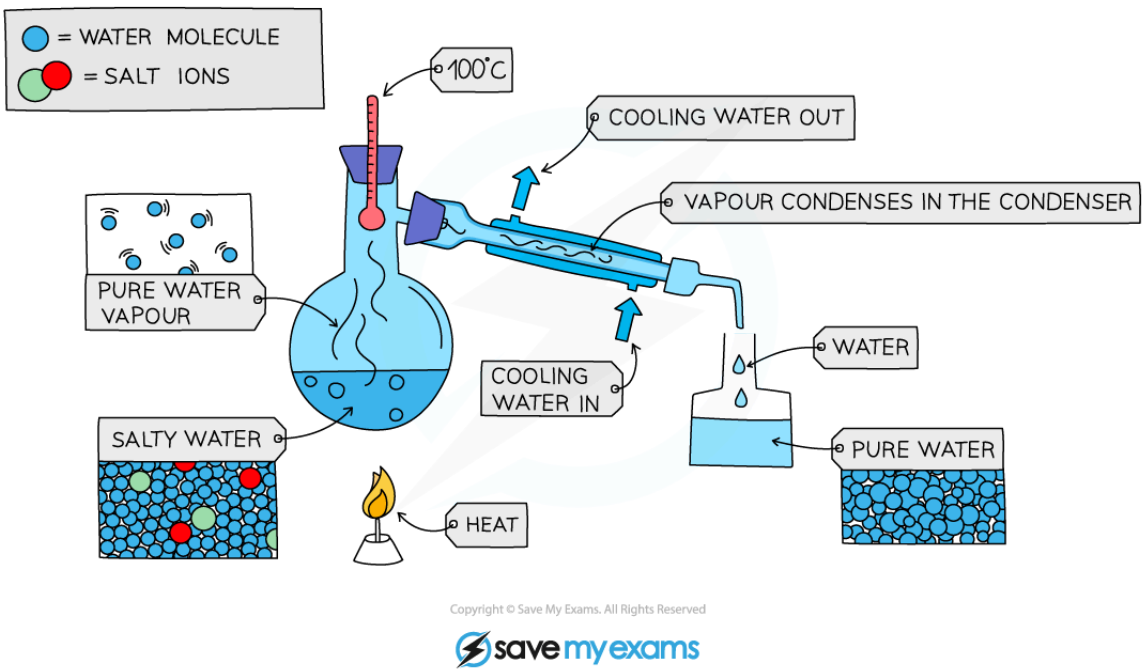



*Water treatment involves filtration, sedimentation and chlorination*

## Making Sea Water Potable

- This process is done in some areas of the world where very **hot** and **dry climates** prevail and where a lack of water.
- Sea water contains mainly salts and can therefore be **distilled** to separate the water and the salts.
- The salt remains in the liquid while the steam is **cooled** and **condensed** to make potable water.
- The process is extremely **expensive** as a lot of energy is required to heat the large volumes of water to 100 °C.
- The wastewater produced is also extremely **toxic** due to the very high concentration of salts and must be disposed of correctly

Your notes




*Simple distillation of seawater to make it potable*

## Water in Chemical Analysis

- Most chemical investigations involve the use of water at some stage of the process
- Normally **deionised water** is used, which is water that has had metallic ions such as calcium or copper removed
- Deionisation uses specifically designed **ion-exchange resins** that remove ions by exchange with hydrogen and hydroxide ions in water, which then recombine to form water molecules
- Deionised water is used as the ions could react with the substances under analysis and would give the experiment a **false result**

### Examiner Tips and Tricks

Waste and ground water can be made potable by sedimentation, filtration and chlorination. Sea water can be made potable by using simple distillation. Water used in analysis must not contain any dissolved salts which would interfere with the sensitivity of the tests.