PURIFICATION AND SEPARATION

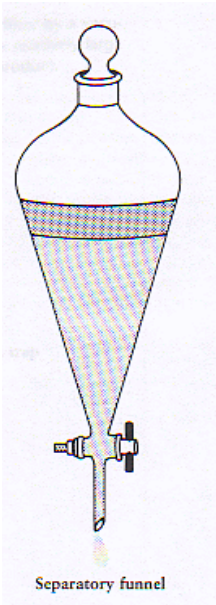
Much of organic chemistry is concerned with the isolation and purification of the desired reaction product. A reaction itself may be completed in a matter of minutes, but separating the product from the reaction mixture is often a difficult and rather time-consuming process. Many different techniques have been developed to accomplish this objective: to obtain a pure compound separated from solvents, reagents, and other products.

BASIC TECHNIQUES

A. EXTRACTION

One way of separating out a desired product is through **extraction**, the transfer of a dissolved compound (here, the desired product) from one solvent into another in which it is more soluble. Most impurities will be left behind in the first solvent. The two solvents should be immiscible (form two layers that do not mix because of mutual insolubility). The two layers are temporarily mixed together so that solute can pass from one to the other. For example, a solution of isobutyric acid is more soluble in water than in ether, and so when the two solvents are placed together, isobutyric acid transfers to the water phase.

The water (aqueous) and ether (organic) phases are separated in a specialized piece of glassware called a separatory funnel. Once separated, the isobutyric acid can be isolated from the aqueous phase in pure form, Some isobutyric acid will remain dissolved in the ether phase, so the extraction should be repeated several times with fresh solvent (water). More product can be obtained with successive extractions; i.e., it is more effective to perform three successive extractions of 10 mL. Once the compound has been isolated in its purified form in a solvent, it can then be obtained by evaporation of the solvent.



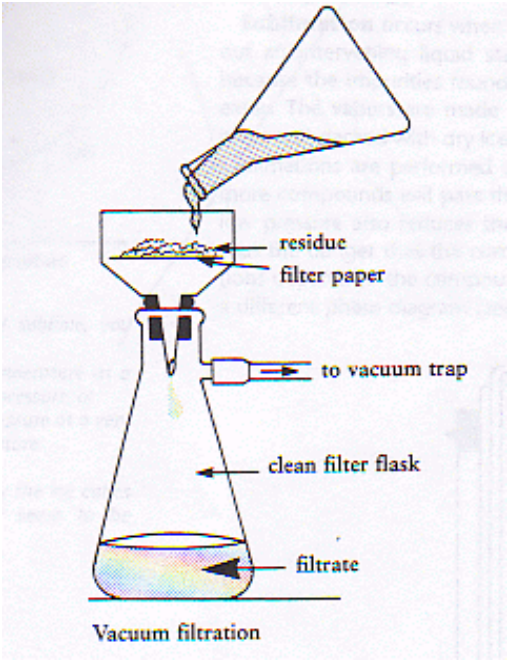
Separatory funnel

An extraction carried out to remove unwanted impurities rather than to isolate a pure product is called a **wash**.

B. FILTRATION

Filtration is used to isolate a solid from a liquid. In this technique, a liquid/solid mixture is poured onto a paper that allows only the solvent to pass through. The result of this process is the separation of the solid (often referred to as the residue) from the liquid or **filtrate**. The two basic types of filtration are **gravity filtration** and **vacuum filtration**. In gravity filtration, the solvent's own weight pulls it through the filter. Frequently, however, the pores of the filter become clogged with solid, slowing the rate of filtration. For this reason, in gravity filtration it is generally desirable for the substance of interest to be in solution (dissolved in the solvent), while impurities remain undissolved and can be filtered out. This allows the desired product to flow more easily and rapidly through the apparatus. To ensure that the product remains dissolved, gravity filtration is usually carried out with hot solvent.

In vacuum filtration, the solvent is forced through the filter by a vacuum on the other side. Vacuum filtration is used to isolate relatively large quantities of solid, usually when the solid is desired product.



Vacuum filtration

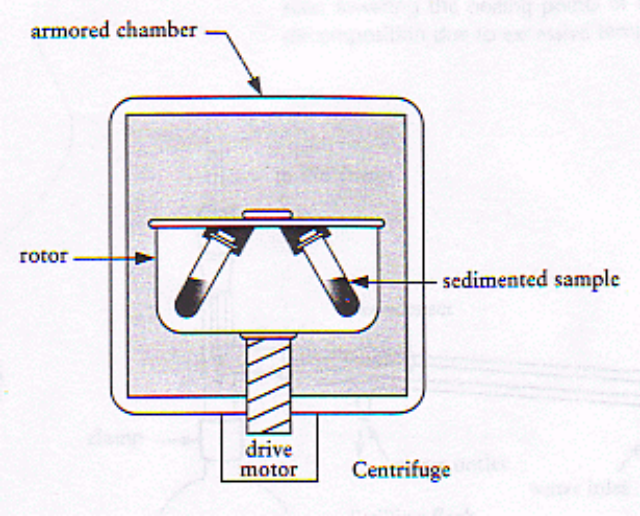
C. RECRYSTALLIZATION

Recrystallization is a process in which impure crystals are dissolved in a minimum amount of hot solvent. As the solvent is cooled, the crystals reform, leaving the impurities in solution. In order for recrystallization to be effective, the solvent must be chosen carefully. It must dissolve the solvent while it is hot, bot not while it is cold. In addition, it must dissolve the impurities at both temperatures, so that they remain in solution. Solvent choice is usually a matter of trial and error, although some generalizations can be made. An estimate of polarity is useful, since polar solvents dissolve polar compounds while non-polar solvents dissolve non-polar compounds. A solvent with intermediate polarity is generally desirable in recrystallization. In addition, the solvent should have a low enough freezing point that the solution may be sufficiently cooled.

In some instances, a mixed solvent system may be used. Here the crude compound is dissolved in a solvent in which it is highly soluble. Another solvent, in which the compound is less soluble, is then added in drops, just until solid begins to precipitate. The solution is heated a bit more to redissolve the precipitate, and then slowly cooled to induce crystal formation.

D. CENTRIFUGATION

Particles in a solution settle, or sediment, at different rates depending upon their mass, their density, and their shape. Sedimentation can be accelerated by **centrifuging** the solution. A centrifuge is an apparatus in which test tubes containing the solution are spun at high speed, which subjects them to centrifugal force. Compounds of greater mass and density settle toward the bottom of the test tubes, while lighter compounds remain near the top. This method of separation is effective for many different types of compounds, and is frequently used in biochemistry to separate cells, organelles, and biological macromolecules.



E. DISTILLATION

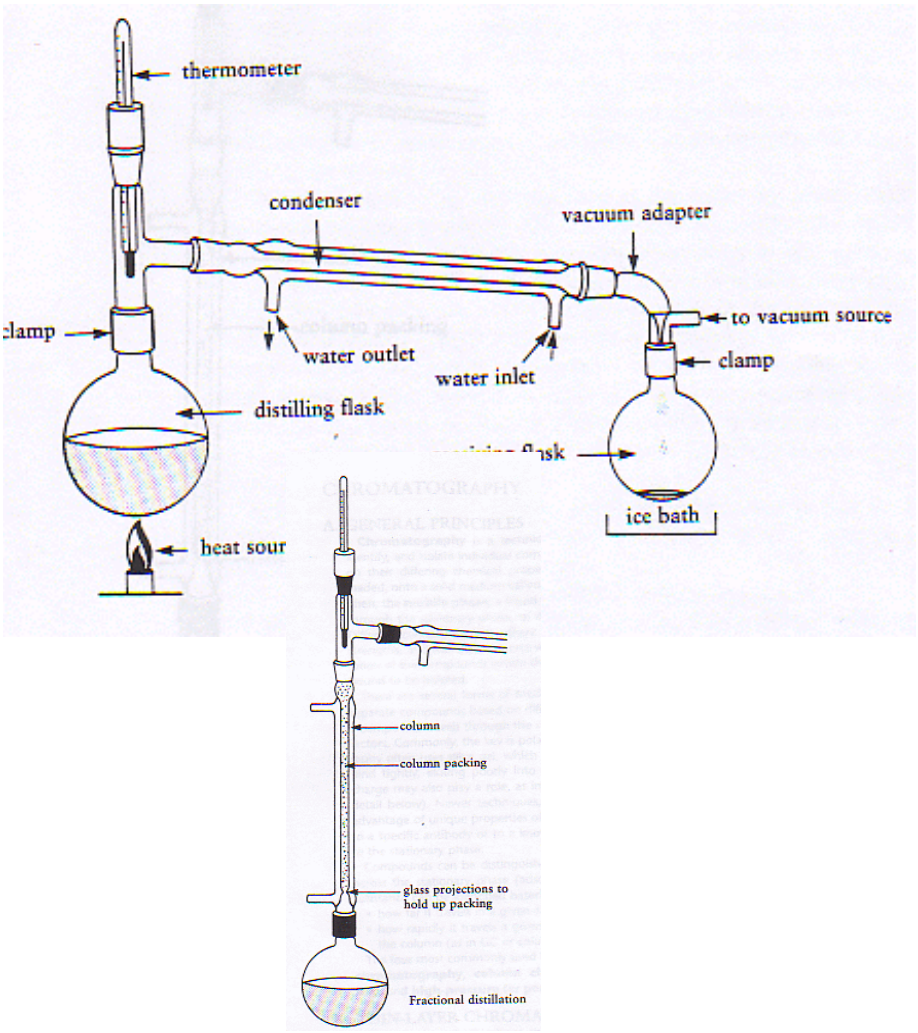
Distillation is the separation of one liquid from another through vaporization and condensation. A mixture of two (or more) miscible liquids is slowly heated; the compound with the lowest boiling point is preferentially vaporized, condenses on a water-cooled distillation column, and is separated from the other, higher-boiling compound(s). (Immiscible liquids can be separated in a separatory funnel and thus do not require distillation.)

1. SIMPLE

Simple distillation is used to separate liquids that boil *below* 150 ^{0}C and at least 25 ^{0}C apart. The apparatus consists of a distilling flask containing the two liquids, a distillation column consisting of a thermometer and a condenser, and a receiving flask to collect the distillate.

2. VACUUM

Vacuum distillation is used to separate liquids that boil above 150 ^{0}C and at least 25 ^{0}C apart. The entire system is operated under reduced pressure, lowering the boiling points of the liquids and thus preventing their decomposition due to excessive temperature.



3. FRACTIONAL

Fractional distillation is used to separate liquids that boil less than 25 ^{0}C apart. A fractionating column is used to connect the distilling flask to the distillation column. It is filled with inert objects, such as glass beads, which have a large surface area. The vapors condense on these surfaces, reevaporate, and then condense further up the column. Each time the liquid evaporates, the vapors contain a greater proportion of the lower-boiling component. Eventually, near the top of the fractionating column, the vapor is composed solely of one component., which will condense on the distillation column and collect in the receiving flask.

SUMMARY OF PURIFICATION METHOD

Method	*Use*
Extraction	separates dissolved substances on differential solubility in aqueous vs. organic solvents
Filtration	separates solids from liquids
Recrystallization	separates solids based on differential solubility; temperature is important here
Centrifugation	separates large things (like cells, organelles and macromolecules) based on mass and density
Distillation	separates liquids based on boiling point, which in turn depends on intermolecular forces