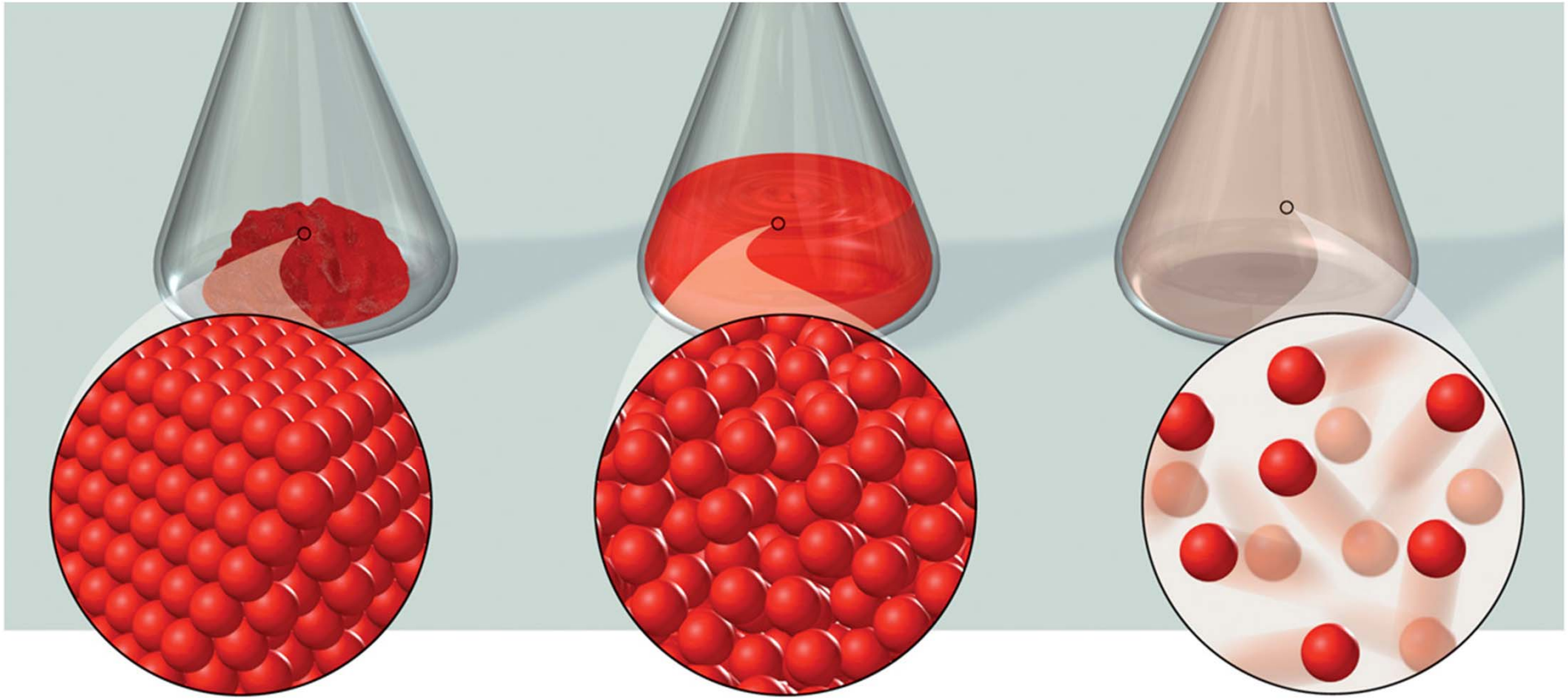
States of matter

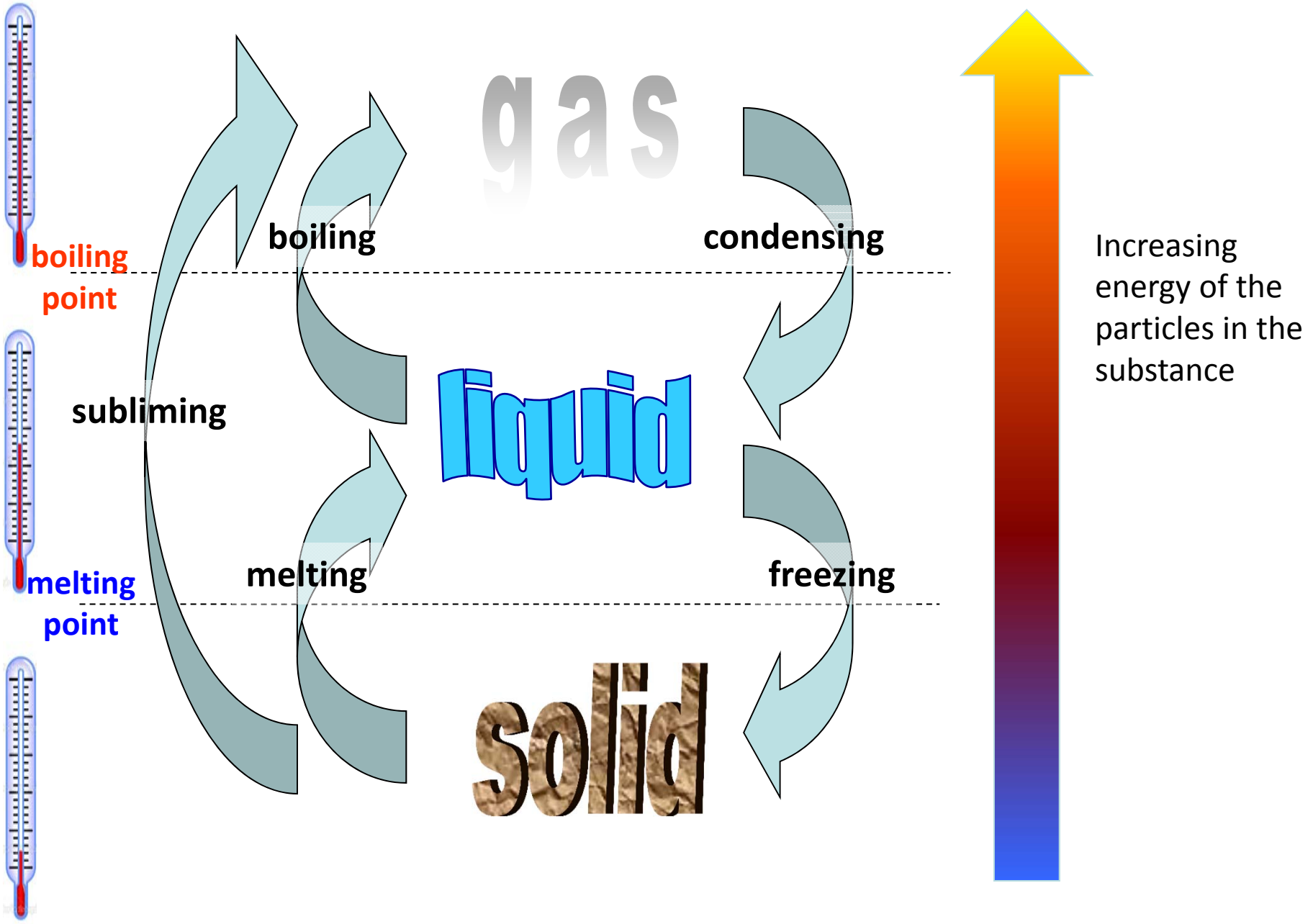


Particles in a solid are closely packed and can vibrate but cannot move around, they have **low energies**.

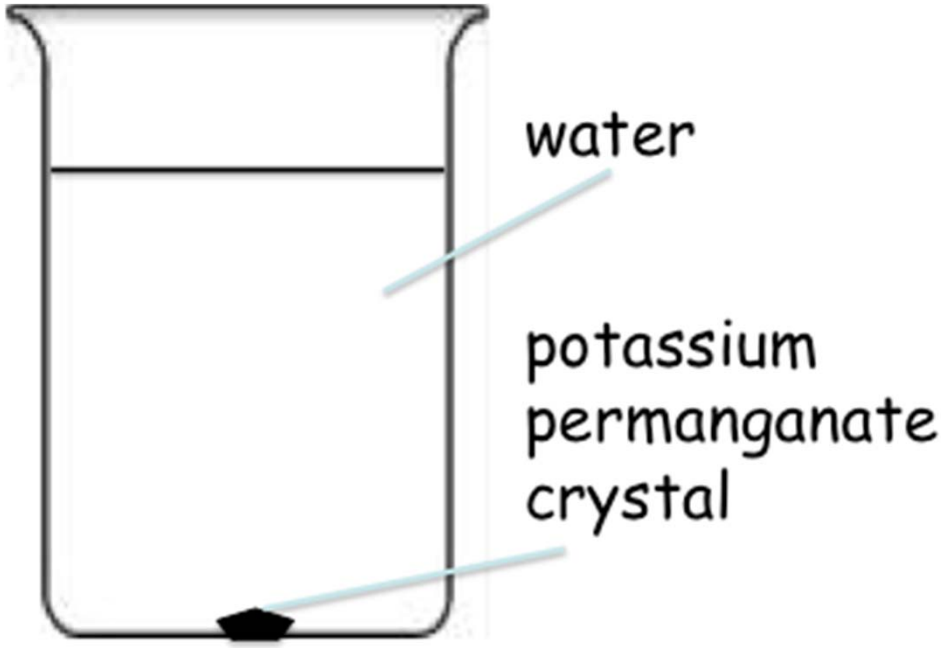
Particles in a liquid are still closely packed, but can both vibrate and move around within the liquid because they have **more energy** – enough to overcome the forces that hold the particles together in the solid.

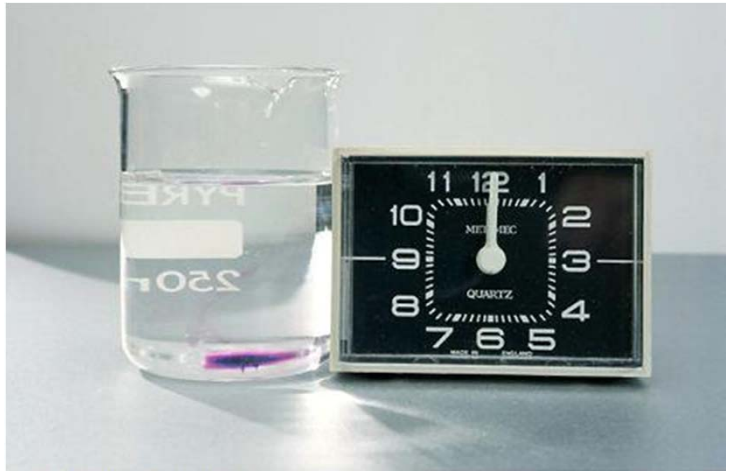
Particles in a gas are widely spread out and can both vibrate and move around freely. They have the **most energy** of the three states.

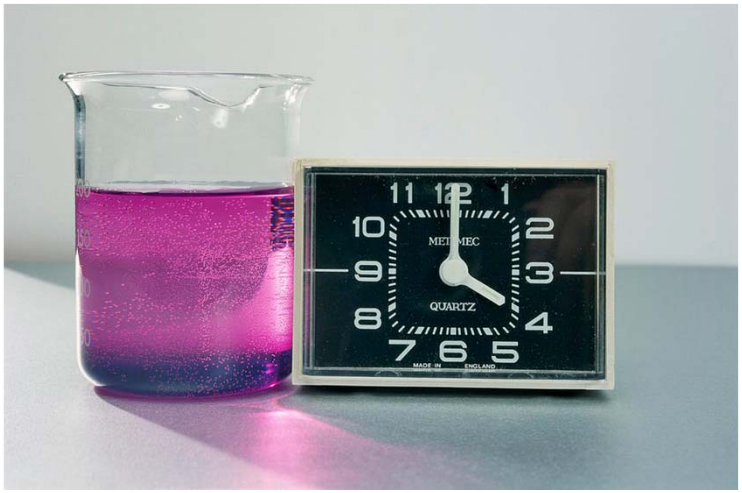
Changing state



Experiment to show how particles move (diffusion) in solution



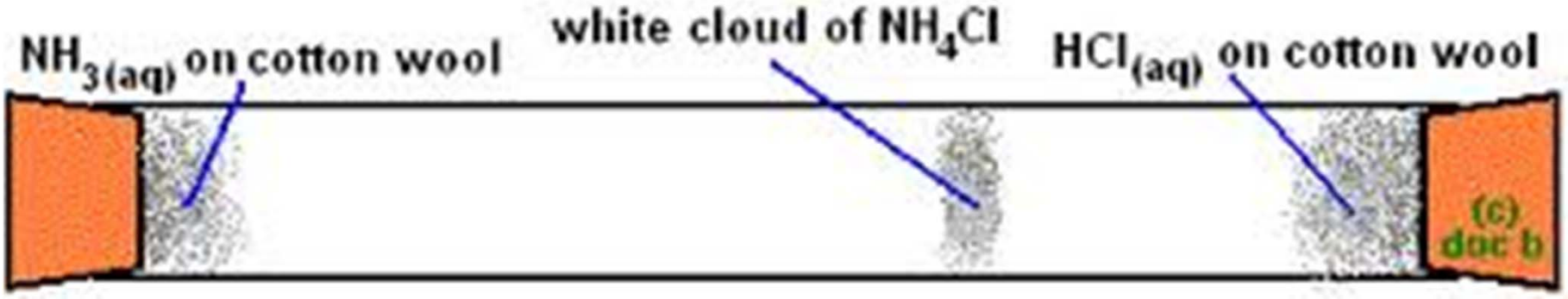




The crystal dissolves, and the purple permanganate ions **diffuse** slowly throughout the whole volume of the water.

They do this because both the water molecules and the dissolved particles of permanganate are constantly moving.

Experiment to show how gas particles move (diffusion)



The hydrogen chloride and the ammonia gases both **diffuse** into the tube, because the particles are constantly moving.

Where they meet, they react forming a white 'smoke ring' of ammonium chloride.

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

The smoke ring forms nearer the hydrogen chloride end, because ammonia moves and diffuses more quickly than hydrogen chloride as the ammonia particles are smaller and lighter.

At **higher temperature**, the gas particles would have more **kinetic energy**, and therefore **diffuse more quickly**.

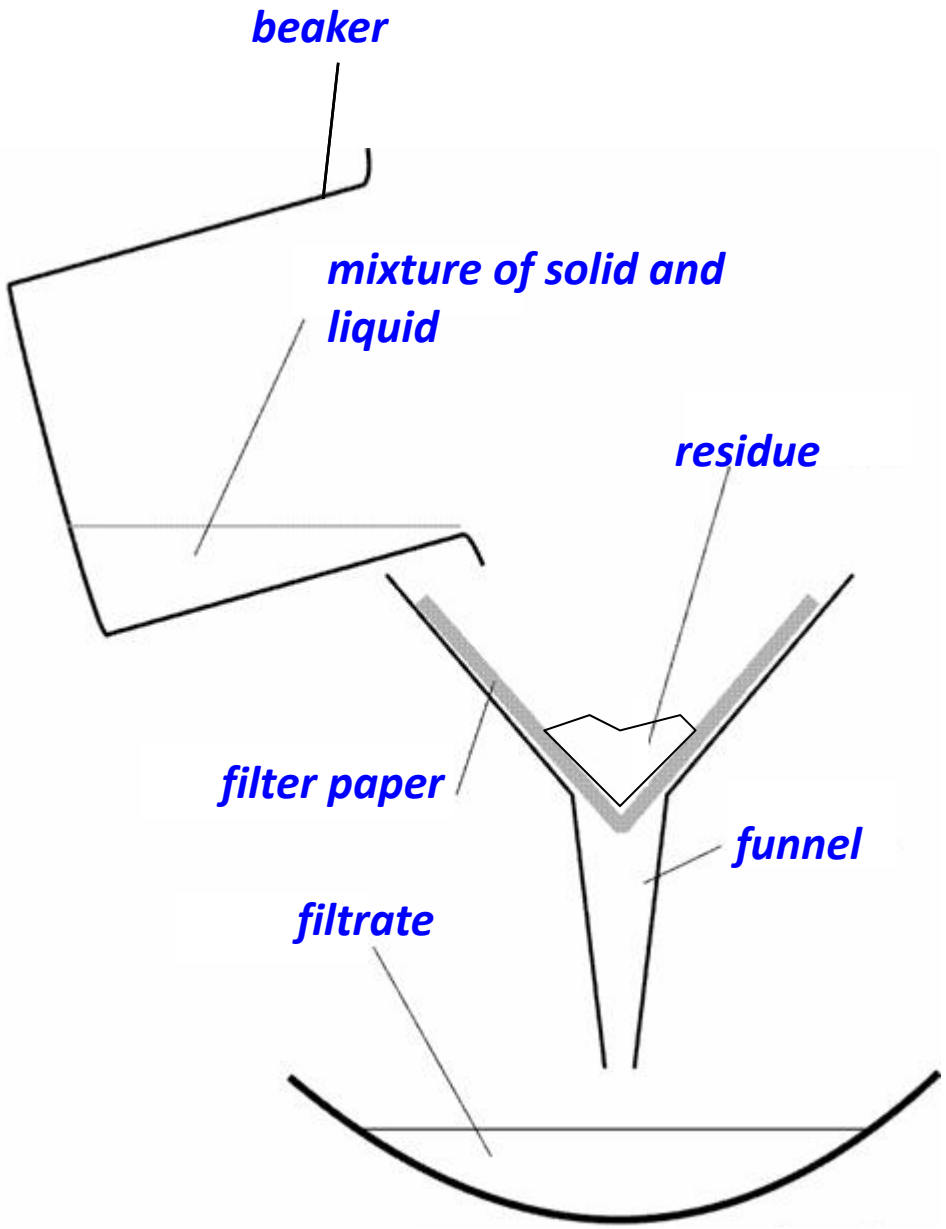
Separation Techniques

Method: Filtration

Separates: Solid from liquid or solution

How it works: solid particles (the residue) are unable to pass through the small gaps between the fibres in the filter paper so remain trapped while the liquid or solution (the fltrate) passes through.

Used for: e.g. removing unreacted solid from a solution of a salt, removing a precipitate from a solution

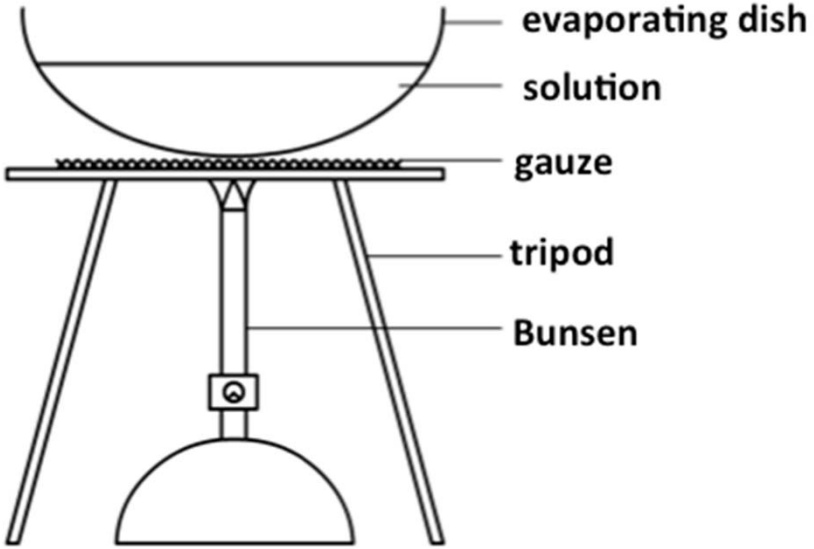


Method: Crystallisation

Separates: A dissolved substance (solute) from a solution

How it works: The solvent molecules gain enough energy to change state from liquid to gas, and escape making the remaining solution more concentrated. Once the solution has become saturated, removing any more solvent molecules causes the solute to form crystals of the solid material. The solid crystals can be removed from remaining solution by filtration.

Used for: Obtaining a sample of crystals of a substance from a solution of the substance.



KEY WORDS:

solute: a solid which will dissolve in a solvent to form a solution

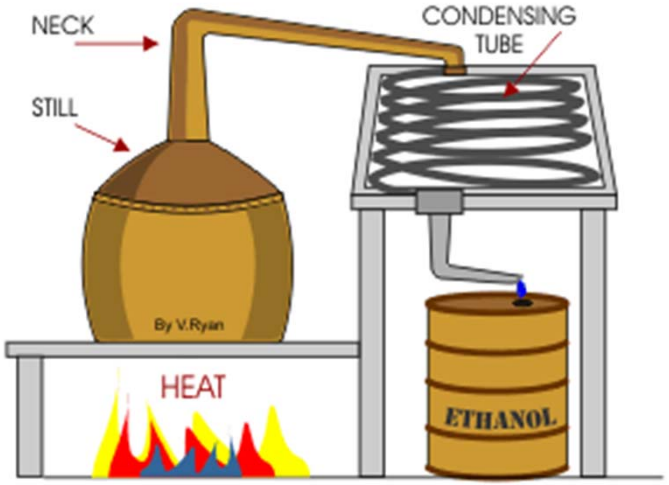
solvent: a liquid in which a solute can dissolve

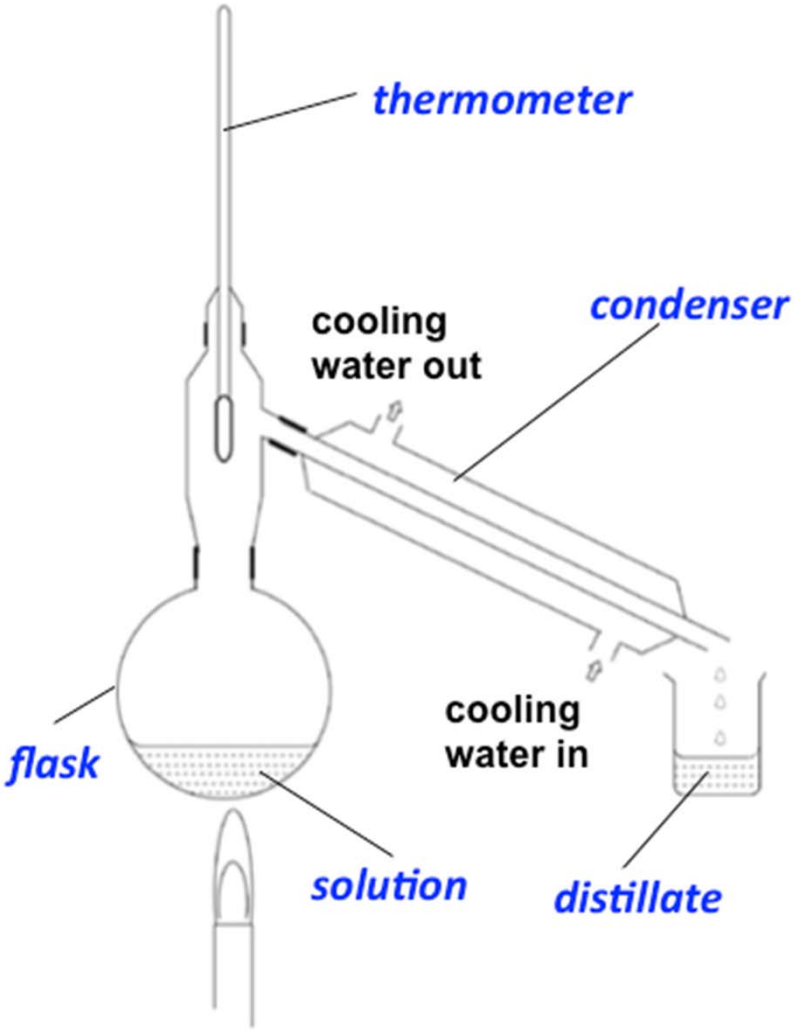
solution: a mixture containing one or more solute dissolved in a solvent

Method: Simple Distillation

Separates: Liquid from a mixture of liquids, or solvent from a solution

How it works: If a solution is heated, the solvent can be evaporated leaving the solute in the flask. If a mixture of liquids is slowly heated, the liquid with the lowest boiling point can be evaporated leaving other liquids in the flask. The evaporated vapour travels into the condenser where it is cooled and condenses to form the distillate which is collected





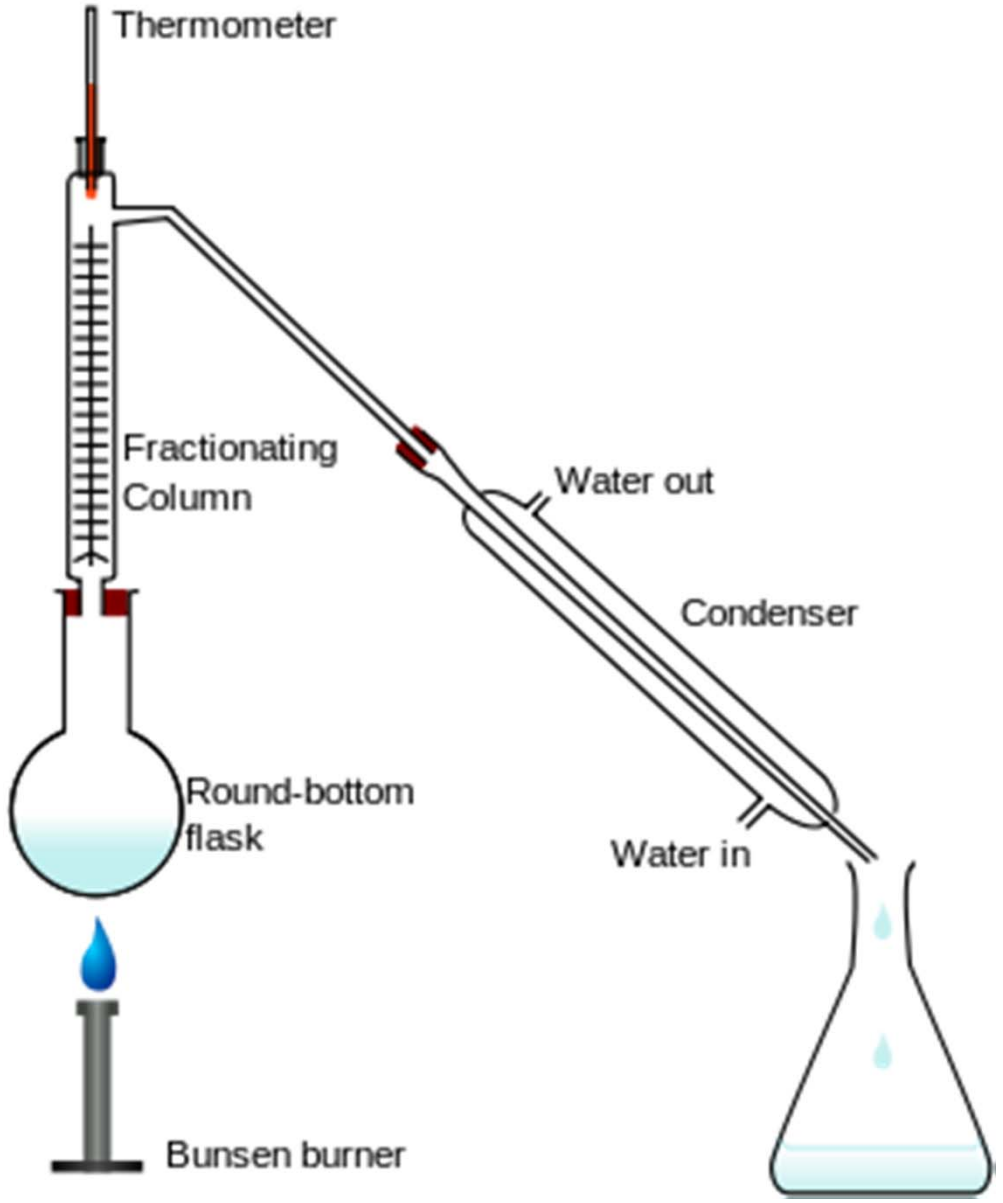
Used for: e.g. Obtaining pure water from salt water (seawater), obtaining pure ethanol (e.g. for a biofuel) from a fermentation mixture

Method: Fractional Distillation

Separates: Liquids from a mixture of several different liquids

How it works: The fractionating column has a temperature gradient; temperature decreases up the column. When each liquid in the mixture reaches its boiling point it evaporates and by slowly increasing the temperature each vapour can be separated and moved into the condenser where it cools and condenses to be collected.

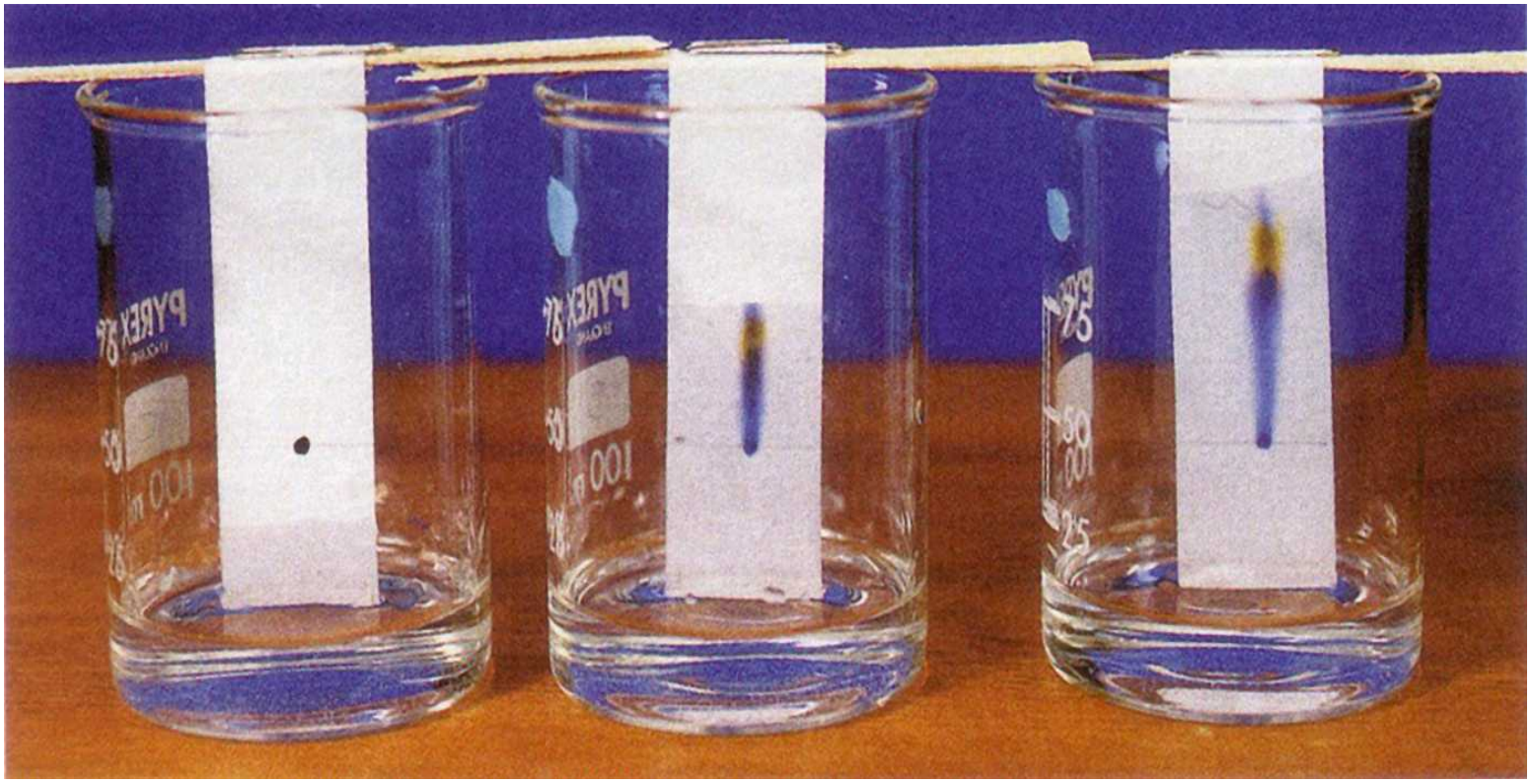
Used for: separating the different fractions in crude oil. Note that a similar technique but at very low temperatures can be used to separate the gases in air



Method: Paper Chromatography

Separates: Different dissolved components of a liquid mixture such as the colouring additives in food, or pigments in inks.

How it works: The solubility of each additive determines how fast it will travel up the chromatography paper when carried along by the solvent (the more soluble, the faster the component moves), so the components end up being separated. Insoluble components won't move at all.

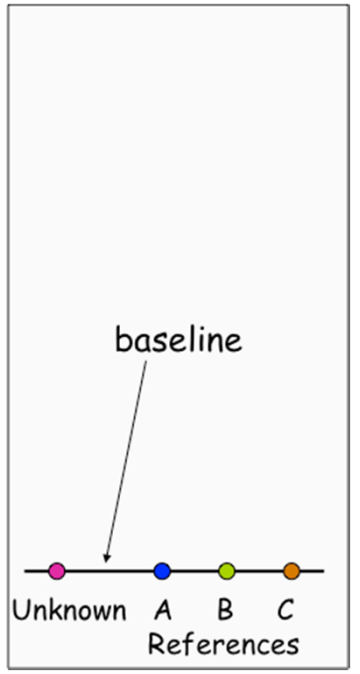


Setting up:
A **baseline** is drawn in pencil on the chromatography paper (not ink, as it would separate too, interfering with the results).

A small spot of the unknown mixture is placed alongside spots of pure substances which may be present (**references**).

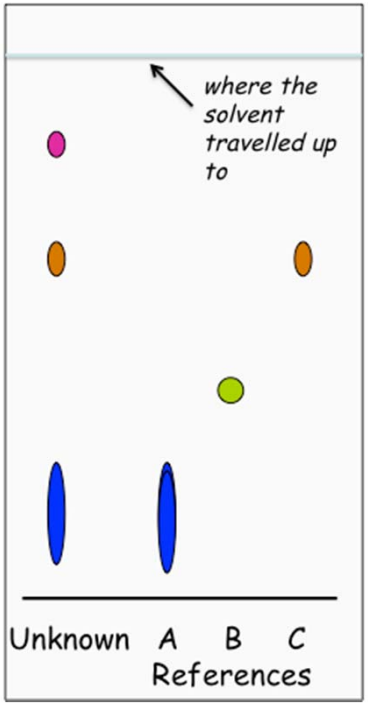
The bottom edge of the paper is then dipped in the solvent (usually water) and left while the solvent slowly soaks up to the top of the paper.

The solvent level must start **below the baseline** so that the substances being separated don't dissolve off the paper into the bulk of the solvent.



Results:
Each spot in the finished chromatogram is a different substance in the mixture (although sometimes substances with similar solubilities produce spots which are **overlapping**).

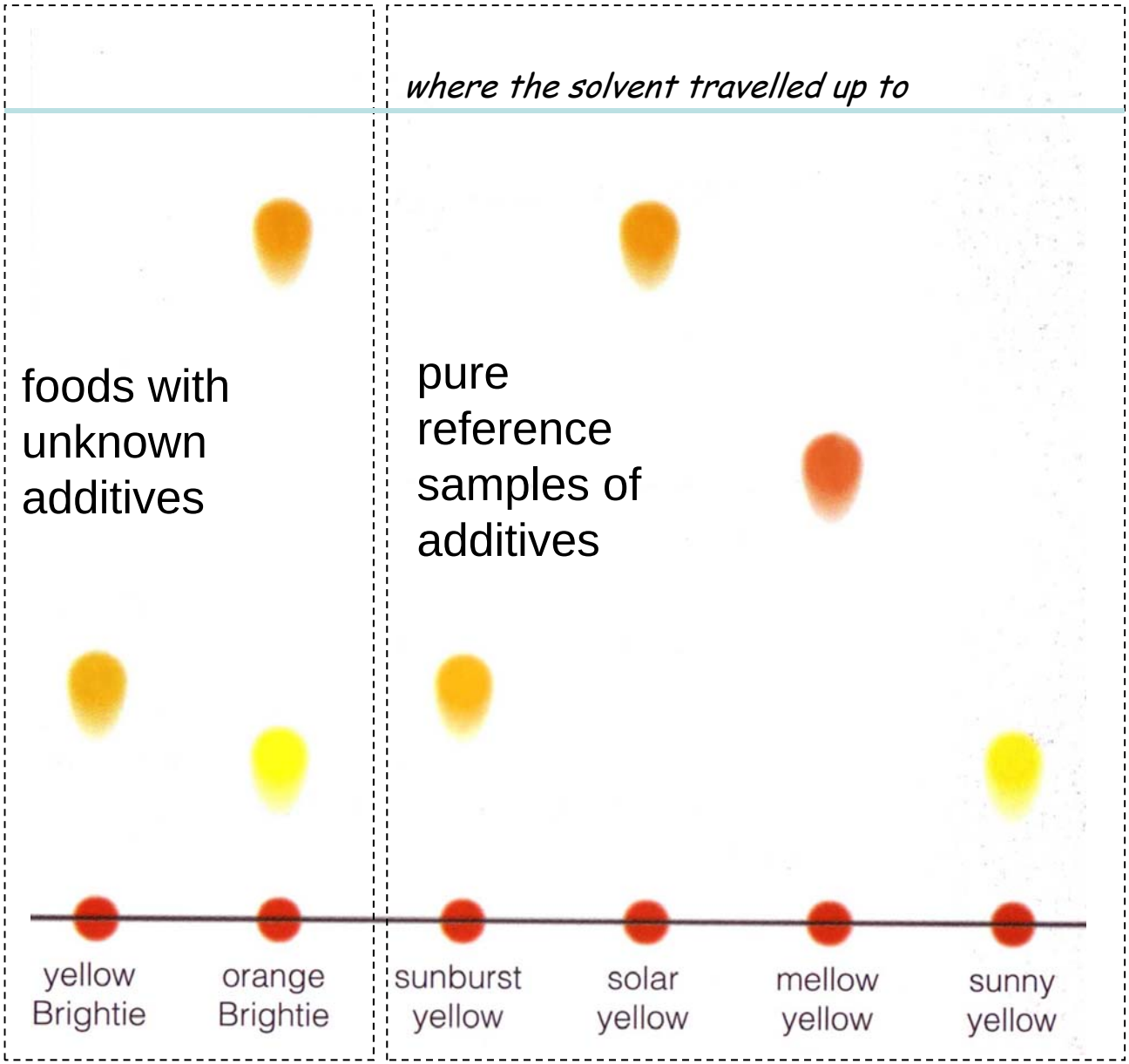
A match is found when one of the spots in the unknown sample is the **same colour** and at the **same height** (i.e. same R_f value) as a reference spot.



An R_f value can be calculated to help identify any spot:

$$R_f = \frac{\text{distance spot moved from baseline}}{\text{distance solvent moved from baseline}}$$

Practice:



Interpret the results of this chromatography experiment.

How many valid conclusions can you draw?

What is the R_f value of mellow yellow ?

Answers:

Conclusions:

- Yellow Brightie only contains one colouring additive, which is sunburst yellow.
- Orange Brightie contains two colouring additives. One of them is sunny yellow and one of them is solar yellow.
- Neither of the sweets contains mellow yellow.
- There are no unidentified additives in either of the sweets.

Rf value of mellow yellow:

Distance mellow yellow spot has travelled from baseline = 68mm
Distance solvent front has travelled from baseline = 122mm
Rf = 68 ÷ 122 **= 0.56**