FACTFILE:
GCSE CHEMISTRY: UNIT 1.9

Rewarding Learning

Chemical Analysis

Learning Outcomes

Students should be able to:

1.9.1 demonstrate knowledge and understanding that a pure substance is a single element or compound not mixed with any other substance;

1.9.2 demonstrate knowledge and understanding that pure elements and compounds melt and boil at specific temperatures and melting point and boiling point can be used to distinguish pure substances from mixtures;

1.9.3 demonstrate knowledge and understanding that a formulation is a mixture that has been designed as a useful product and is formed by mixing together several different substances in carefully measured quantities to ensure the product has the required properties, for example alloys, medicines and fertilisers;

1.9.4 demonstrate knowledge and understanding of the terms soluble, insoluble, solute, solvent, solution, residue, filtrate, distillate, miscible, immiscible, evaporation and condensation;

1.9.5 investigate practically how mixtures can be separated using filtration, crystallisation, paper chromatography, simple distillation or fractional distillation (including the use of fractional distillation in the laboratory to separate miscible liquids, for example ethanol and water);

1.9.6 describe paper chromatography as the separation of mixtures of soluble substances by running a solvent (mobile phase) through the mixture on the paper (stationary phase) which causes the substances to move at different rates over the paper;

1.9.7 interpret a paper chromatogram including calculating Rf values;

1.9.8 analyse given data on mixtures to make judgements on the most effective methods of separation, and plan experiments to carry out this separation;

1.9.9 describe how waste and ground water can be made potable, including the need for filtration, sedimentation and chlorination;

1.9.10 describe how seawater can be made potable using distillation;

1.9.11 use anhydrous copper(II) sulfate to test for water;

1.9.12 describe how to carry out a flame test using nichrome wire and concentrated hydrochloric acid to identify metal ions;

1.9.13 demonstrate knowledge of the flame colours of different metal ions:

- lithium (crimson);
- sodium (yellow/orange);
- potassium (lilac);
- calcium (brick red); and
- copper (blue-green/green-blue);

1.9.14 describe the test for Cu^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Zn^{2+} and Mg^{2+} ions in solution using sodium hydroxide solution and ammonia solution;

1.9.15 describe the tests for the following:

- chloride, bromide and iodide (using silver nitrate solution);
- sulfate (using barium chloride solution); and
- carbonate (using dilute acid and identifying the carbon dioxide evolved);

1.9.16 **write ionic equations for the halide and sulfate ion tests and tests for metal ions using sodium hydroxide solution;**

1.9.17 demonstrate knowledge and understanding that many tests for anions and cations are precipitation reactions; and

1.9.18 plan experiments to identify cations and anions present in an unknown or a given compound.

Pure substances

In chemistry **a pure substance is a single element or compound not mixed with any other substance.**

For example 'pure' orange juice is not a single element or compound but contains water, citric acid, vitamin C and other ingredients – it is not a pure substance. It is a mixture.

Melting and boiling point of pure substances and mixtures

Melting point is the temperature at which a solid changes into a liquid.

Boiling point is the temperature at which a liquid changes into gas.

Pure elements and compounds have specific melting points and boiling points. For example the compound water has a boiling point of 100 °C and a melting point of 0 °C .Substances can be identified by their melting points and boiling points.

Impure substances do not have sharp melting or boiling points, but melt or boil over a range of temperatures.

Formulations

A formulation is a mixture that has been designed as a useful product and is formed by mixing together several different substances in carefully measured quantities to ensure the product has the required properties.

Example of formulation	Description
alloys	An alloy is a **mixture of two or more elements, at least one of which is a metal** – it is a formulation made by mixing measured quantities to ensure the alloy has the specific properties required for its use.
medicines	Medicines are formulations of the active drug and flavourings.
fertilisers	Fertilisers are mixtures of different nitrogen, phosphorus and potassium compounds, in measured quantities suitable for different plants.

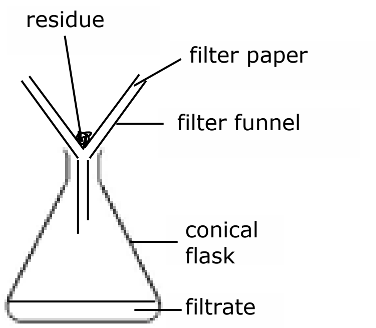
Separating Mixtures

- **A mixture is defined as two or more substances mixed together.**
- **A solute is the substance that dissolves in a solvent**
- **A solvent is the liquid in which a solute dissolves**
- **A solution is a solute dissolved in a solvent**
- **A soluble substance is one which will dissolve in a solvent**
- **An insoluble a substance is one which does not dissolve in a solvent**

Different methods are used to separate different types of mixtures

1. Filtration

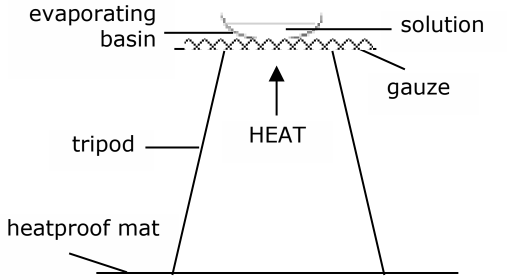
Filtration is used to separate an *insoluble solid from a liquid*. **The liquid which passes through the filter paper during filtration is called the filtrate. The solid that remains on the filter paper during filtration is called the residue.**



Separation of an insoluble solid from a liquid

2. Crystallisation

This involves heating a solution to boil off some of the solvent and create a saturated solution. The saturated solution is then cooled and the dissolved solid (solute) becomes less soluble and so cannot remain dissolved and crystallises out of solution. The crystals are often then separated from the saturated solution by filtration.

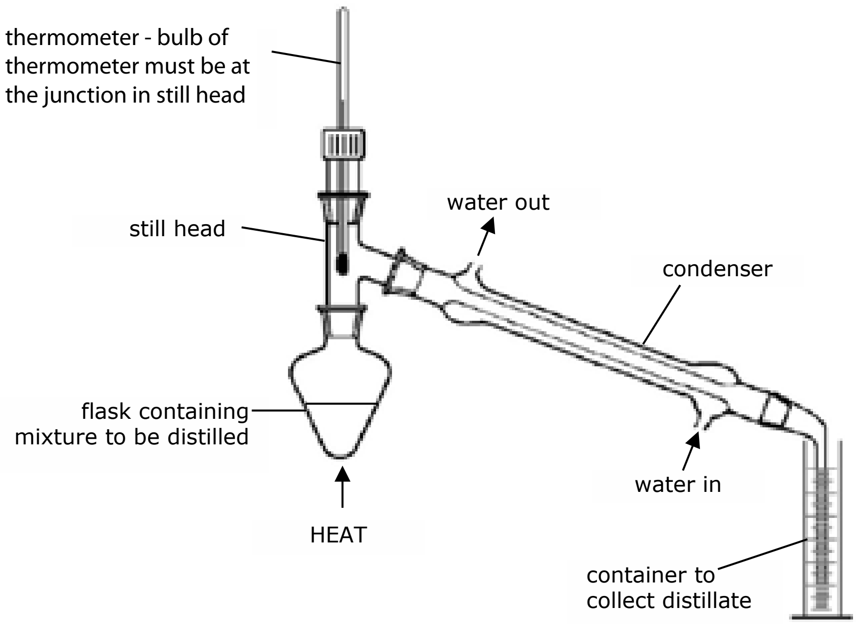


Obtaining salt from a salt solution

3. Simple Distillation

To separate a solvent from a solution, simple distillation is used. Distillation is evaporation followed by condensation.

Anti-bumping granules are added to the mixture in the flask to promote smooth boiling.
The solution is heated and the vaporised solvent passes into the condenser where it cools and condenses and then runs into the collection flask. **The distillate is the liquid which is cooled from the vapour and collected during distillation.**



Separating water from a salt solution using simple distillation

4. Fractional distillation

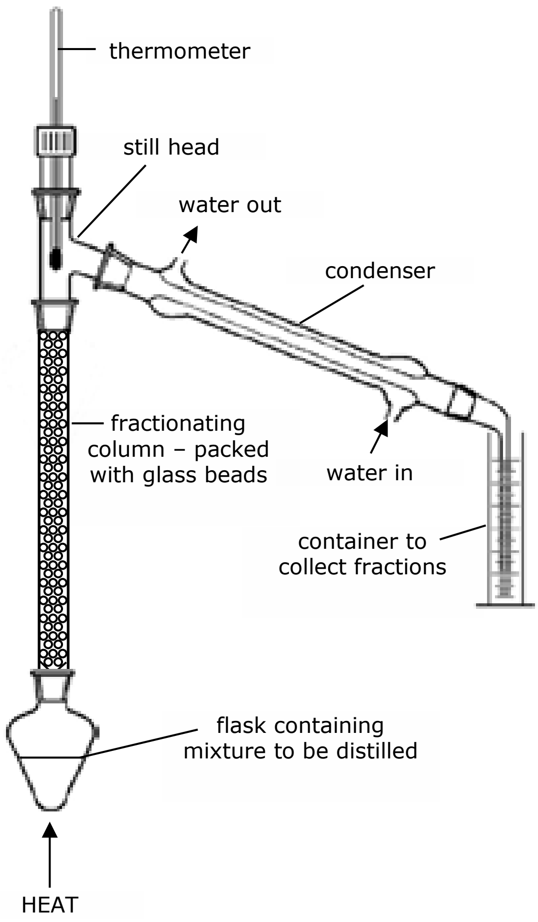
Fractional distillation is used to *separate miscible liquids* which have different boiling points, for example alcohol and water.

Miscible liquids are liquids that mix together, for example alcohol and water.

Immiscible liquids are liquids which do not mix together but form two layers, for example oil and water.

The mixture is heated and the liquids in it boil one by one as the temperature rises. Each vapour rises up, is condensed and collected. The distillate collected at each different temperature is called a *fraction*, and a different receiver is used for each fraction. Ethanol boils at 79 °C and is condensed and collected first. The temperature then rises to 100 °C and water boils and is collected.

A *fractionating column* packed with glass beads is used - any evaporated liquids below their boiling point condense on the glass beads and run back to the flask.



Fractional distillation of a water/ethanol mixture

5. Paper chromatography

Chromatography can be used to separate *mixtures of soluble substances* in a solution, e.g. inks.

Method

1 Draw a pencil base line 1–2cm from bottom of chromatography paper. Pencil is used as it will not dissolve in the solvent.

2 Place a spot of substance on the base line using a capillary tube, dry and add another spot on top, to make a concentrated spot.

3 Hang the paper in a beaker with the bottom touching the solvent.

4 The solvent soaks up the paper. It is removed and the level that the solvent reached is marked. (solvent front).

If the tested substance is a mixture it should have separated into different components, which are seen as spots on the paper. If the spots are colourless and not visible, they can be sprayed with a chemical developing agent.

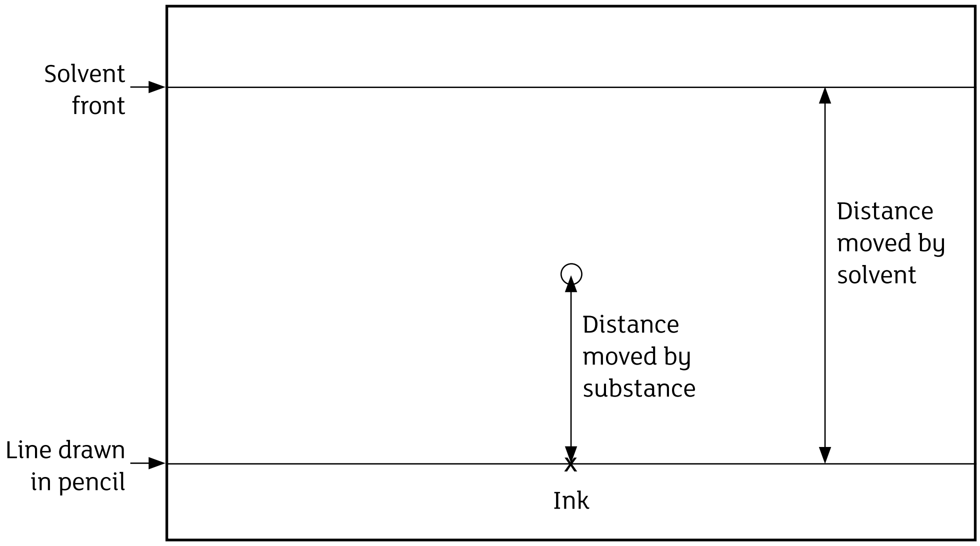
Solvent front is the furthest distance travelled by the solvent

How chromatography works

In paper chromatography the *stationary phase* is the sample mixture on the paper, and the solvent is the *mobile phase*, which runs through the stationary phase and causes the substances in the mixture to move at different rates over the paper. To identify the separated components the R_f value can be calculated

$$R_f = \frac{\text{distance moved by substance}}{\text{distance moved by solvent}}$$

The distances can be measured from the chromatogram using a ruler.



Types of water

Water that is safe to drink is called potable water.

Making water potable

Potable water from fresh water.

Fresh water is water which is naturally occurring in lakes, ice caps, rivers and underground rocks and it contains minerals, microbes and stones. **Ground water** is fresh water found underground **in soil spaces and in porous rocks**. They are treated as shown below:-

Filtration to remove insoluble solids, e.g. soil by passing the water through filter beds containing layers of sand

↓

Sedimentation by adding aluminium sulfate to clump tiny particles together into larger particles which settle out and can be filtered off

↓

Chlorination to kill microbes by bubbling chlorine into the water

Potable water from seawater

Desalination is the process of removing dissolved substances from sea water. It can occur by distillation which requires much energy, so it is an expensive process.

Test for water

Test	Observation
Add a few drops of the liquid to white anhydrous copper(II) sulfate	White anhydrous copper(II) sulfate turns blue

Cation tests

Cations can be identified in two different ways.

1. Flame tests

Method

- Make a loop on the end of a piece of nichrome wire.
- Dip the loop into concentrated hydrochloric acid and then into the salt to be tested.
- Place the loop into a blue Bunsen burner flame and record the first colour observed.

Metal ion present	Flame colour
Lithium (Li^+)	Crimson
Sodium (Na^+)	Yellow/orange
Potassium (K^+)	Lilac
Calcium (Ca^{2+})	Brick red
Copper (Cu^{2+})	Blue-green/green-blue

2. Test using sodium hydroxide solution or ammonia solution

Method

- If it is a solid salt, make a solution by dissolving a spatula of the solid in water
- Place about 5 cm^3 of the metal ion solution into a test tube and add a few drops of sodium hydroxide (or ammonia) solution.
- Record the colour of the precipitate formed. **A precipitate is a solid formed when two solutions are mixed.**
- Continue to add sodium hydroxide solution (or ammonia) until it is in excess, and record the effect.

Metal ion	Copper(II) Cu^{2+}	Iron(II) Fe^{2+}	Iron(III) Fe^{3+}	Magnesium Mg^{2+}	Aluminium Al^{3+}	Zinc Zn^{2+}
Result on adding dilute sodium hydroxide or ammonia solution	Blue ppt of copper(II) hydroxide	Green ppt of iron(II) hydroxide	Brown ppt of iron(III) hydroxide	White ppt of magnesium hydroxide	White ppt of aluminium hydroxide	White ppt of zinc hydroxide
Ionic equation **[Higher tier]**	$Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_2(s)$	$Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s)$	$Fe^{3+}(aq) + 3OH^{-}(aq) \rightarrow Fe(OH)_3(s)$	$Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$	$Al^{3+}(aq) + 3OH^{-}(aq) \rightarrow Al(OH)_3$ s)	$Zn^{2+}(aq) + 2OH^{-}(aq) \rightarrow Zn(OH)_2(s)$
Effect of excess sodium hydoxide solution	Blue ppt remains	Green ppt remains	Red-brown ppt remains	White ppt remains	White ppt dissolves and a colourless solution is produced	White ppt dissolves and a colourless solution is produced
Effect of excess ammonia solution	Blue ppt dissolves and a deep blue solution is produced	Green ppt remains	Brown ppt remains	White ppt remains	White ppt remains	White ppt dissolves and a colourless solution is produced

A **precipitation reaction** occurs – when two solutions are mixed, the positive ions from one react with the negative ions of the other and an insoluble solid precipitate forms. The sodium hydroxide solution and the ammonia solution contain hydroxide ions. The negative hydroxide ions react with the positive metal ions to form an insoluble metal hydroxide.

Anion tests

1. Test for chloride/bromide/iodide

Method

- If the sample is a solid, dissolve in water, or if insoluble in water use nitric acid.
- Add a few drops of **silver nitrate solution**
- If a white ppt forms – the solid contained chloride ions
- If a cream ppt forms – the solid contained bromide ions
- If a yellow ppt forms – the solid contained iodide ions

Ionic equation: $Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$ [higher tier]
$Ag^{+}(aq) + Br^{-}(aq) \rightarrow AgBr(s)$ [higher tier]

This is a precipitation reaction.

2. Test for sulfate ions

Method

- If the sample is a solid, dissolve in water, or if insoluble in water use nitric acid.
- add a few drops of **barium chloride solution**
- If a white ppt forms – the solid contained sulfate ions

Ionic equation: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ [higher tier]

This is a precipitation reaction.

3. Test for carbonate ions

Method

- Add dilute hydrochloric acid to the solid sample
- Test the gas produced with limewater
- If the limewater changes from colourless to milky then a carbonate is present.

Ionic equation : $2H^{+}(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$

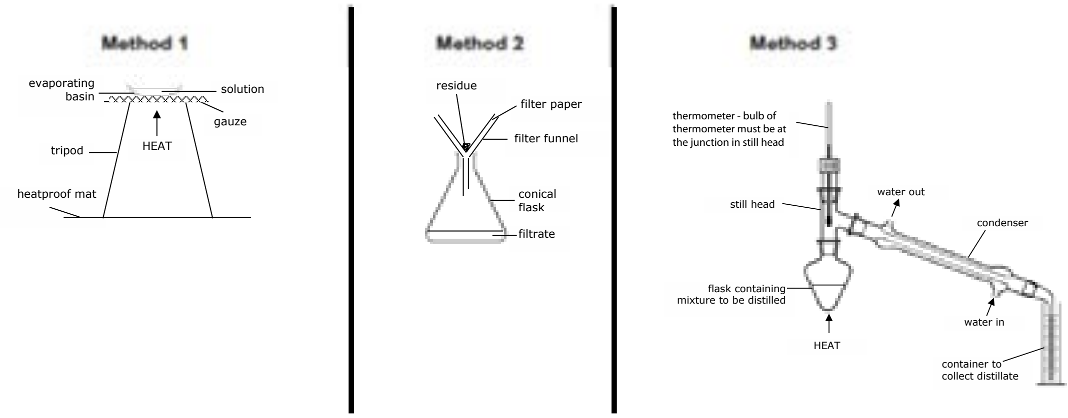
This is also the test for hydrogencarbonate ions. The ionic equation is

$H^{+}(aq) + HCO_3^{-}(aq) \rightarrow CO_2(g) + H_2O(l)$ [Higher tier]

Questions

1 Mixtures may be separated in the laboratory in many different ways.

(a) Three different methods of separating mixtures are shown below.



(i) Which method (**1**, **2** or **3**) would be most suitable for obtaining water from salt solution?

____ [1]

(ii) Which method would be most suitable for removing sand from a mixture of sand and water?

____ [1]

(iii) Explain fully why Method 2 would **not** be suitable to separate copper(II) sulfate from copper(II) sulfate solution.

____

____ [1]

(iv) What general term is used for liquid **A** collected in Method 2 and liquid **B** collected in Method 3?

A ____

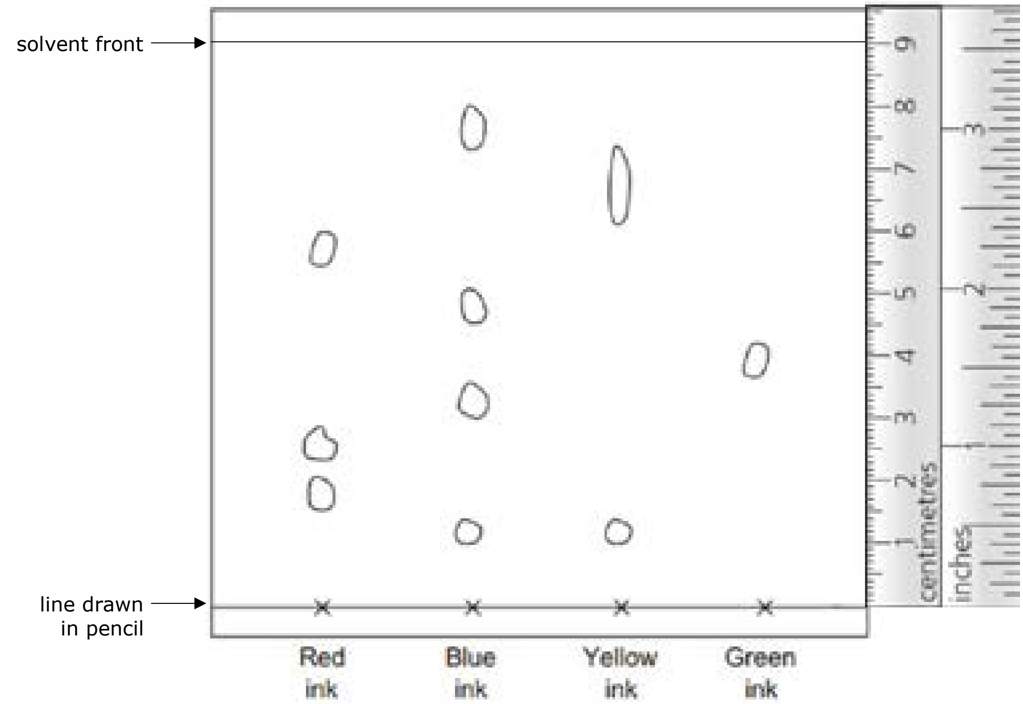
B ____ [2]

(v) Liquid B was found to have a boiling point range of 79 and 82 °C. Is liquid B pure? Explain your answer.

____

____ [2]

(b) A student analyses four different inks using paper chromatography. The inks are spotted along a pencil line. The chromatography paper is placed in a solvent and the coloured components in the inks separate out. The resulting chromatogram is shown below.



(i) Which ink contains four different components?

______________________________ [1]

(ii) Which ink contains the most soluble component?

______________________________ [1]

(iii) Which **two** inks contain one common component?

______________________________ [1]

(iv) What do you understand by the term solvent?

______________________________ [1]

(v) Which ink is a pure substance?

______________________________ [1]

(vi) What is meant by the term **pure substance**?

____

____ [1]

(vii) Calculate the R_f value for green ink. Take your measurements to the centre of the spot.

____

____

____

____ [2]

(viii) Name the stationary phase in this experiment.

____

____ [1]

2 Potable water can be produced from fresh water.

(a) What is potable water?

____

____ [1]

(b) Name and state the purpose of the three keys steps in the production of potable water from fresh water.

____

____

____

____

____

____ [3]

(c) What is desalination?

____

____ [1]

3 (a) Describe the method of a flame test, and state the result if copper(II) chloride is tested in a flame test.

____

____

____

____ [4]

(b) Describe a different test for to prove that copper(II) chloride contains copper(II) ions, and state the result for a positive test.

____

____

____

____ [4]

(c) Describe a test to identify a chloride ion and state the result for a positive test.

____

____

____ [3]

(d) People who suffer from anaemia are often prescribed iron supplements. The supplements contain iron(II) sulfate.

Describe in detail how a solid iron supplement may be tested to confirm the presence of iron(II) ions and sulfate ions.

Your answer should include:

- The chemical test for iron(II) ions and the expected result
- The balanced ionic equation for the test for iron(II) ions
- The chemical test for sulfate ions and the expected result
- The balanced ionic equation for the sulfate ion test.

In this question you will be assessed on your written communication skills including the use of specialist scientific terms.

____

____

____

____

____

____

____

____

____

____ [6]