Methods of Separating and Purifying Substances Notes

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There are a number of different ways to separate different substances. Whether it is filtration, evaporation or distillation etc, we need to know how each method works and of equal importance we must know when each one is used. Before we look at this let's look at the meaning of the word "pure" in Chemistry.

A pure substance: consists only of one element or one compound. Pure substances melt and boil at specific temperatures.

A mixture: consists of two or more different substances, not chemically joined together. Mixtures melt and boil over a range of temperatures.

A compound: consists of two or more elements chemically combined.

Before we continue let's start by defining a few key terms that we will used a lot in our explanations 😊

Solute: the substance, usually a solid that is dissolved. For example, sugar.

Solvent: the substance that dissolves the solute. For example, hot water.

Filtrate: the liquid that is collected once it passes through the filter paper and filter funnel.

Distillate: the liquid that comes out of the condenser at the end of the distillation.

A fraction: (in terms of fractional distillation): a part of crude oil.

Formulations: a mixture that has been designed as a useful product. Most substances are formulations.

Simple Distillation

Simple distillation: the process of separating a solvent from a solution by evaporating the solution and then condensing the solvent so that it can be collected.

How does it work? Simple distillation works by separating different substances based on their boiling points.

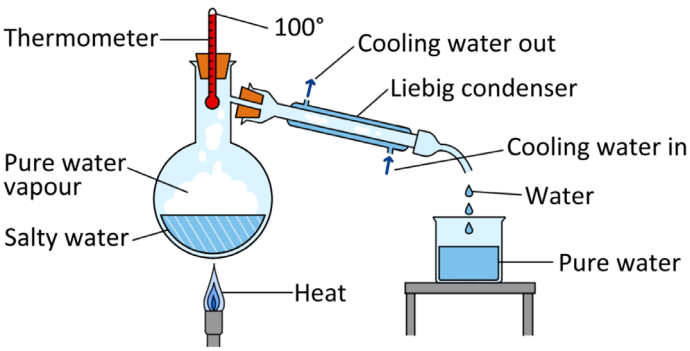
Here's a step by step for how distillation works 😊

Step 1: Heating and evaporation: The solution is heated, the solvent has a much lower boiling point than the solute, the solvent boils and evaporates, turning into a vapour. The solute is left behind in the flask.

Step 2: Cooling and condensation: The hot vapour rises and is forced down into a Liebig condenser.
The condenser is wrapped in a cooling jacket with cold water constantly flowing through it. This causes the hot vapour to condense from a vapour to a liquid.

Step 3: Collection: The pure liquid drips into a collecting beaker. This collected pure liquid is known as the distillate.

Where is it used? Separating pure liquid water from salty water and making distilled water.



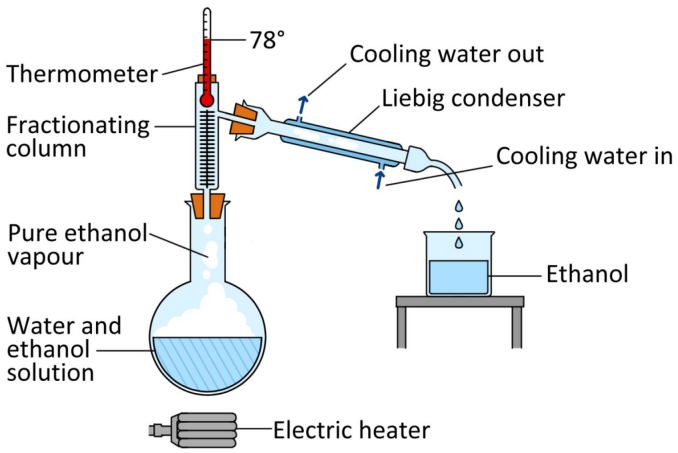
The figure shows the set up for a simple distillation

Fractional Distillation

Fractional distillation: a method of separating a mixture of liquids with different boiling points into individual components called fractions.

Where is it used? It is useful for separating ethanol (alcohol) from a mixture of ethanol and water and for separating crude oil into its different fractions for example, gasoline and kerosene. Let's look at each of these methods 😊

Fractional Distillation – Ethanol and Water



This works in a very similar way to simple distillation and it follows similar steps.

Heating and evaporation – An electric heater is used as ethanol is flammable. Both liquids evaporate and rise into the column.

Separation in the Column – The fractionating column is hotter at the bottom and cooler at the top.
Water vapour cools, condenses, and drips back down.

Cooling and condensation – Ethanol vapour reaches the top of the column and enters the Liebig condenser, which condenses it back into a liquid.

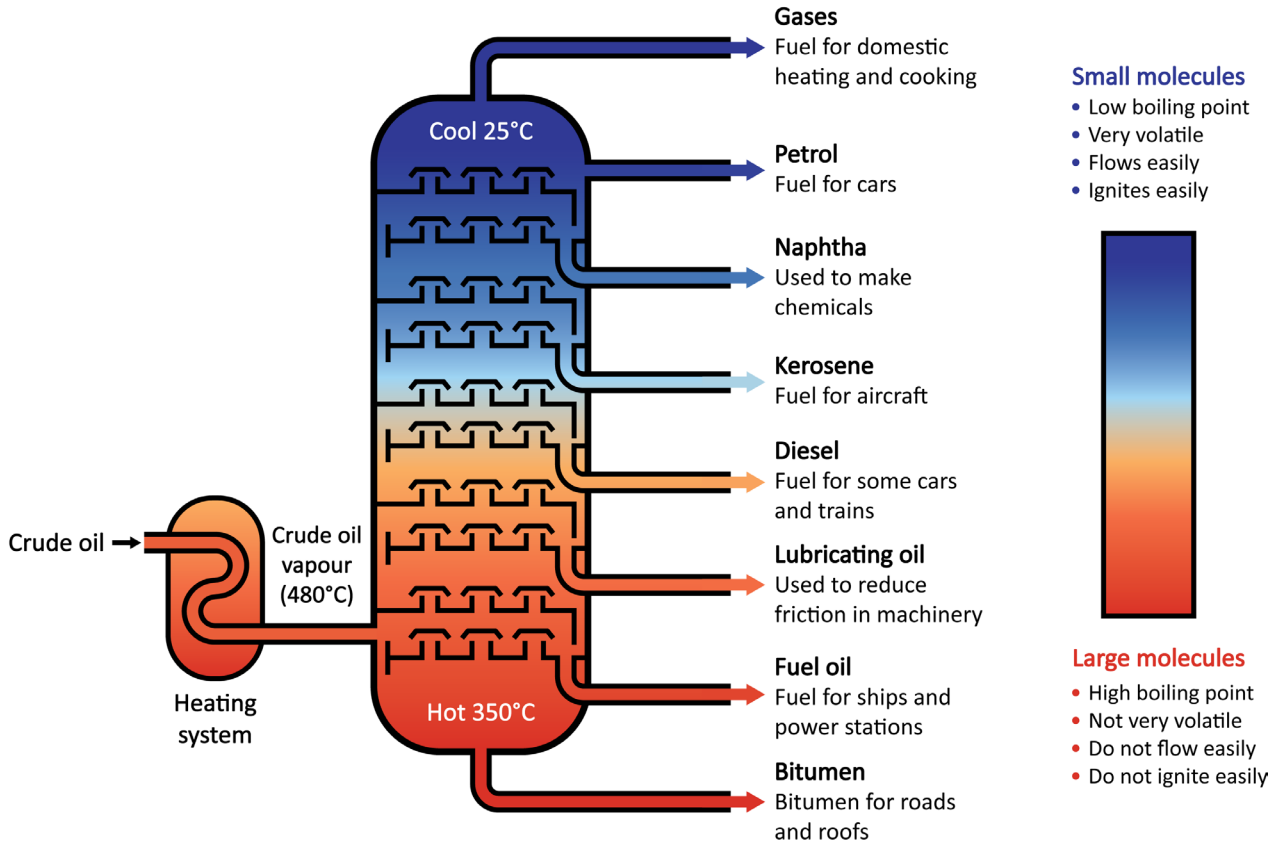
Collection – the ethanol liquid is collected.

Fractional Distillation – Crude Oil

Questions in exam papers tend to ask about fractional distillation in the form of fractionating columns dealing mostly with separating crude oil into its various fractions.

How does it work? Heated crude oil vapours rise, cool, and condense into liquids when they reach their specific boiling points.

The diagram below gives a guide to the fractional distillation of crude oil. Please be aware of roughly where each fraction comes off and a use of each fraction.

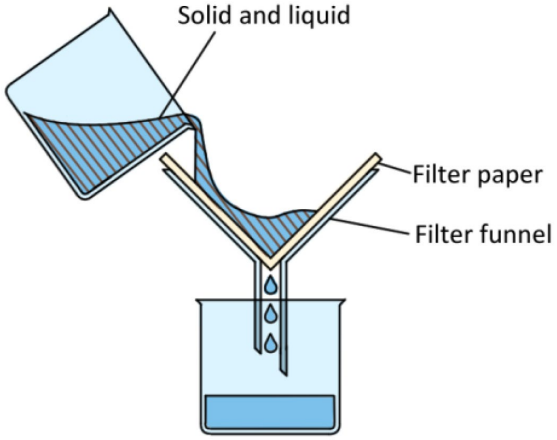


Filtration

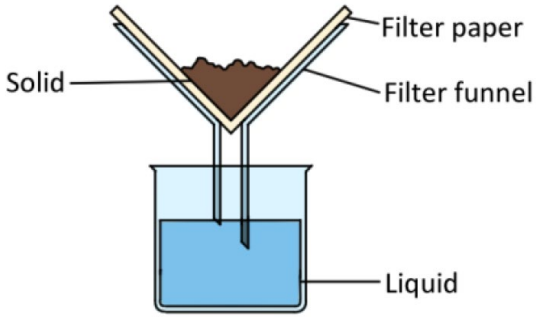
Filtration: separates different substances based on their solubility. Insoluble material is caught in the filter and removed.

Where is it used?
To remove solid debris from a solution. We see this used in water treatment, to produce clean safe drinking water. Filtration is used here to remove things like leaves and any large debris in the water.

How does it work?
Filtration works because the filter paper has pores in it. These are large enough to let small molecules such as water and dissolved ions through, but not the much larger particles of undissolved solid such as sand.



Beginning of filtration



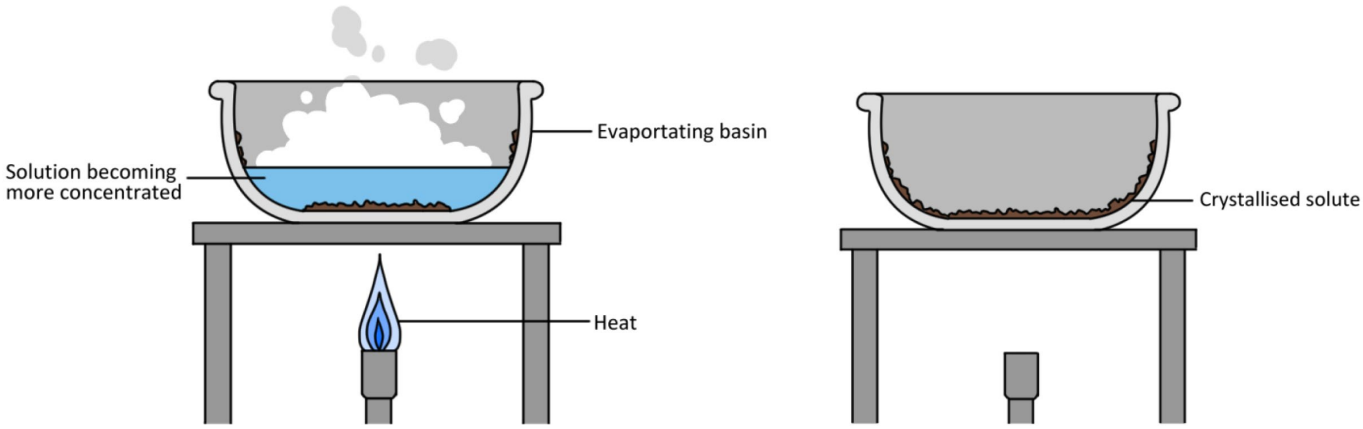
End of filtration

Crystallisation

Crystallisation: separating the solute from the solution by evaporating the solvent.

Where is it used?
The best example for GCSE involves sea salt. People who make sea salt trap sea water when the tide is in. When it goes out the sun evaporates the water that's trapped leaving behind crystals of salt, sodium chloride. Besides that, there are many industrial uses but we won't be asked to provide more than one example.

How does it work?
Crystallisation works by separating different substances based on evaporating the water that the solute is dissolved in.



Chromatography

Paper chromatography: chromatography carried out by spotting (placing) drops of the sample on to paper and then allowing a solvent to move up the paper. Different components in the samples travel up the paper in the solvent at different rates.

Note: The line is drawn in pencil as pencil (graphite) is not soluble in water.

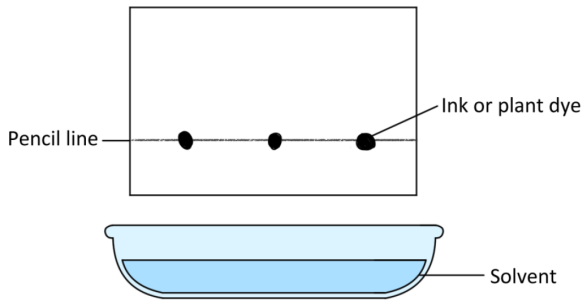
Where is it used? Paper chromatography is used to separate mixtures of soluble substances such as inks. It can be used in forensic science to help police determine which pen was used to write a letter for example.

How does it work? Basically, paper chromatography separates different substances based on their solubility. Less soluble substances don't move very far while very soluble materials could be found quite near the top.

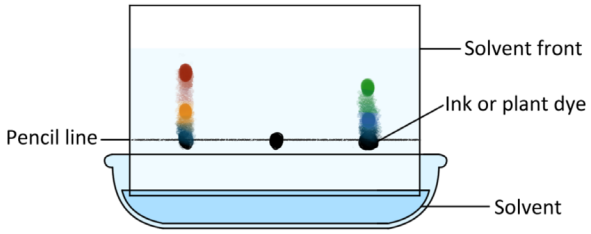
Chromatography has **two** phases the stationary phase and the mobile phase.

1. In the **stationary phase,** the samples are placed on to the paper.
2. In the **mobile phase,** the solvent moves up the paper, carrying the solutes as it moves.

The different dissolved substances in a mixture are attracted to the two phases in different proportions. This causes them to move at different rates through the paper.



The stationary phase



The mobile phase

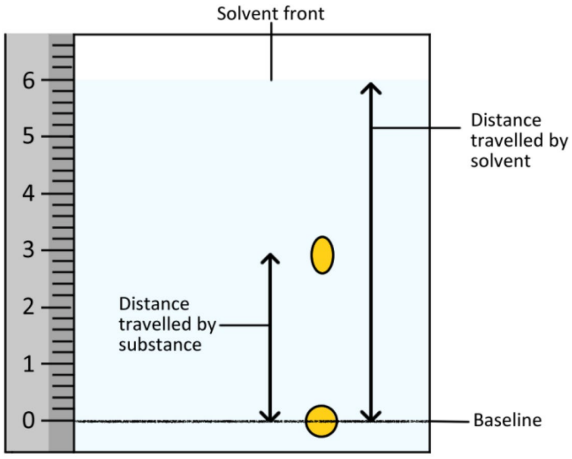
Calculating Rf

What is Rf and how do we calculate it? Rf is a value that represents how far a specific substance travels up the chromatography paper compared to the solvent. Every pure substance travels a specific distance in a given solvent, the Rf value acts as a unique numerical identifier that can be used to figure out what an unknown chemical is.

How is Rf calculated? The R_f value of a sample is calculated using the following formula:

$$Rf = \frac{\textit{distance moved by the substance}}{\textit{distance moved by the solvent}}$$

Take the following example:



$R_f = {}^{3}/_{6}$

$R_f = 0.5$

That's it 😊 R_f does not have a unit.

Exam hint: your calculated R_f value should be between 0 to 1. If you get values outside of this range something has gone wrong.

And finally, let's look at how to answer a very popular exam paper question. These types of questions ask you how to get a pure dry sample of a substance, usually out of a reaction that they give you in the question.
Let's look at an example question and the ideal answer.

"Describe how a sample of pure, dry nickel sulfate crystals can be obtained from the mixture of nickel sulfate solution and excess solid nickel carbonate in the beaker."

Ideal Answer

Content:	**Marks**
First, we should filter the solution to remove any remaining solid nickel carbonate.	(1)
Any two of the remaining points used correctly:	
The filtrate/solution should then be heated in an evaporation dish to remove some of the water.	(1)
The solution should then be left to cool and crystallise.	(1)
Dry the crystals between two pieces of filter paper.	(1)
	Total: 3 marks

The underlined content is the key information that you must mention to get the mark.