8.1.1 SEPARATION OF USEFUL MATERIALS[M5]

8.1.1.1 Source of Useful Materials

Most of the materials useful to man are derived from the solid crust of the earth. A limited number are derived from the sea while a much smaller number still are derived from Earth's atmosphere.

8.1.1.2 Separation of Materials

There are many different methods that may be employed in separating the individual components of a mixture. The most appropriate method for a particular application will be entirely dependent on the composition of the mixture in question. In many cases, one or more of the [physical] methods described below will achieve the desired result. The separation of sugar from sugar cane, for example, involves the processes of filtration, crystallisation, centrifuge action, adsorption and recrystallisation.

In other cases however, some components of a mixture may need to be chemically modified before they can be separated.

8.1.1.2.1 Sedimentation and Filtration

Perhaps the simplest mixture to separate is one involving an insoluble solid and a liquid. Mixtures of this kind will invariably be heterogeneous. In such cases, solid material may be extracted from a liquid by **sedimentation**, by **filtration**, or by using a **centrifuge**.

Observe the results of Experiments 5.1 – 5.4.

In the case of filtration, the liquid that passes through a filter paper is called the **filtrate**. The solid that remains in the filter paper is called the **residue**.

8.1.1.2.2 Solution

If a solid dissolves in the liquid from which it is to be separated, the methods described in 8.1.1.2.1 above will not achieve any result. A dissolved solid (the **solute**) may however be recovered from a solution by simply evaporating off all the liquid (the **solvent**), or by **crystallisation** of the solid from the solution.

Two solids may thus be separated using a solvent that will dissolve one and not the other. We can also use a sequence of the processes used so far to separate mixtures containing, soluble and insoluble solids from a liquid.

Observe the results of Experiments 5.5 – 5.9.

Note that solids that dissolve readily in one liquid (solvent), will not necessarily dissolve in another. In general, 'like dissolves like', but the subject of solubility will be discussed in greater detail later in this course.

We can use the particle theory of matter to explain the dissolution of some solids as follows. Particles of the solid leave their fixed positions in the solid and mix with the particles of the liquid forming a homogeneous mixture. The movement of particles from the solid into the liquid is due to the attractive forces between the solid and liquid particles. This attractive force between unlike particles is called **adhesion** and the forces called **adhesive forces**.

If the **adhesive forces of attraction** between the solid and liquid particles are greater then the **cohesive forces of attraction** between the solid particles, the substance will **dissolve**. If not, it will remain insoluble.

Since water is the most commonly encountered solvent, a solution of a material in water has a special name: it is called an **aqueous solution**.

A **dilute solution** is one that contains only a small amount of solute. A **concentrated solution** contains a large amount of solute in a given amount of solvent. A **saturated solution** at a given temperature is a solution which will not dissolve any more of the solute at that temperature.

8.1.1.2.3 Crystallisation

Crystallisation is the process of growing crystals of a solid from a solution that is saturated with that solid.

Observe the results of Experiments 5.10 – 5.12.

Impure crystalline materials can often be purified by **recrystallisation** from a suitable solvent. For example, common salt is crystallised from sea-water by evaporation, then purified by recrystallisation.

8.1.1.2.4 Distillation

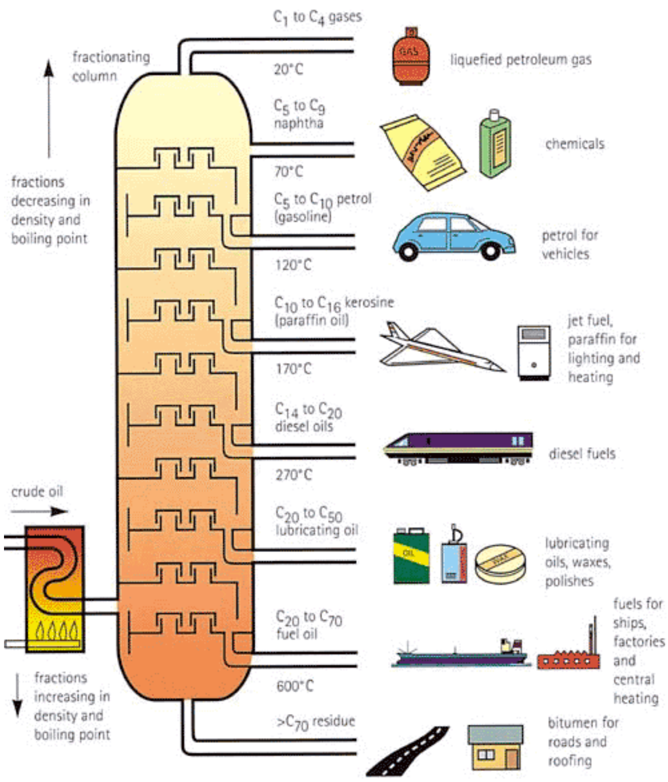
Liquids can be separated from mixtures or solutions by boiling the solution and condensing the vapour, a process known as **distillation**. The liquid that condenses is called the **distillate**.

Observe the results of Experiments 5.13 – 5.14.

Fractional distillation can be used to separate two liquids that have different boiling points. A fractionating column provides a larger surface area [than a normal distillation head] on which vapour can condense, while allowing the condensed liquid to remain in contact with the hot, rising vapour. The vapour, as it gets nearer to the top of the fractionating column becomes richer in the substance which has the lower boiling point, since the substance with the lower boiling point condenses out first.

Observe the results of Experiment 5.15.

The various components of crude oil have different sizes, weights and boiling temperatures and the first step in the refining of crude oil is to separate these components. Because they have different boiling temperatures, they can be separated easily by fractional distillation. The crude oil mixture is usually heated with high pressure steam to a temperature of about 600 °C.



The vapour enters the bottom of a long column (fractional distillation column) that is filled with trays or plates that increase the contact time between the vapour and the liquids in the column. These trays also help to collect the liquids that form at various heights in the column.

Since there is a temperature gradient up the column (hot at the bottom, cool at the top), substances with the lower boiling points will condense higher in the column and substances with higher boiling points will condense lower in the column. The fractions collected in this way may be used directly but most must be refined further, by other chemical means, before they can be used.

Distillation doesn't have to be carried out at high temperatures. Oxygen may be separated from the air by the fractional distillation of liquid air at around -183 °C.

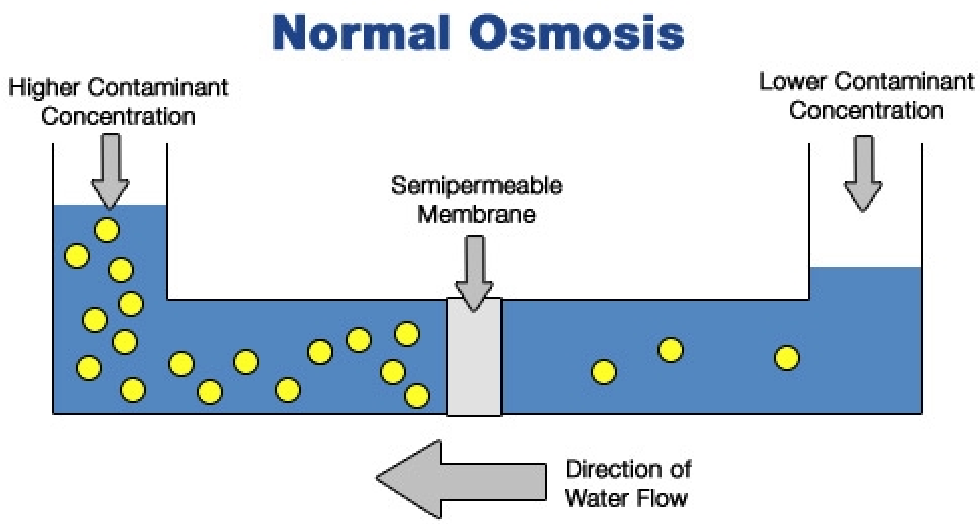
8.1.1.2.5 Osmosis

Osmosis is the movement of a solvent through a **semipermeable membrane**. The process occurs when a solution is separated from of the pure solvent by a membrane that acts like a piece of filter paper. The solvent, obeying the laws of diffusion, moves from where it is more concentrated (*i.e.* where it is pure) to where it is more dilute (*i.e.* where it is part of a solution).

Observe the results of Experiment 5.16.

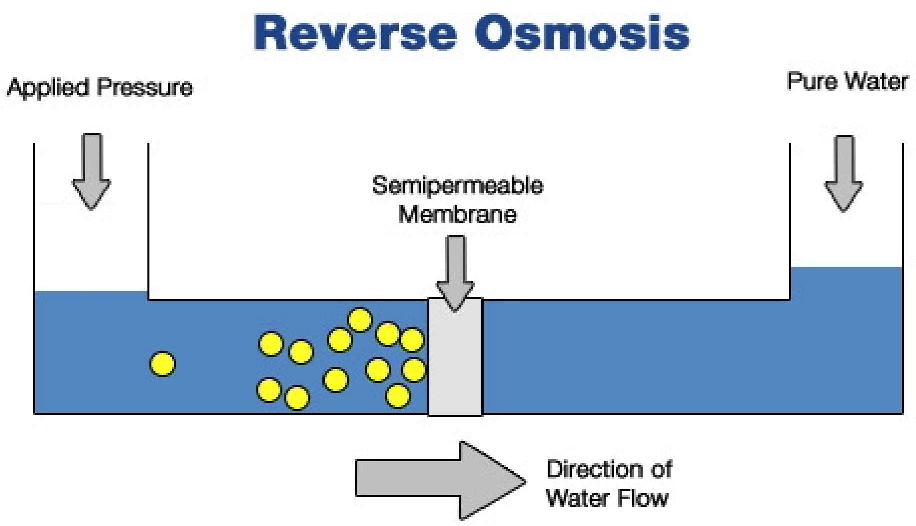
When we look more closely at living things, we will see that they depend on osmosis for the absorption of water from their environment.

Perhaps more commonly used by human beings, however, particularly in the purification of water, is the process of **Reverse Osmosis**[1]. Reverse osmosis works on the principle described above, but takes advantage of the fact that the solvent flow can be *reversed* by applying pressure to one side of the membrane. The membrane still acts as a selective barrier, but now it effectively removes contaminants, producing water safe for drinking.



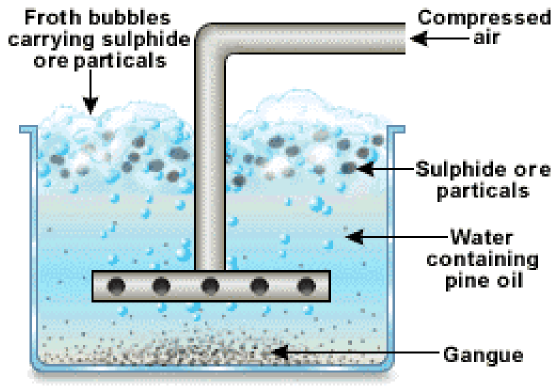
The normal process of osmosis is illustrated above. In a water purification system, the goal is not to dilute the salt solution, but to separate the pure water from the salt and other contaminants. When the natural osmotic flow is reversed, water from the salt solution is forced through the membrane in the opposite direction by application of pressure. Through this process, illustrated below, water can be purified by screening out the salts and other contaminants.

[1] http://www.zenon.com/resources/glossary/reverse_osmosis.shtml



8.1.1.2.6 Froth Flotation[2]

Froth flotation is a process, invented by Australian chemical engineer Graeme Jameson, by which some minerals can be separated from useless rock material (gangue) due to the ability of these minerals to be 'wetted' by a special oil. Finely crushed ore is mixed with water and a small amount of the wetting oil. Air is blown into this mixture, creating a froth that carries the valuable minerals to the top while the gangue sinks to the bottom.

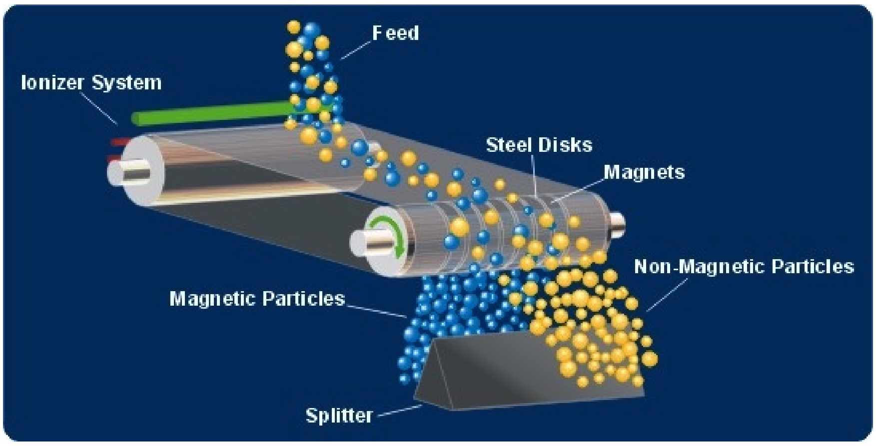


Froth floatation process for the concentration of sulphide ores.

Observe the results of Experiment 5.17.

8.1.1.2.7 Magnetic Separation[3]

This method of separation or concentration is used in mining applications when ore and gangue particles have different magnetic properties: if, for example, ore particles are magnetic and gangue particles are non-magnetic.



Magnetic separation using belt on magnetised roller

[2] Diagram from: http://home.att.net/~cat6a/metals-IX.htm
[3] Diagram from: http://www.outokumputechnology.com/pages/Page____35207.aspx

Typically the powdered ore is poured over a conveyer belt where one of the rollers of the belt is magnetic. The magnetic roller holds the magnetic ore particles on the belt, as illustrated, so that they travel further than the gangue. Iron and manganese ores are concentrated by this process.

High-Gradient Magnetic Separation (HGMS)[4] is also used in the decontamination of materials such as soils and water that contain radioactive material or [toxic] heavy metals. In this process, the material is slurried with water (made into a sloppy mixture) and passed through a magnetic mesh of stainless steel wool or nickel foam.

8.1.1.2.8 Adsorption

Adsorption is the process whereby a material becomes attached to the surface of a [usually finely divided] substance such as carbon, silica gel or alumina. This process can be used to remove unwanted material from a mixture, or it can be used to extract a desired product. The adhesive binding is usually relatively weak and reversible, so that, in the latter case, the product can be readily freed from the adsorbing material once it has been extracted from the mixture.

Observe the results of Experiments 5.19 – 5.20.

8.1.1.2.9 Chromatography

Chromatography is a method of separating substances by exploiting the different rates at which a solvent carries them across an adsorbing surface. The use of different absorbing surfaces and solvents provides a range of alternatives for separating different kinds of materials.

Observe the results of Experiment 5.21.

[4] See http://www.lanl.gov/source/orgs/nmt/nmtdo/Aqarchive/96winter/HGMS.html