Isolation and Purification of Organic Compounds Recrystallization (Expt #3)

Recrystallization, which relies on equilibria at a solid-liquid interface, occurs when a solid material precipitates from a cooling solvent in which it was originally dissolved at high temperature. The compound precipitates because its concentration exceeds its molar solubility as the solution cools. Purification of the solid can occur for two reasons:

- **if the impurities are insoluble in the hot solvent because of less favorable solubility equilibrium at high temperature than the desired compound they can be removed by filtration of the hot solvent**
- **If the impurities have a more favorable solubility equilibrium than the desired compound at low temperature the impurities will remain in solution while the desired compound crystallizes from solution as the temperature decreases**

Recrystallization is a dynamic process. In a supersaturated solution the compound is precipitating and dissolving at the same time, but the rate of precipitation is larger. Best results are obtained if the solution cools slowly with little disturbance.

Choice of Solvent

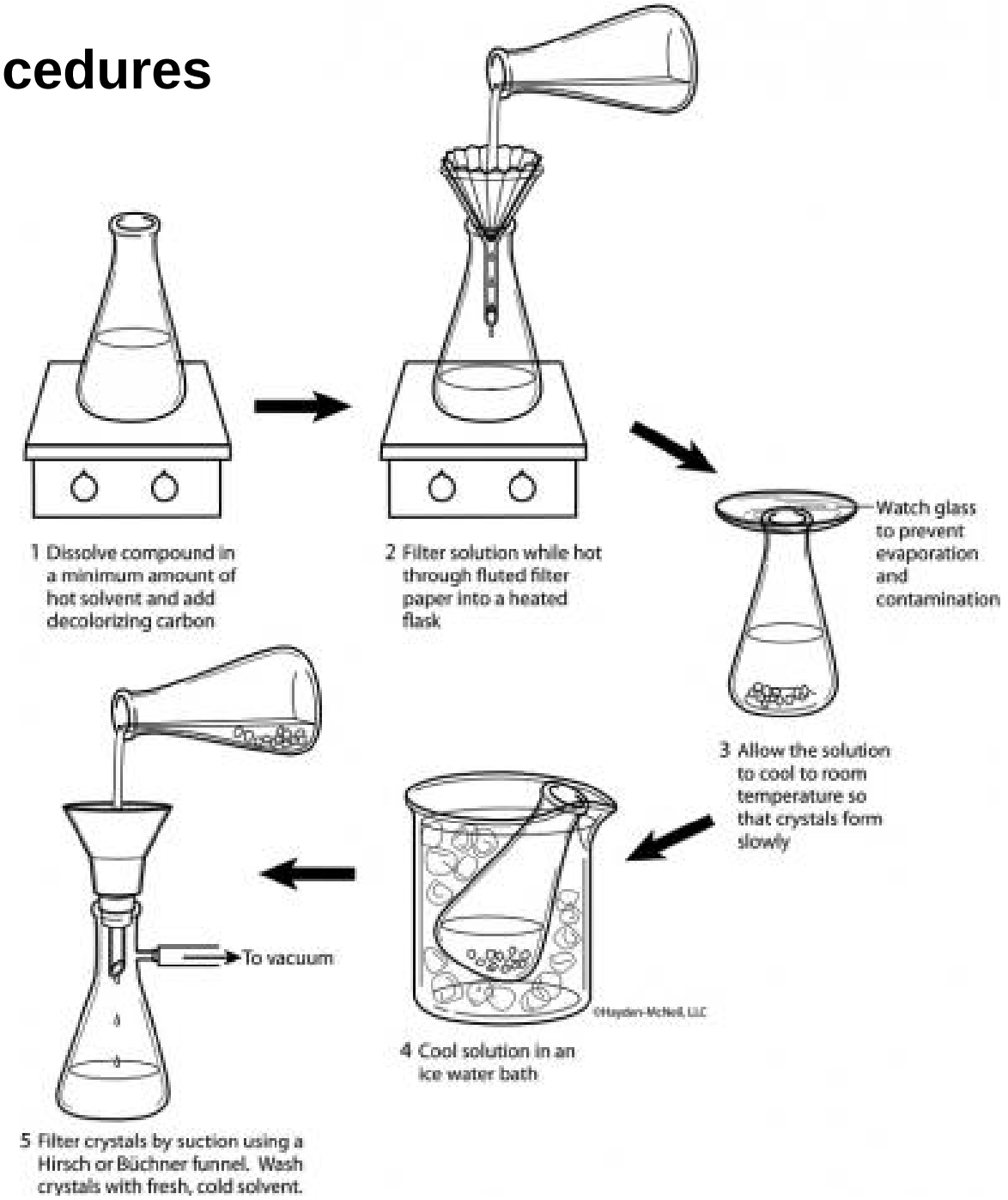
Finding a solvent with correct characteristics to perform the recrystallization is critical. The following guidelines are useful:

- **The solid substance should be insoluble in the cold solvent but substantially soluble in the hot solvent**
- **The boiling point of the solvent should be below the melting point of the solid to prevent the solid from coming out of solution as a liquid, typically called “oiling out”. The liquid-liquid equilibrium that occurs during oiling out can cause substantial impurities to dissolve in the desired compound**
- **The solvent must be un-reactive with the solid solute**
- **Co-solvent mixtures can be used when a single solvent does not have the desired properties. The co-solvents must be miscible with each other, but should have different polarities to assist the recrystallization process**

Typically, the polarity of the solid solute and the solvent must be partially mis-matched so that the solubility of the solid at low temperature is not too large. The solvents listed in Table 1-2 of Padias are a good starting point for choosing recrystallization solvents.

Recrystallization Procedures

This diagram illustrates the overall process for recrystallization. There are several steps, so organization is important. New students typically boil the solution too vigorously so that too much solvent volume is lost. Putting the solution into an ice-water bath before crystallization is complete at RT can lead to significant impurities.

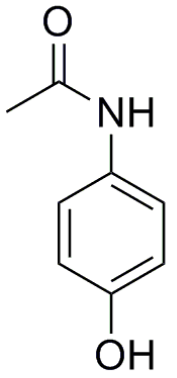


Post-recrystallization

- **After cooling, isolation of the pure solid relies on vacuum filtration to separate the liquid and solid phases**
- **The solid is usually washed with a small volume of the cold recrystallization solvent to remove surface impurities**
- **The solid is dried by drawing air through the Buchner funnel, or by allowing the solid to air dry on a clean surface**
- **If significant amounts of the desired compound remain in solution after recrystalization, the volume of the solvent can be reduced by evaporation and a second recrystallization can be performed**
- **Purity of the solid is judged by physical properties (melting point) or by spectroscopic properties (IR and NMR spectroscopy)**

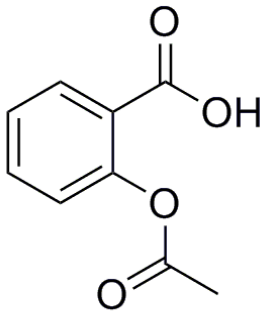
This Week's Experiment

Last week you isolated the three organic components of Extra Strength Excedrin®. This week you will recrystallize two of them (acetylsalicylic acid and acetaminophen). You will judge the success of the recrystallization by taking melting points before and after recrystallization.



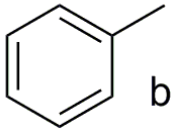
acetaminophen
mp 169-170 ^{o}C

Recrystallized from:
H_2O
bp 100 ^{o}C



acetylsalicylic acid
mp 135-137 ^{o}C

Recrystallized from:



bp 110 ^{o}C

In this experiment the recrystallization solvents are identified for you. Notice that the boiling points of both solvents are below the melting points of the respective solids, and that the polarities of solvents and solutes are somewhat different. Water is more polar than acetaminophen, and toluene is less polar than acetylsalicylic acid. In future experiments you will choose your own solvents.

Experimental Hints

1. **Make sure to pack melting point tubes with both compounds before you start the experiment.**
2. **You also need about 25 mg of each compound for Expt #4. Set these aside in labeled vials.**
3. **Top off your compounds with “technical grade” samples of each compound so that you start with (1.00 ± 0.10) g of each sample. Record the masses of each compound in your notebook.**
4. **The recrystallization of acetaminophen requires clean glassware, but it does not have to be completely dry glassware because you are using water as the recrystallization solvent.**
5. **The recrystallization of acetylsalicylic acid requires clean and dry glassware because toluene is not miscible with water.**
6. **Wash each compound with small volumes of the cold recrystallization solvent because both compounds have some solubility in the cold solvents.**
7. **Take melting points and masses after the samples are thoroughly dried.**