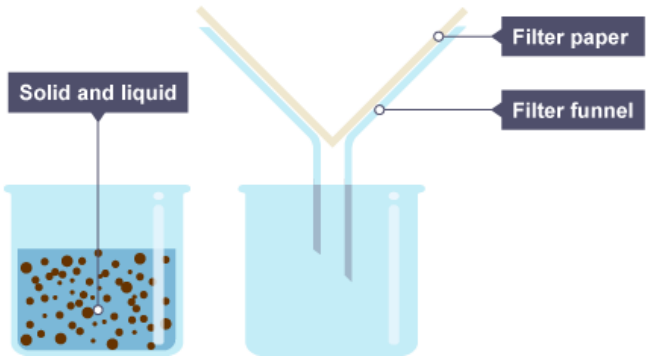
SEPARATION TECHNIQUES

If a substance does not dissolve in a solvent, we say that it is insoluble. For example, sand does not dissolve in water – it is insoluble.

Filtration is a method for separating an insoluble solid from a liquid. When a mixture of sand and water is filtered:

- the sand stays behind in the filter paper (it becomes the residue)
- the water passes through the filter paper (it becomes the filtrate)



1. A beaker containing a mixture of insoluble solid and liquid. There is filter paper in a filter funnel above another beaker.

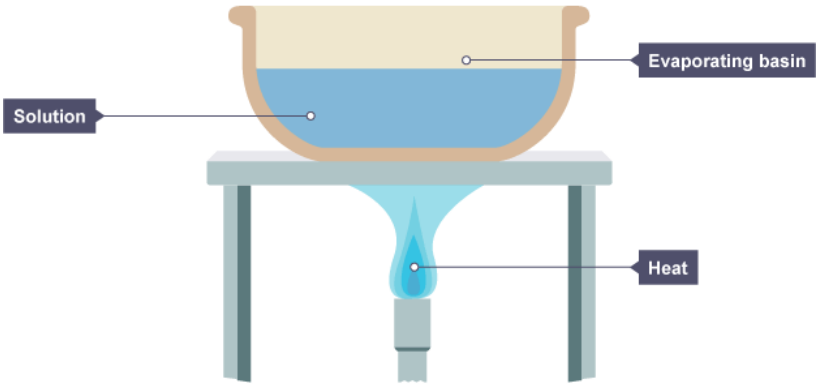
2. Pour the mixture through the filter funnel.

3. Let the water drain and leave the insoluble solid to dry.

Eg. Separating sand from Salt water.

Evaporation is used to separate a soluble solid from a liquid. For example, copper sulfate is soluble in water – its crystals dissolve in water to form copper

sulfate solution. During evaporation, the water evaporates away leaving solid copper sulfate crystals behind.

1. 

2. A solution is placed in an evaporating basin and heated with a Bunsen burner.
3. Reduce the volume of the solution until you get a saturated solution (concentrated solution)
4. Leave the sample to cool down and evaporate at room temperature
5. Filter the crystals from the solution and let it dry over a blotting paper.

Separating mixtures of liquids

Mixtures of liquids can be separated according to their properties. The technique used depends on whether the liquids dissolve in each other, and so are *miscible*, or if they are immiscible.

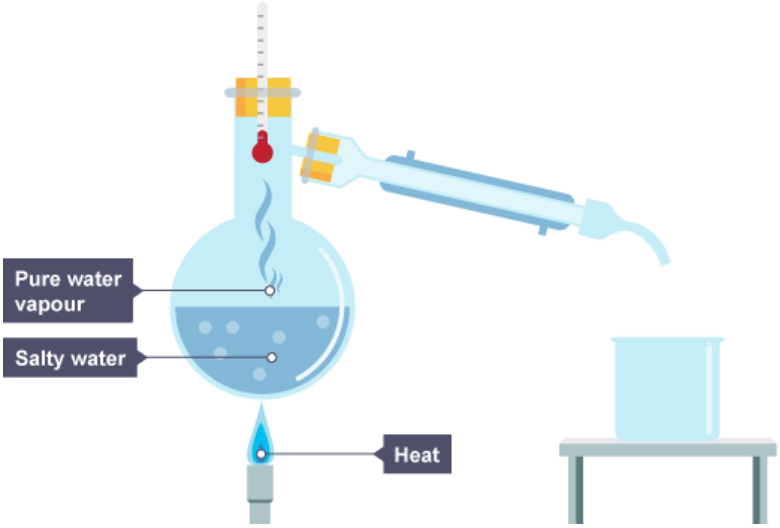
- Fractional distillation is a technique used to separate miscible liquids according to their boiling points.
- Simple distillation is to separate mixture of two miscible solvents
- Chromatography is used to separate mixtures of coloured compounds.

Separating the solvent from a solution – simple distillation

Simple distillation is a method for separating the solvent from a solution.

- For example, water can be separated from salt solution by simple distillation. This method works because water has a much lower boiling point than salt. When the solution is heated, the water evaporates.

- It is then cooled and condensed into a separate container. The salt does not evaporate and so it stays behind.



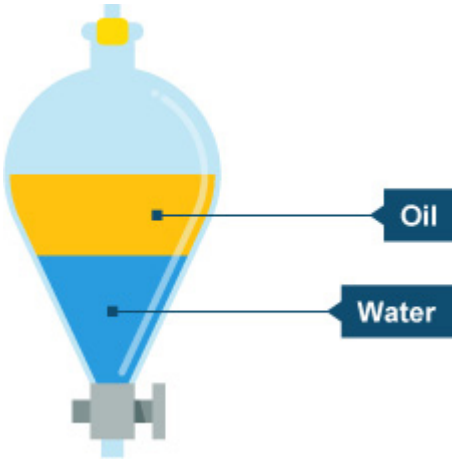
Every pure substance has its own particular melting point and boiling point. One way to check the purity of the separated liquid is to measure its boiling point. For example, pure water boils at 100°C. If it contains any dissolved solids, its boiling point will be higher than this.

Separation of liquids

- Liquids can be described in two ways –
  1. immiscible -do not mix together
  2. miscible – mix together

The separation technique used for each liquid depends on the properties of the liquids.

Immiscible liquids



- Oil and water can be separated using a funnel
- Immiscible means that the liquids don't dissolve in each other – oil and water are an example.
- It is possible to shake up the liquids and get them to mix but they soon separate.
- Separating immiscible liquids is done simply using a separating funnel. The two liquids are put into the funnel and are left for a short time to settle out and form two layers.
- The tap of the funnel is opened and the bottom liquid is allowed to run. The two liquids are now separate.

Miscible liquids

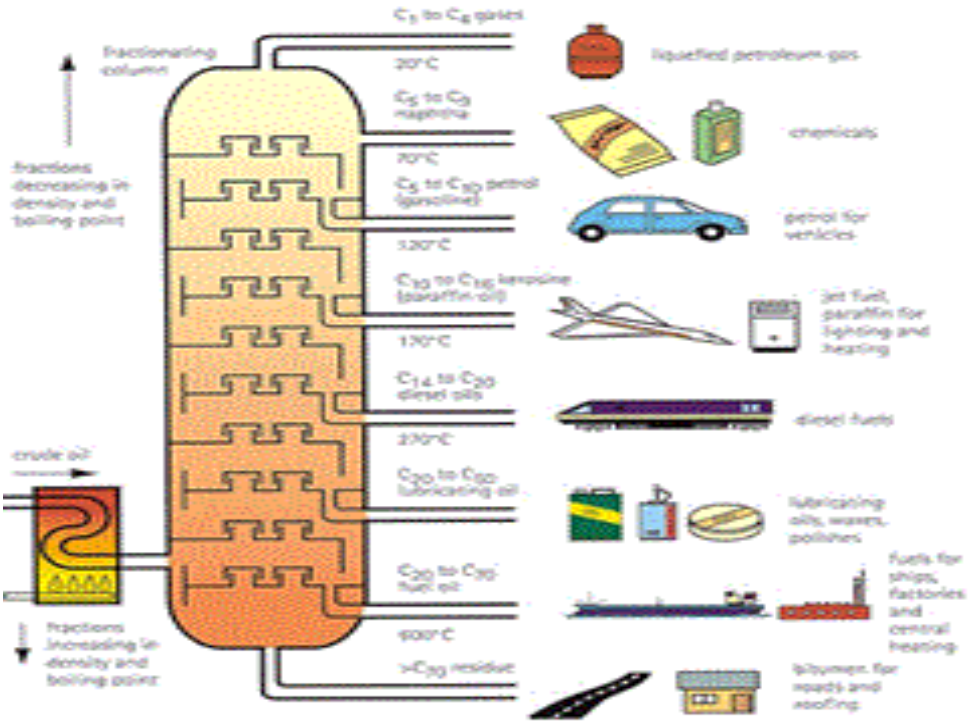
- Miscible liquids are harder to separate as they dissolve in each other.
- Miscible liquids are often separated using fractional distillation.
- This is possible as miscible liquids have different boiling points.

Fractional distillation of liquid air

You need to be able to explain how nitrogen and oxygen are obtained from the air.

- About 78 per cent of the air is nitrogen and 21 per cent is oxygen.
- These two gases can be separated by fractional distillation of liquid air.

Fractional Distillation column at an oil refinery



Liquefying the air

Fractional distillation

Air is filtered to remove dust, and then cooled in stages until it reaches –200°C. At this temperature it is a liquid. We say that the air has been liquefied.

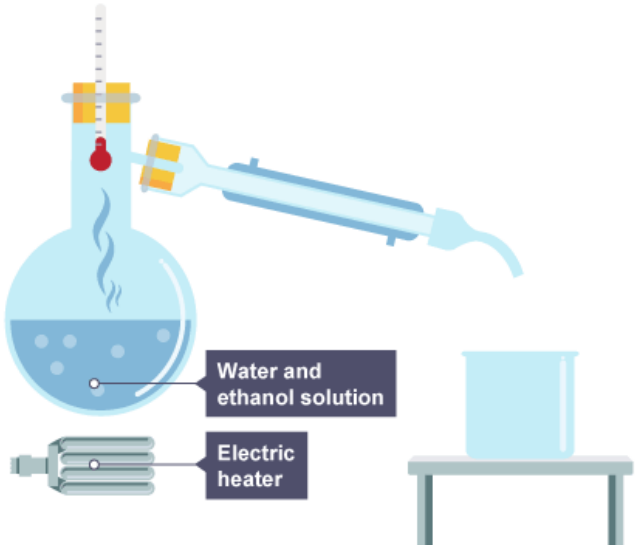
Here's what happens as the air liquefies:

1. Water vapour condenses, and is removed using absorbent filters
2. Carbon dioxide freezes at –79ºC, and is removed
3. Oxygen liquefies at –183ºC
4. Nitrogen liquefies at –196ºC

The liquid nitrogen and oxygen are then separated by fractional distillation.

Ex:

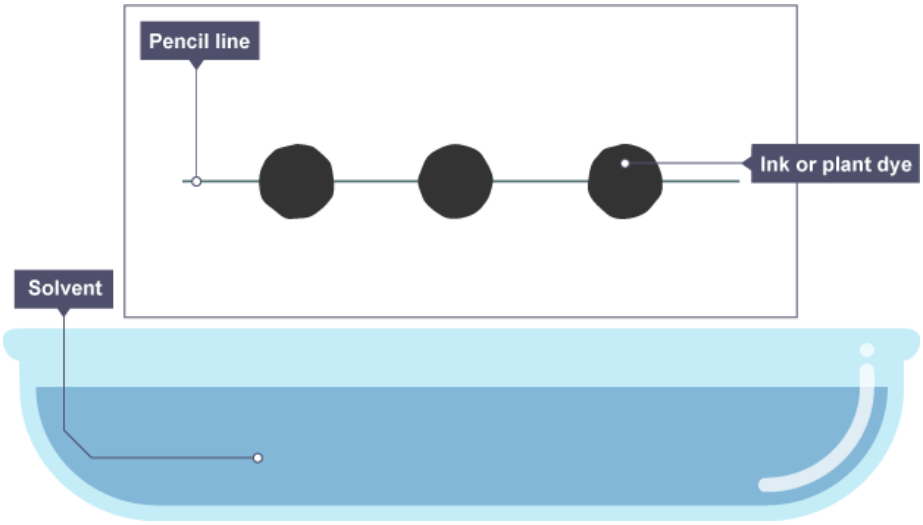
- Ethanol can be separated from a mixture of ethanol and water by fractional distillation.
- This method works because the liquids in the mixture have different boiling points.
- When the mixture is heated, one liquid evaporates before the other.



- One way to check the purity of the separated liquids is to measure their boiling points.
- For example, pure ethanol boils at 78°C and pure water boils at 100°C

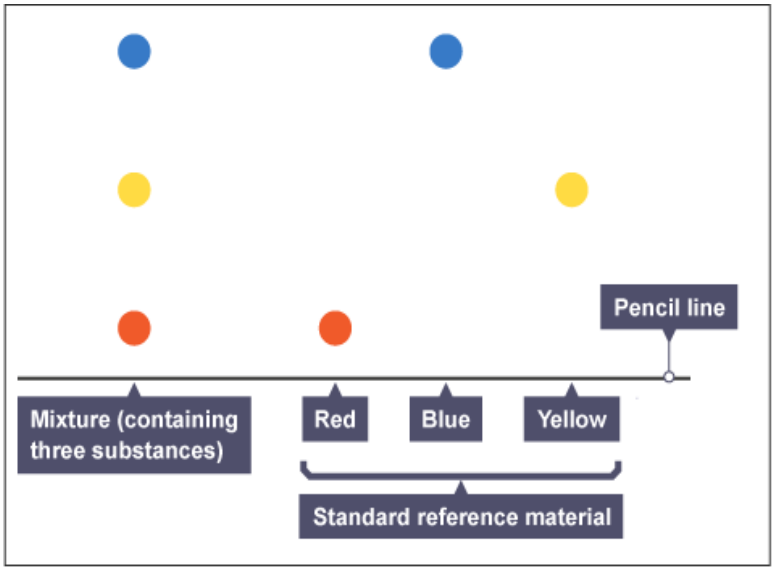
Chromatography

- Paper chromatography is a method for separating dissolved substances from one another.
- It is often used when the dissolved substances are coloured, such as inks, food colourings and plant dyes.
  t works because some of the coloured substances dissolve in the solvent used better than others, so they travel further up the paper.

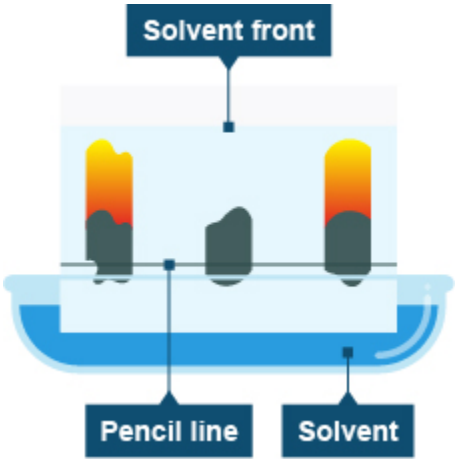


A pencil line is drawn, and spots of ink or plant dye are placed on it. There is a container of solvent, such as water or ethanol.[1]

- A pure substance will only produce one spot on the chromatogram during paper chromatography. Two substances will be the same if they produce the same colour of spot, and their spots travel the same distance up the paper.
- In the example below, red, blue and yellow are three pure substances. The sample on the left is a mixture of all three.



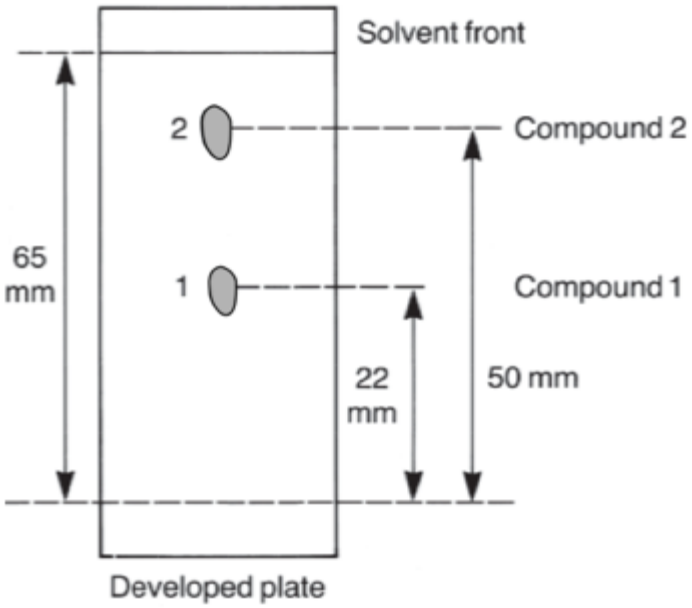
A chromatogram, the results of a chromatography experiment



- The colours separate and move up the paper at different rates
- Chromatography can be used to separate mixtures of coloured compounds.
- Mixtures that are suitable for separation by chromatography include inks, dyes and colouring agents in food.

Method

1. Simple chromatography is carried out on paper.
2. A spot of the mixture is placed near the bottom of a piece of chromatography paper and the paper is then placed upright in a suitable solvent, eg water.
3. As the solvent soaks up the paper, it carries the mixtures with it.
4. Different components of the mixture will move at different rates.
5. This separates the mixture out.



R_f values (Retardation factor) or Retention Value

- Different chromatograms and the separated components of the mixtures can be identified by calculating the Rf value using the equation:
- The Rf value is defined as the ratio of the distance moved by the solute (i.e. the dye or pigment under test) and the distance moved by the the solvent (known as the Solvent front) along the paper, where both distances are measured from the common Origin or Application Baseline, that is the point where the sample is initially spotted on the paper

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

- The Rf value of a particular compound is always the same - if the chromatography has been carried out in the same way.
- This allows industry to use chromatography to identify compounds in mixtures

Separation of Mixtures

In a mixture, since the constituent substances do not lose their identity, they can be separated easily by physical methods, taking advantage of the differences in their physical properties.

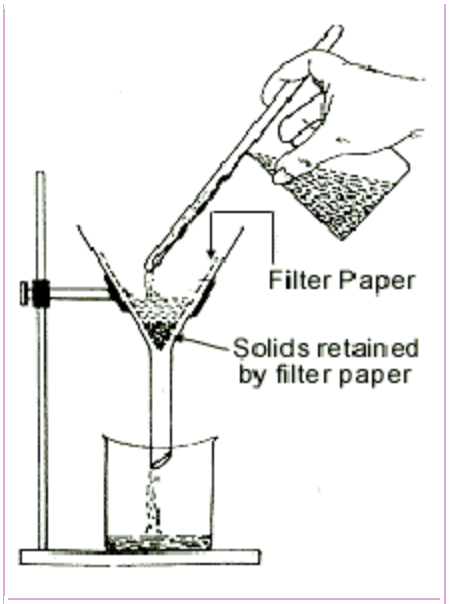


Fig 1: Filtration

Mixture of Solids and Liquids

Sedimentation and Decantation

Sedimentation is the process of separating an insoluble solid from a liquid in which it is suspended by allowing it to settle to the bottom of the container. If this also involves pouring off of the liquid leaving the solid behind, it is called decantation.

Filtration

Filtration is used for separating insoluble solids from a liquid.

When a mixture of *chalk* and *water* is poured through a filter paper in a funnel, *chalk*particles remains as *residue* in the filter paper, while the *water* gets collected in the beaker below as *filtrate*. (see Fig. 1)

Evaporation

Evaporation is used for recovering dissolved solid substances from solutions by evaporating the solvent. The solute "dissolves out" and is left behind.

Sugar can be recovered from a *sugar-water* mixture by evaporation.
The *water* evaporates to leave the solute behind. *Copper sulphate*, *potash alum*, *potassium nitrate* etc. can also be recovered from their aqueous solutions by evaporation.

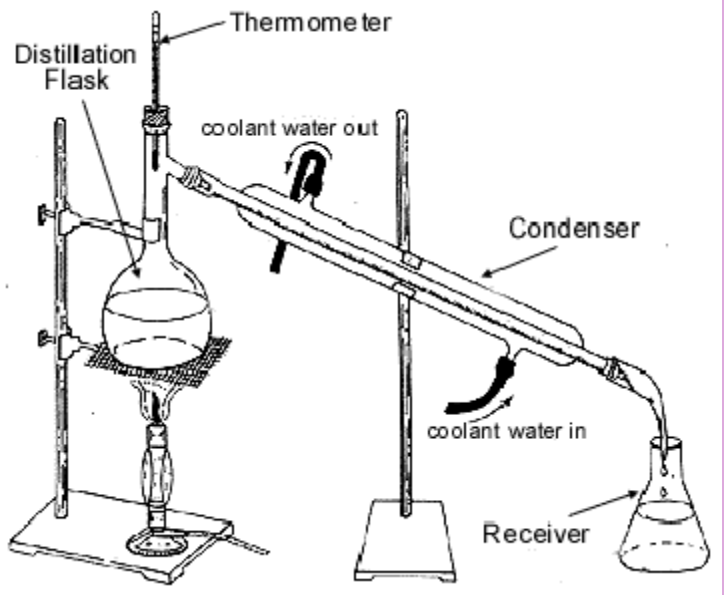


Fig 2: Distillation

Distillation

Distillation is the process of heating a solution containing soluble solids to form vapours of the liquid and then cooling the vapours to get the liquid back.

A mixture of *common salt* and *water* is taken in a *distillation flask* and heated. *Steam* rises up and comes out into the *condenser*, which is a coaxial tube with a central tube for vapour to pass through, and an outer tube through which cold water circulates to form a cold water jacket. *Steam*condenses in the central tube and collects in a *receiver* as *distillate*. (see Fig. 2)

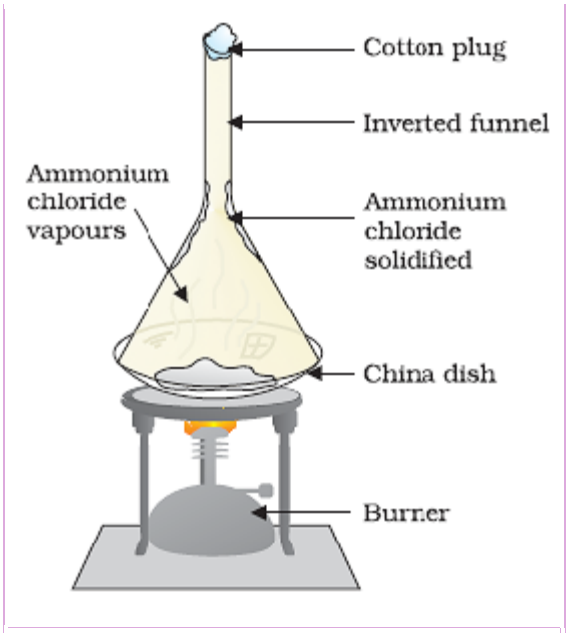


Fig 3: Sublimation of *ammonium chloride*. (Source: NCERT, Science IX, p. 8)

Mixture of Solids

Sublimation

Sublimation is a process in which some solids, on heating, are transformed directly to vapour without passing through the liquid phase. This technique can be used to separate a mixture of solids, one of which can undergo sublimation. The vapours are then cooled separately to get the sublimed solid back, a process called deposition. (Fig. 3)

Sublimation is used in the separation of substances like *ammonium chloride*, *iodine*, *napthalene*, *camphor* and *sulphur*.

Extraction

In some cases, one substance in the mixture is soluble in a particular liquid solvent whereas the other(s) is(are) insoluble in it. The process of dissolving out the

soluble component from a mixture, and subsequently treating the solution to get the solid, is called extraction.

Crystallisation is a sophisticated form of evaporation technique in which crystals of the solute are encouraged to develop during the process of "dissolving out" from the solution as the solvent evaporates.

Magnetic Separation

This method of separation is exemplified by the separation of *iron* filings.

A mixture with *iron* filings as one of the components can be separated using a magnet to attract the *iron* particles away from the mixture.

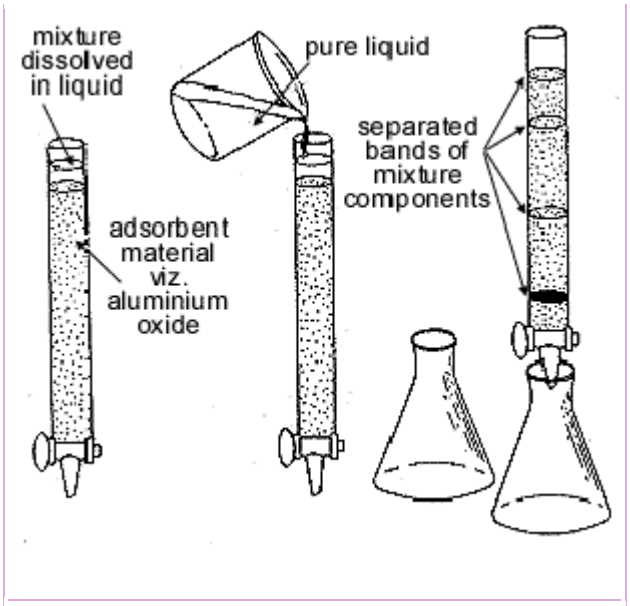


Fig 4: Chromatography

Chromatography

Chromatography is an advanced technique of separation in which individual components of a mixture are separated from each other using the property

of *differential migration*(different rates of flow). Here, a mobile phase, carrying the mixture, is passed through a selectively *adsorbent* stationary phase, which can retain the components of the mixture to different degrees. (Fig. 4)

Mixture of Liquids

Fractional Distillation

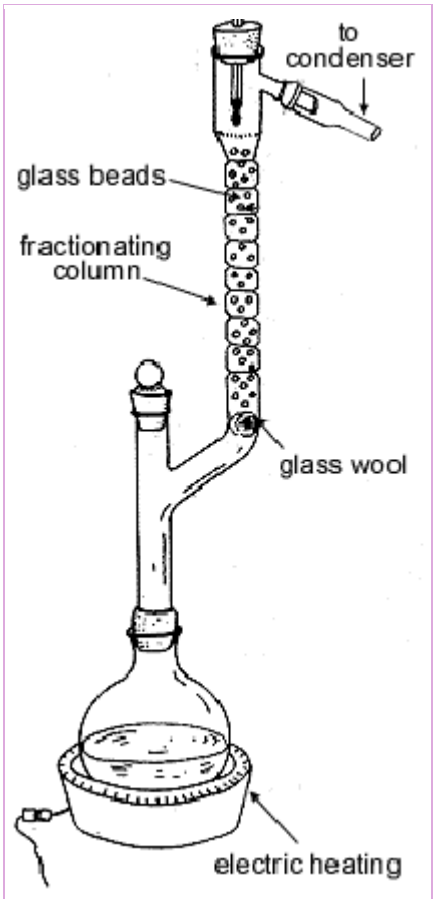


Fig 5: Fractional Distillation

Fractional distillation is the process of separating two or more miscible liquids by a modified distillation process, in which the distillates are collected as *fractions* having different boiling points. The separation of the liquids by this method is based on the difference in their boiling points. (Fig. 5)

Fractional distillation makes use of a *fractionating column* or *distillation column*, a tube which provides different temperature zones inside it during distillation, the temperature decreasing from bottom to top. It provides surfaces on which condensations (of less *volatile* liquids) and vaporizations (of more volatile liquids) can occur before the vapours enter the condenser in order to concentrate the more volatile liquid in the first fractions and the less volatile components in the later fractions.

Fractional distillation is very effective is separating mixtures of volatile components, and is widely used in laboratories and industries.

Crude petroleum is separated by the process of fractional distillation into different fractions like *gasoline*, *lubricating oil*, *kerosene*, *diesel* etc.

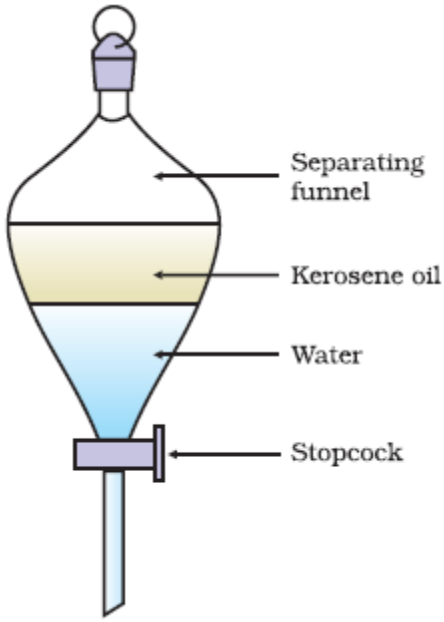


Fig 6: Gravity Separation. (Source: NCERT, Science IX, p. 20)

Gravity Separation

In **gravity separation**, a mixture of two immiscible liquids can be separated using a *separating funnel*, the working of which is based on the differences in the densities of the liquids. The heavier liquid which settles below is drained out first from below the funnel into a beaker, and then the lighter liquid is drained out into another beaker.