

Organic Chemistry Appendixes

Appendix 1 – Chromatography

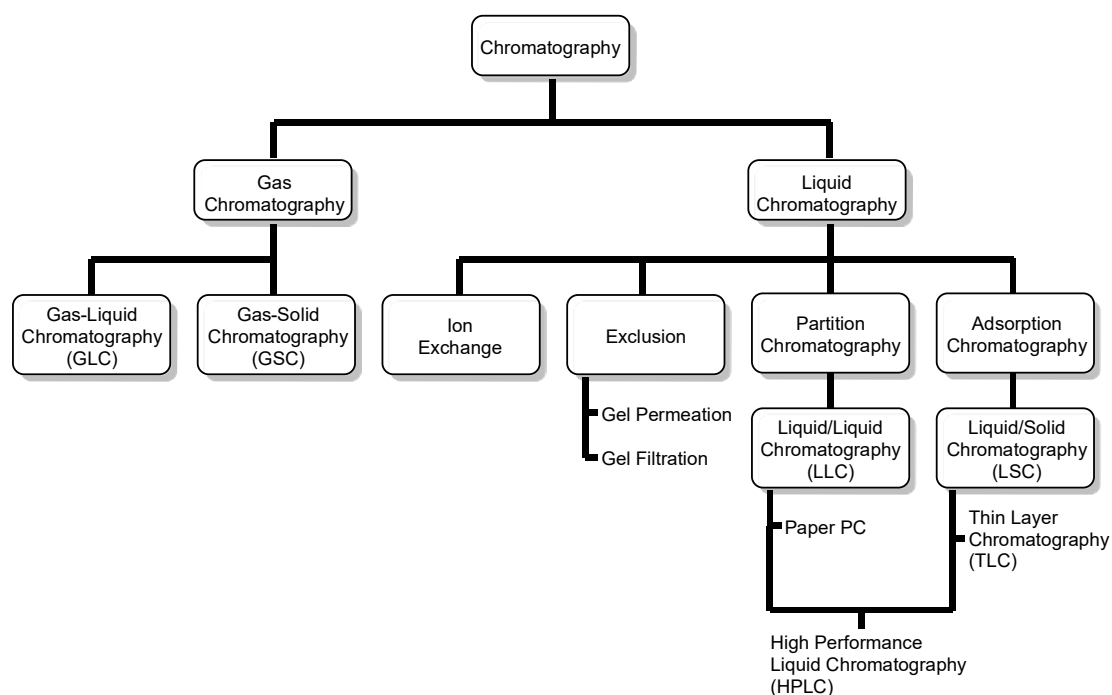


Figure S 1 Different separation techniques used in chemistry.

Figure S 1 summarizes the different types of chemical separation techniques. Generally, the chromatographic systems are separated into two categories: gas and liquid – as dictates by the mobile phase of the technique.

GAS CHROMATOGRAPHY

Gas-liquid Chromatography (GLC) proceeds mainly by partition chromatography i.e. separation depends upon the different solubilities of the components at equilibrium between the gas and liquid phase. The stationary phase is a liquid supported on a solid contained in a tube. The mobile phase is an inert gas which also acts as a carrier of the mixture. This mixture can be solid, liquid or gaseous.

The mixture in solution is injected by means of a syringe and at a temperature high enough to ensure vaporisation of the components. It is carried by means of the inert gas through a heated long tube containing the liquid phase and is subject to many solubility equilibria. After separation the components & carrier gas pass through a detector which indicates when a

compound is being eluted by drawing a curve on chart paper. The area under the curve can be proportional to the number of moles eluted.

The compounds can be characterized by their Retention Times (R_t) i.e. the time taken from being injected to being eluted under set conditions as illustrated in the *Figure S 2*.

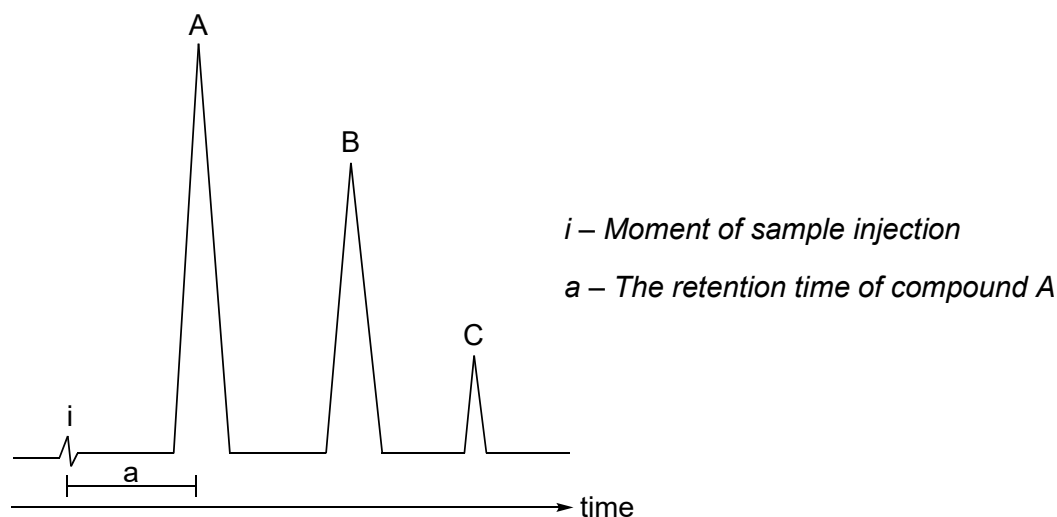


Figure S 2 GLC mock spectra.

Gas–solid chromatography (GSC) is used for applications that can broadly be characterized as those difficult to achieve by gas–liquid chromatography above ambient temperatures. These include the separation of gases, solvents, and volatile hydrocarbons and halocarbons (typically compounds containing <12 carbon atoms and with a boiling point <200 °C).

Retention results from adsorption on surfaces with different types and number of active sites providing for complementary selectivity to liquids and an enhanced capability for the separation of isomers and isotopomers. The carrier gas can play a significant role in the separation process by competing with analyte molecules for adsorption at active sites on the stationary phase. Selectivity, therefore, can be modified by the selection of the carrier gas and using gas mixtures.

LIQUID CHROMATOGRAPHY

Ion exchange uses ionic groups bonded into a polymeric resin. Ionic compounds (e.g. amino acids) have different affinities to the resin and can be separated.

Exclusion chromatography uses a highly porous material or gel which separates compounds (usually polymers) according to the molecular size.

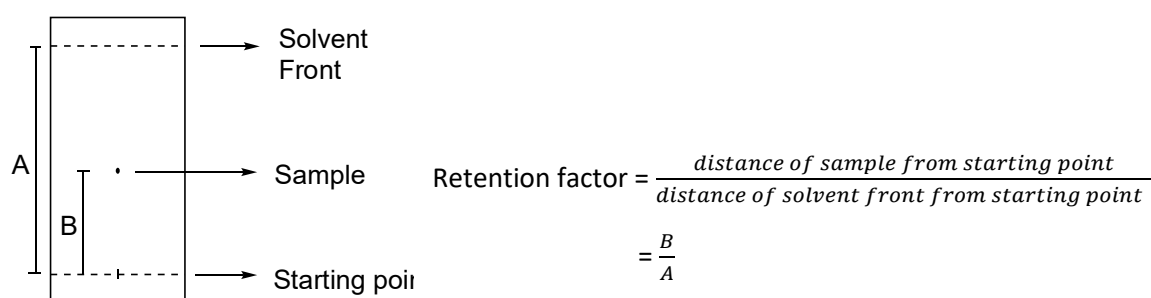
Liquid/liquid chromatography (LLC) or column chromatography (CC) is a partition chromatography. The sample is retained by partitioning between the mobile liquid and the stationary liquid, e.g. in paper chromatography the stationary phase is water held on the fibres of cellulose.

Liquid/solid chromatography (LSC) is an adsorption chromatography. It consists of a stationary solid phase, known as the adsorbent, supported in a column and of mobile liquid phase which can flow down the column. This is referred to as the eluent. In column or thin layer TLC the sample is adsorbed on the adsorbent silica gel or alumina. In practice silica gel or alumina has varied amounts of moisture so that the chromatography is a combination of LLC and LSC.

Thin layer chromatography (TLC) is a modification of column chromatography. In this case the adsorbent is supported on a flat surface. To develop the chromatogram the plate is placed vertically in a tank containing the eluent which flows upwards by capillary action. Unlike column chromatography it is not possible to alter the polarity of the solvent during development of the chromatograph but by using suitable proportions of mixed solvents a separation is usually achieved.

Silica-gel and alumina are the most common adsorbents. For TLC those are usually combined with Plaster of Paris which acts as a binding agent.

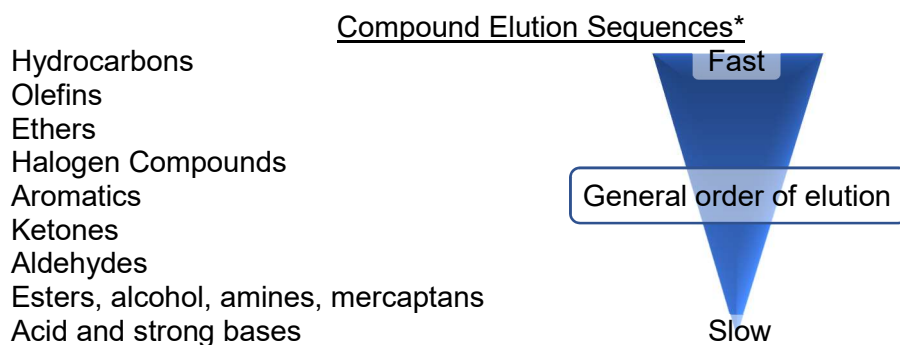
As in paper chromatography, a R_f value can be calculated where



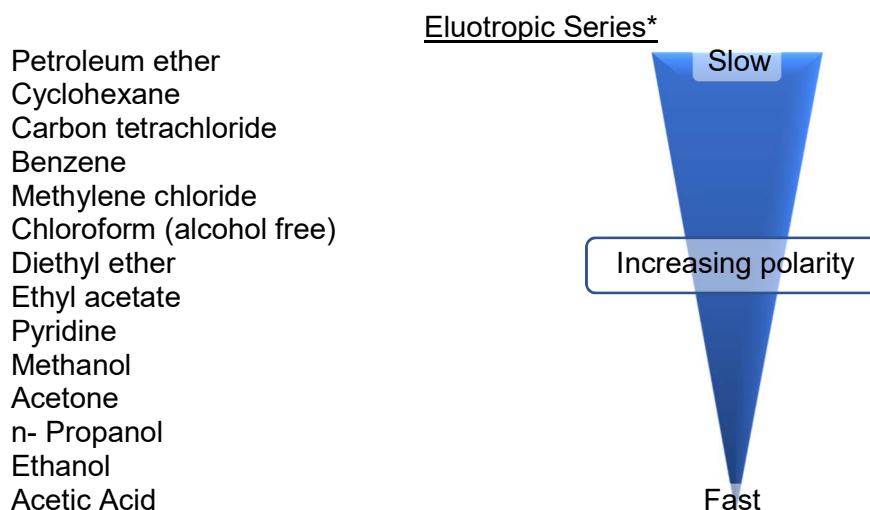
If the components are colourless, they can be detected by various means, e.g. using U.V. light, iodine vapour or charring with sulphuric acid.

The great advantage of T.L.C. is its short development time, usually < 30 mins.

In a normal phase LSC (*reverse phase LSC works in the opposite: Pasto and Johnson, Organic Structure Determination), the mixture to be separated is introduced onto the adsorbent at the top of the column in solution form. The two components will be adsorbed to different extents depending upon the polarity of the molecules. The eluent is introduced and allowed to flow down the column. The components of the mixture will undergo many adsorption desorption processes as they pass down, the least polar molecule moving more quickly.



Increasing the polarity of the eluent will normally increase the speed at which the components move down the column. It is usual to begin with a solvent of low polarity and gradually change to more polar solvents.



The type of adsorbent chosen also effects the speed at which the compounds are eluted. The more active the adsorbent the more slowly the compounds will move down the column.

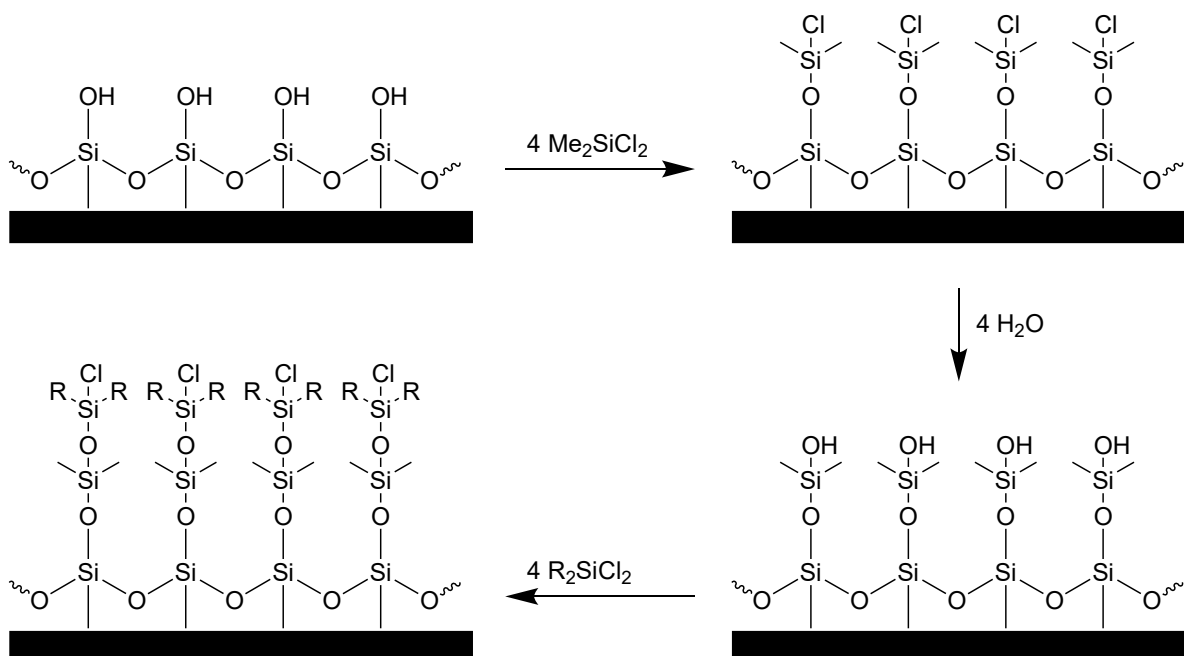
Adsorbents for Adsorption Chromatography*

Cellulose
Starch
Sugars
Magnesium silicate
Calcium sulphate
Silicic acid
Floredil
Magnesium oxide (magnesia)
Aluminium oxide (alumina)
Activated Charcoal

General order of increasing activity

By suitable choice of adsorbent and eluent it is possible to separate compounds of similar chemical constitution. If two molecules are very similar it is necessary to choose conditions whereby they move slowly down the column. This ensures they reach equilibrium in more adsorption desorption processes which facilitates separation.

In addition to the techniques mentioned above, **bonded phase chromatography (BPC)** is an additional chromatography technique similar LSC or LLC, except that the adsorbent material is chemically modified silica gel or similar substance. The OH groups of silica gel can be silylated and various organic groups can be attached as shown below:



Bonded phases are advantageous as different polarity types may be synthesized and both organic or aqueous solvents can be used. When using aqueous organic solvent mixture, it may be noted that the less polar material adsorbs on the stationary phase while the more polar compounds are eluted by the polar aqueous eluent. This is referred to as reverse phase chromatography.

A summary of the LC types and adsorbents is given in the tables below.

Modes of Liquid Chromatography

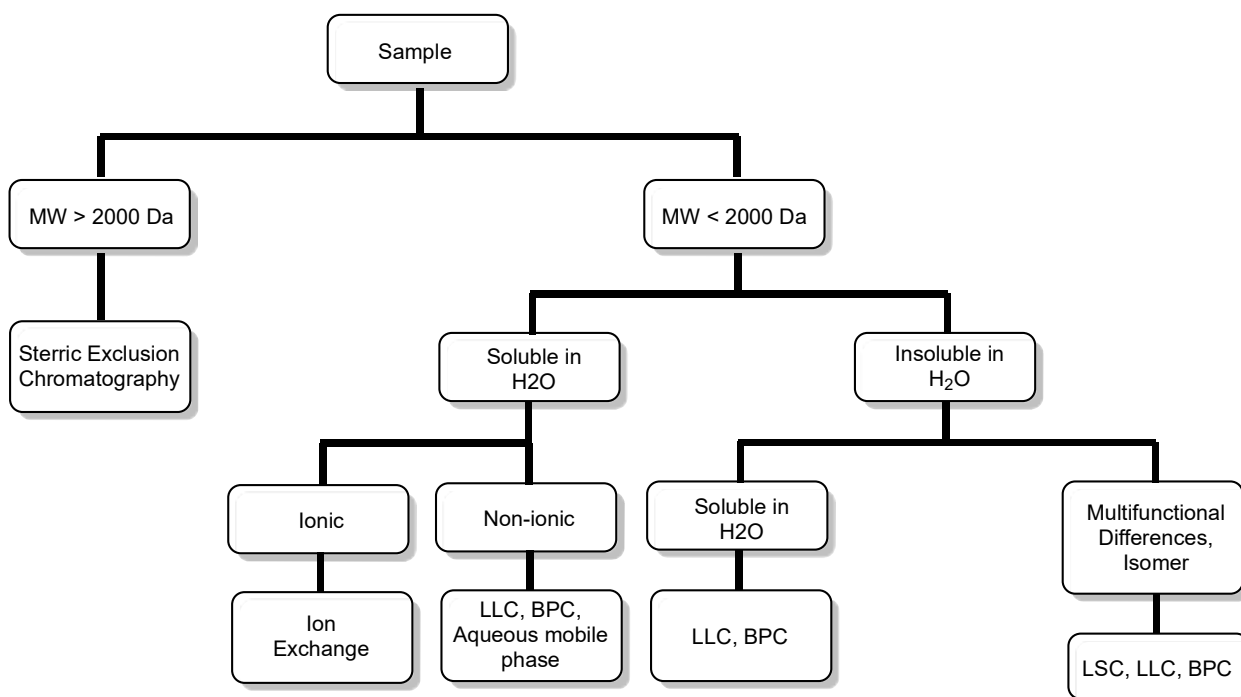
Modes	Abbr.	Predominant Mechanism	Common Names
Liquid – Solid	LSC	Adsorption of Surface	Adsorption chromatography, liquid – solid chromatography, linear elution adsorption chromatography
Liquid – Liquid	LLC	Partition in Liquid Phase	Partition chromatography, Sorption chromatography
Bonded Phase	BPC	Partition and / or adsorption	Gel chromatography
Reverse Phase	RPC	Partition and / or adsorption	Sorption chromatography
Ion Exchange	None	Adsorption on Fixed Ionic Site	Cation or Anion Exchange
Steric Exclusion	None	Diffusion into Pores	Gel permeation (GPC), molecular exclusion, gel filtration (GFC)

Solid-Liquid Adsorbents

Adsorbent	Chemical Structure	Estimated Usage %	Surface Properties	Application
Silica	$(\text{SiO}_2)_x$	70	Slightly acidic	General purpose
Alumina	$(\text{Al}_2\text{O}_3)_x$	20	Slightly basic *	General purpose
Charcoal		1	Graphitized – nonpolar, Oxidized – Polar (slightly basic)	Sample clean-up

Adsorbent	Chemical Structure	Estimated Usage %	Surface Properties	Application
Florisil	Magnesia – Silica Coprecipitate	2	Strongly acidic	General purpose adsorbent
Polyamides		2	Basic	Phenols and aromatic nitro compounds
Others (clay, Kieselguhr, diatomaceous earth, Celite)		5	Relatively nonpolar	Very polar compounds

A guide to a section of the type of LC is as follows:



Appendix 2 – Crystallization

The solute is dissolved in a solvent to give a hot* saturated solution. This is filtered** to remove insoluble contaminants. On allowing to cool slowly*** to R.T. the solution becomes supersaturated and deposits crystals. The crystallized compound is collected by suction filtration and washed to remove mother liquor.

* Care must be taken when choosing the solvent. A highly volatile solvent such as diethyl ether is less suitable due to the risk of combustion. Consult MSDS of the solvent before use.

** The solution is filtered through a fluted filter paper under gravity. While filtering this crystal may be deposited. This can be avoided by: **(a)** warming the funnel and receiving conical flask in an oven and use it while it is still hot (in a fumehood); **(b)** Having prepared a hot saturated solution, adding more solvent (warm), filtering and evaporating until the original volume is obtained.

*** Cooling to R.T. crystallization can be enhanced by: **(a)** cooling in iced-water bath, **(b)** scratching of the flask's wall, and **(c)** seeding – addition of a small amount of the crystal of solute.

From Mixed Solvents The two solvents must be miscible and are chosen such that the compound is soluble in solvent 1 and insoluble or appreciably less soluble in solvent 2. A hot solution is prepared in solvent 1. After filtering solvent 2 is added dropwise until the solution just turns cloudy. On cooling crystals are formed.

Choosing A Solvent A suitable solvent is found by trial and error, and this should be conducted on a small scale. The aim is to find a solvent or combination of solvents in which the solute is soluble at high temperatures and much less soluble at room temperature.

Generally polar solvent will dissolve polar compounds. It is better if the boiling point of the solvent is lower than the melting-point of the solute, otherwise an oil may be formed. The solvent should be sufficiently volatile so that the crystals can be easily dried.

Recrystallisation is used for purifying a compound which is contaminated with one more other compounds. These may have similar solubilities to the major component but as they are present in smaller amounts they can be separated by one or more recrystallisation.

Fractional crystallization is the separation of two components of similar solubility and present in comparable amounts by successive crystallizations and recombination of fractions. During this process the first component becomes more and more concentrated in the crystals and the mother liquor becomes more enriched with the second component. This is a tedious way of separating two components.

Appendix 3 – Distillation

Fractional Distillation is used to separate liquid mixtures which cannot be separated by ordinary distillation because their boiling points are too close.

It consists of a continual process of repeated vaporisation and condensation and is based on the principle that when a liquid mixture boils, the vapour will be richer in the more volatile component and when this vapour condenses, the less volatile component will condense first. Liquids which do not form an azeotropic (non-ideal) mixture and whose boiling points are separated by at least 30°C can be separated this way.

*See Renfrow Hawkins, Organic Chemistry Laboratory Operations p 13, 147 Louis F. Fieser, Organic Experiment p.30

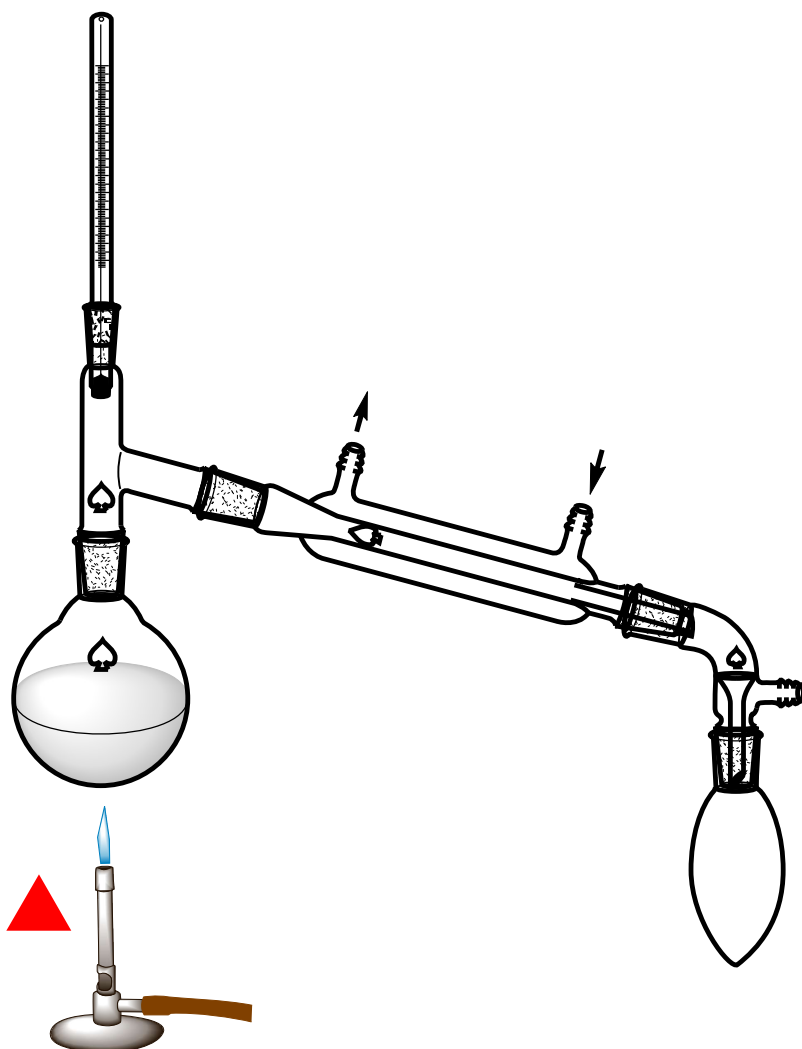


Figure S 3 Basic setup for distillation

Small Scale Fractional Distillation at Low Pressure

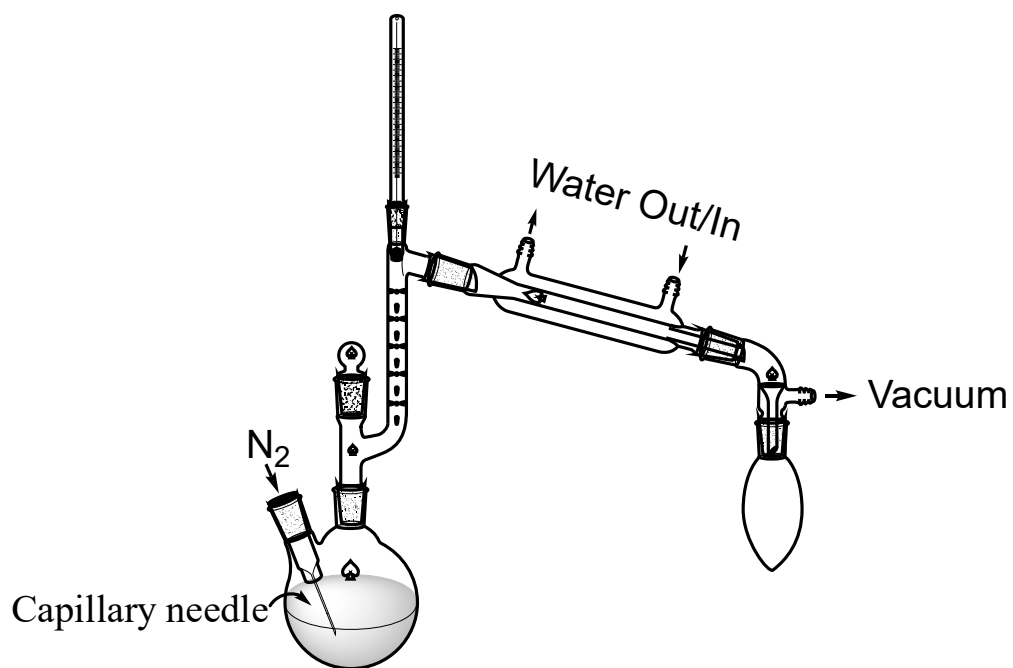


Figure S 4 Setup 1

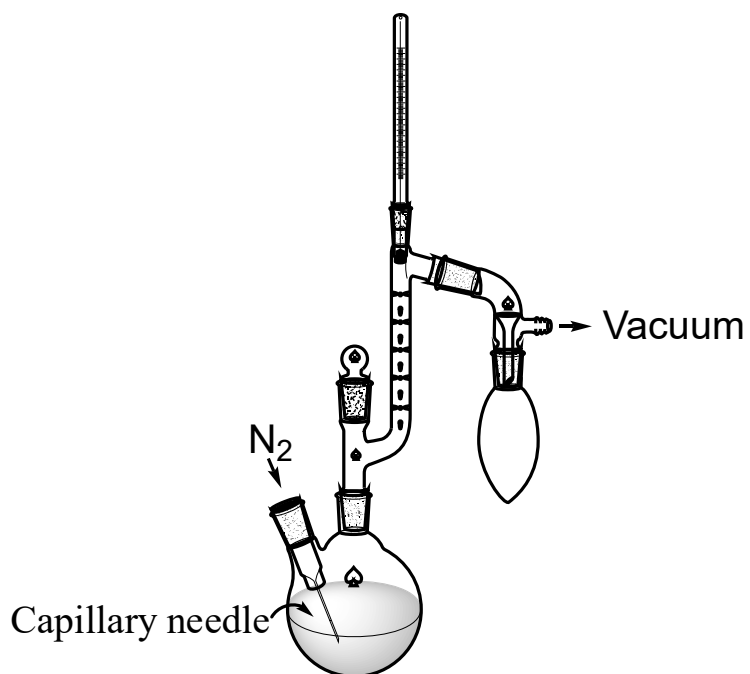
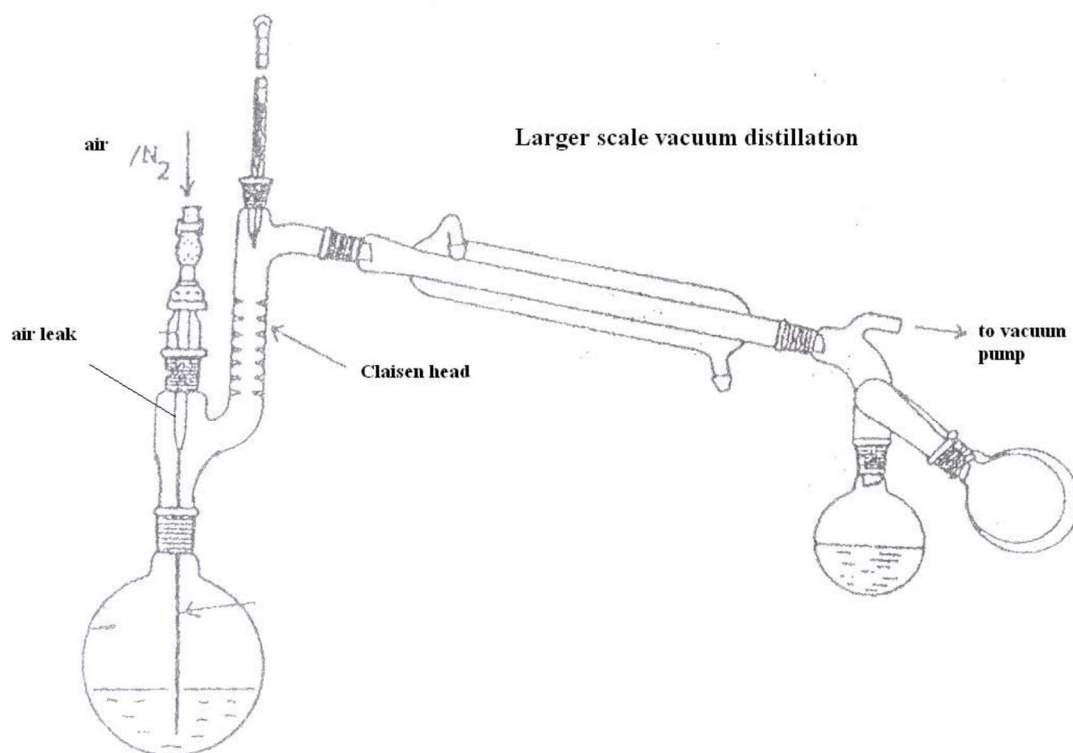
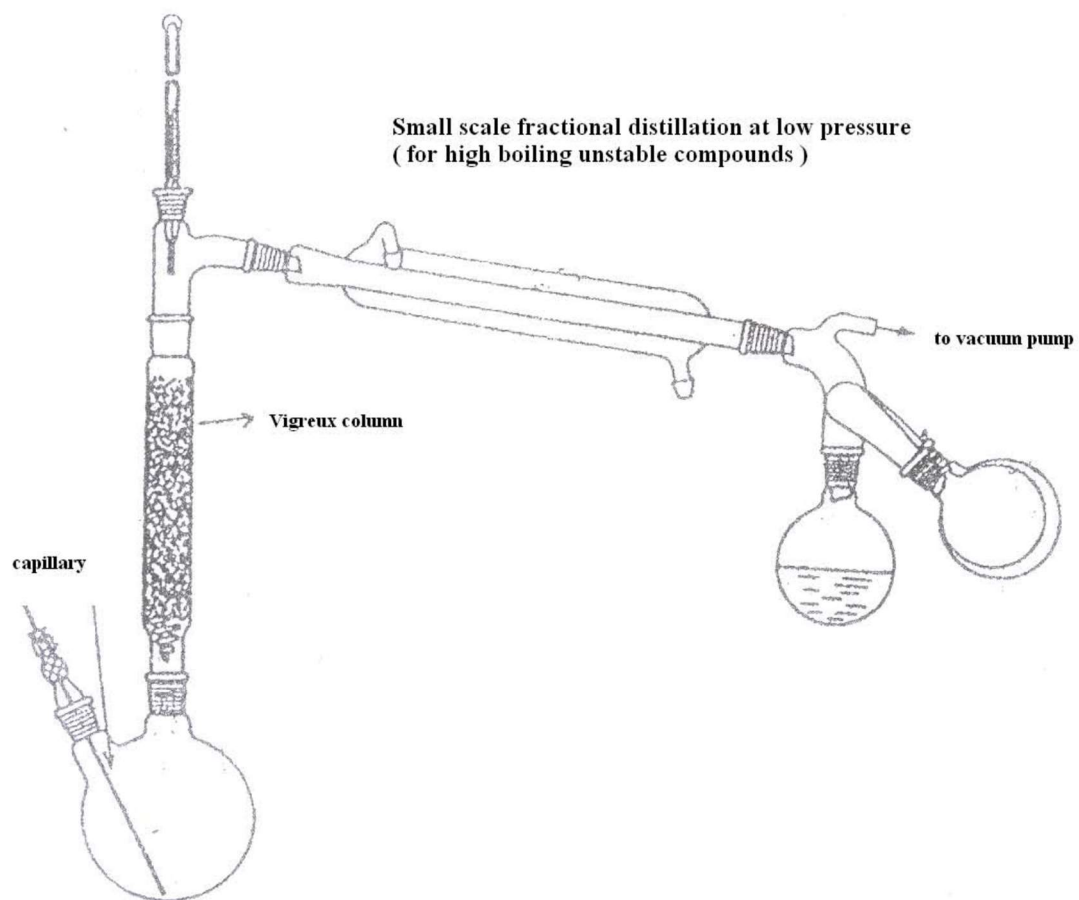


Figure S 5 Setup 2

Small Scale Fractional Distillation at Low Pressure



Flash Distillation

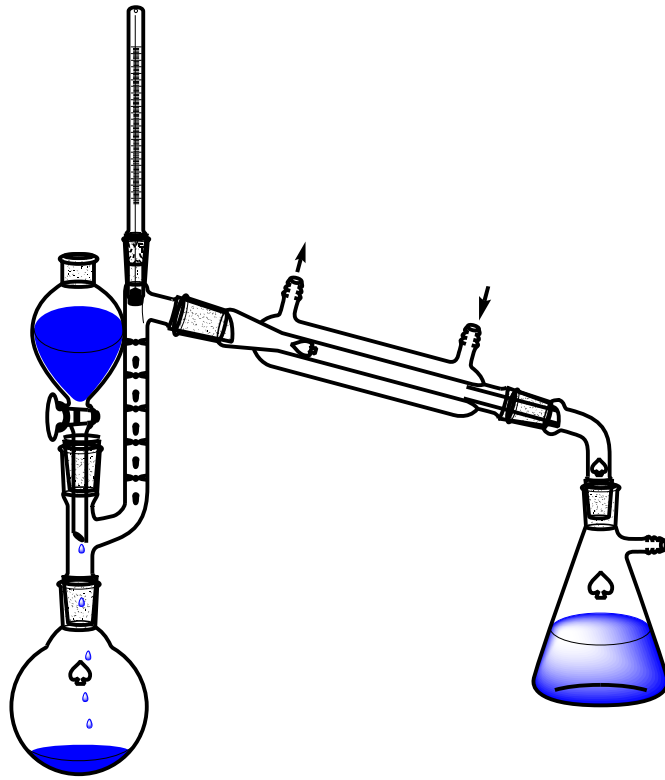


Figure S 6

Vacuum Distillation

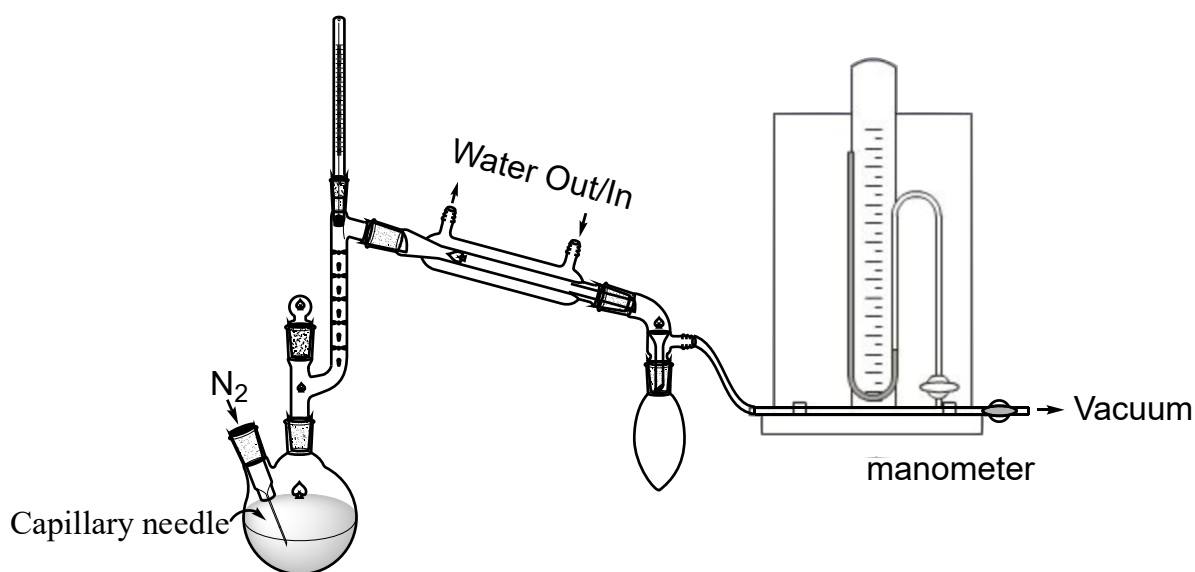


Figure S 7

See:

1. Renfrow Hawkins, Organic Chemistry Laboratory Operation, m.s. 13, 147
2. Louis F. Fieser Organic Experiments, m.s. 30.
3. Louis F. Fieser Organic Experiments p. 250
4. Renfrow Hawkins Organic Chemistry Laboratory Operations p.143

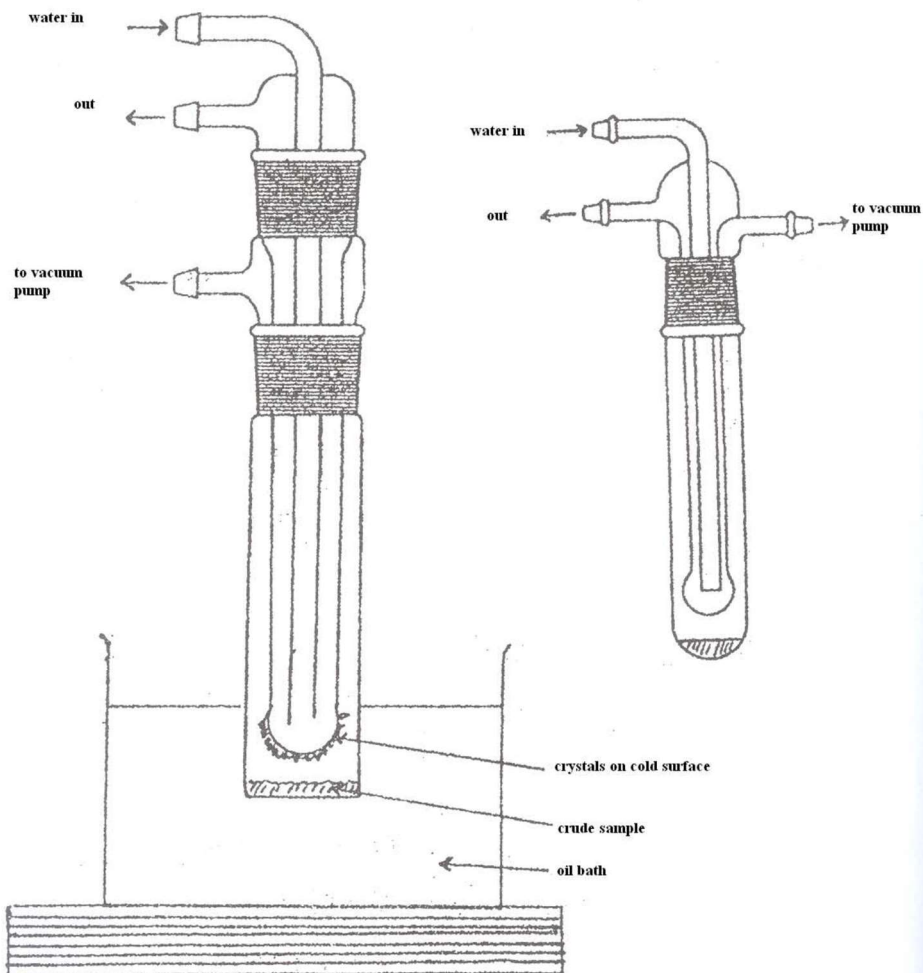
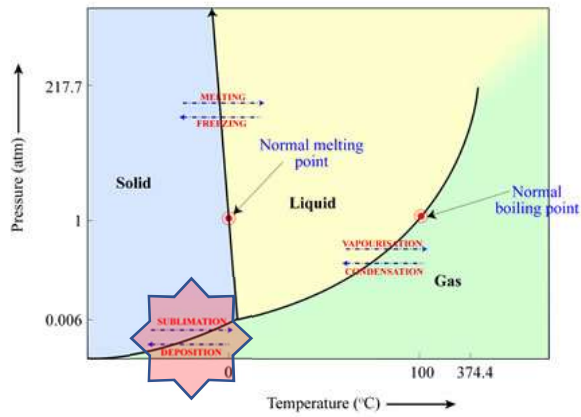
The pressure at which the liquid boils is measured by a manometer. The most common type is a closed-end monometer. The pressure in the closed arm is zero. This manometer is kept closed off from the system as solvent vapour can dissolve in the mercury. Then the pressure in the closed arm will no longer be zero, resulting in an incorrect reading. This type of manometer is accurate up to a few millimetres of mercury.

For lower pressure, $1-10^{-2}$ mmHg, an Adwards' Vacustat is used.

J.A. Elvidge and P.G. Sammes. A course in Modern Techniques of Organic Chemistry p. 115.

Appendix 4 – Sublimation

Sublimation occurs when a compound passes directly from the solid phase to vapour phase when heated. This process is usually performed under reduced pressure and is used as a method of purification.

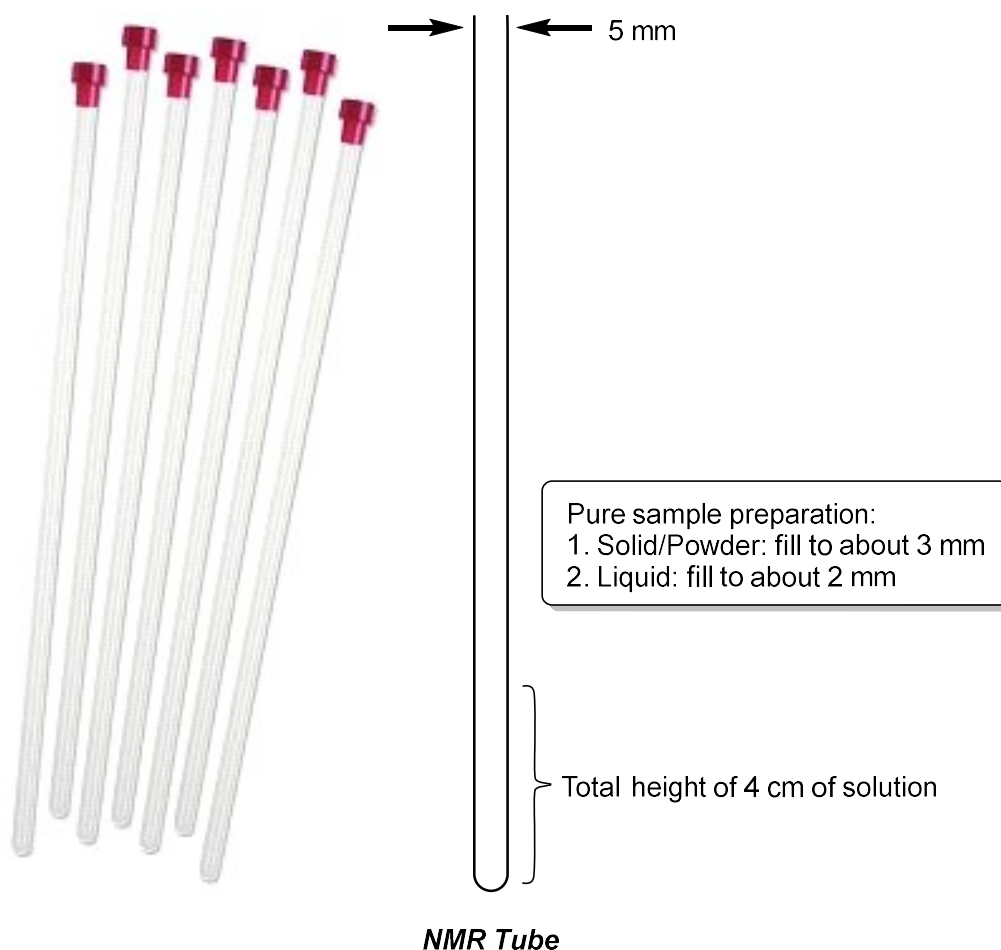


Appendix 5 – NMR Sample Preparation

Clean NMR tubes are available from the laboratory assistant. To clean tubes use organic solvent e.g. acetone, ethanol, water etc. Rinse with acetone and finally dry in an oven (60°C).

Your compound should be soluble in deuterated chloroform (CDCl_3 – most common NMR solvent). Determine solubility using normal chloroform. If insoluble, consult the lecturer.

For mixtures or impure samples instruct the spectroscopist of your requirements.



Appendix 6 – IR Sample Preparation

The measurement method used must be selected according to the sample form. From the sample viewpoint, it is possible to use more than one method to measure an infrared spectrum for a single sample. The Department of Chemistry normally apply three different methods of IR sample preparation: the classical methods (KBr pellet and Nujol) and attenuated total reflection (ATR).

All samples must be DRY, free from water content. Test first to ensure that your sample is NOT water or in an aqueous solution. Water will cause huge overlapping band during IR reading and it can also dissolve the NaCl cells which are rather expensive (>RM 600). Solids can be dried in a vacuum desiccator (overnight) or the oven (for a few minutes to hours).

Liquids can be used neat between NaCl plates. Solids can be micro-pelleted with KBr or be muller in Nujol but note the bands cut off by Nujol (hydrocarbon oil).

Attenuated total reflection (ATR) method can measure powder samples directly. This method involves pressing the sample against a high-refractive-index prism and measuring the infrared spectrum using infrared light that is totally internally reflected in the prism. ATR method is an excellent method for obtaining infrared information for powdered and liquid samples. However, care is required with the wavenumber dependency of the absorption peak intensity and with the peak deformation toward the first-order differential form due to the anomalous dispersion of the refractive index for inorganic and other high-refractive-index samples.

If you get poor spectra go to the instrument room and instruct the lab. assistant as to your requirements.

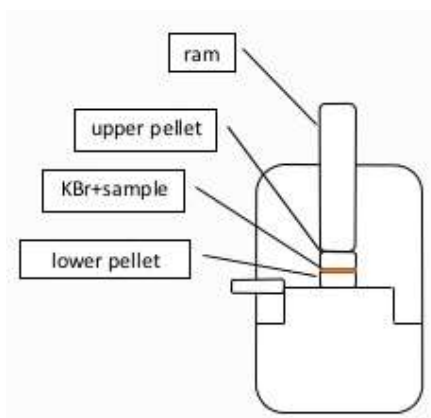


Figure S 8 KBr sample prep cross section

Appendix 7 – Other Laboratory Setups

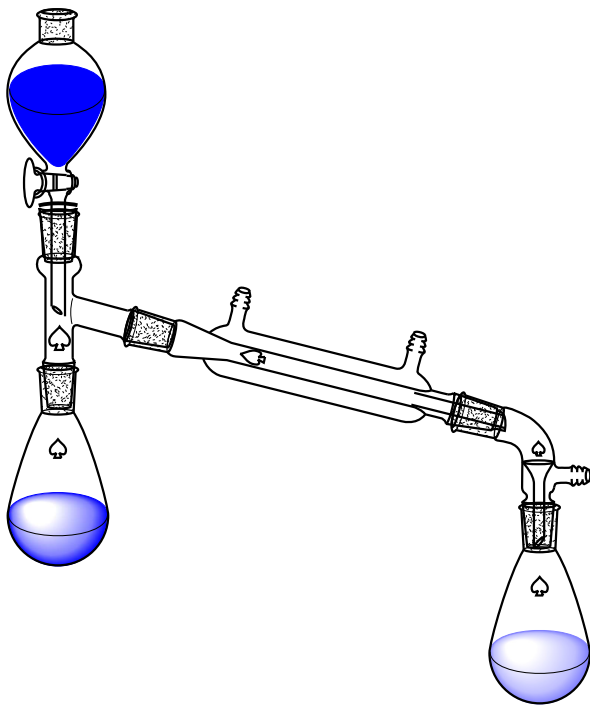


Figure S 9

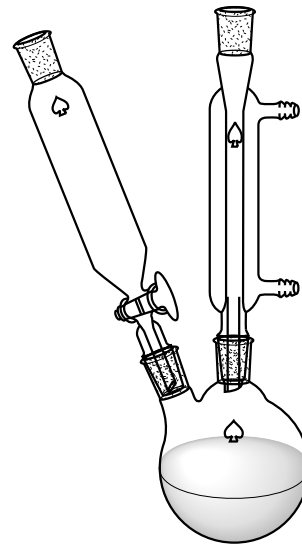


Figure S 11

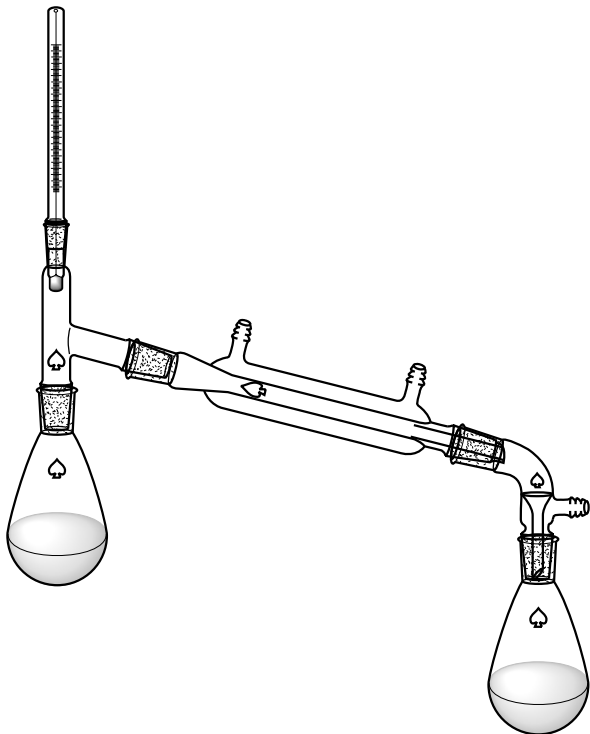


Figure S 10

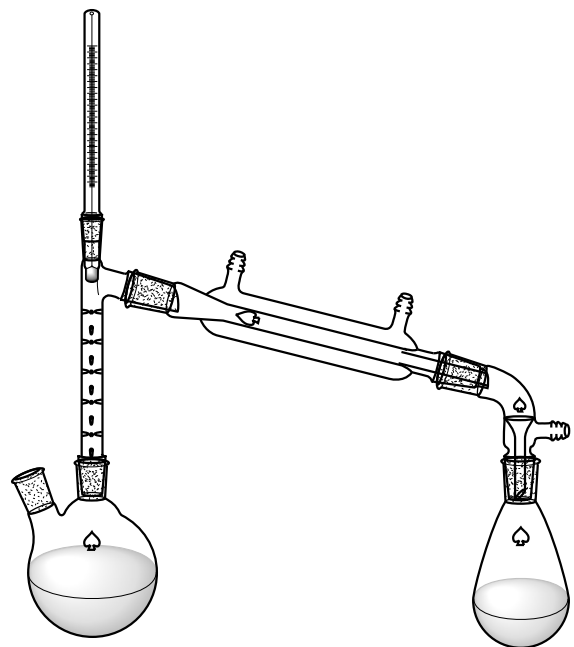


Figure S 12

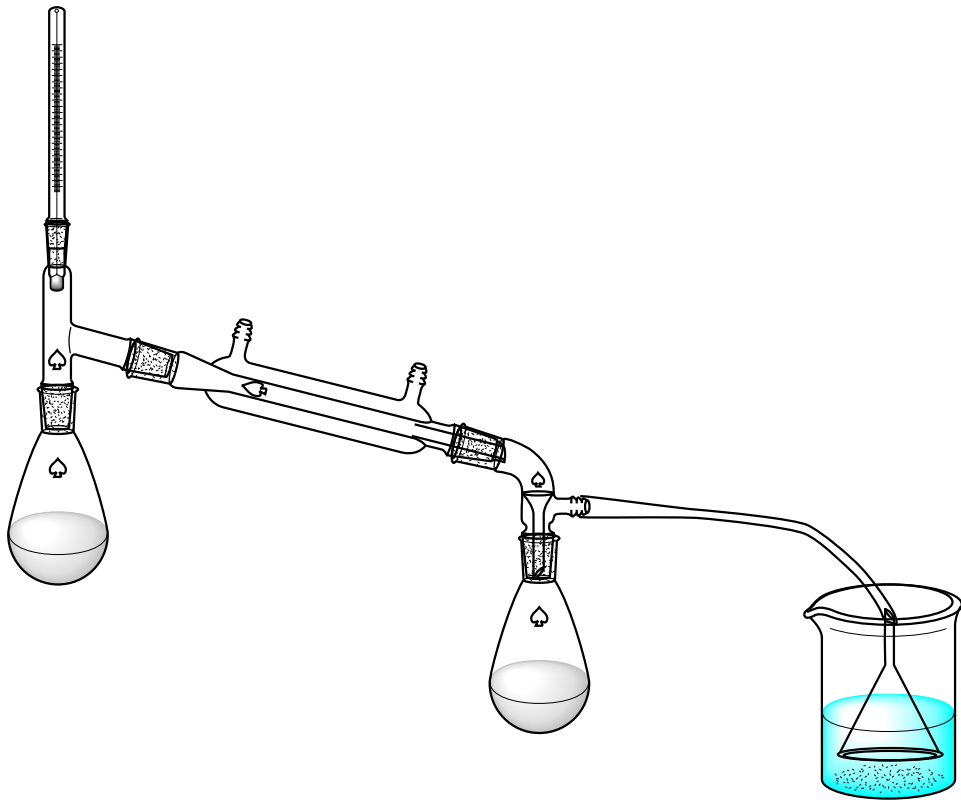


Figure S 13

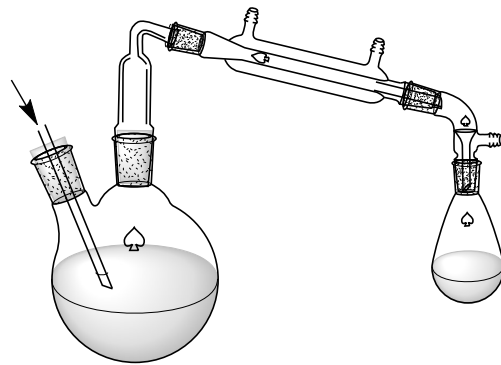


Figure S 14