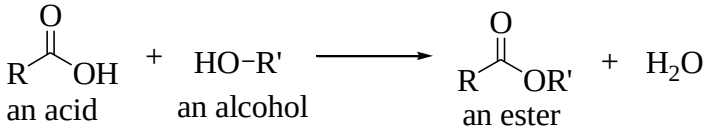
Name: _____ Section: _____

Experiment #15 – Synthesis and Characterization of Aspirin

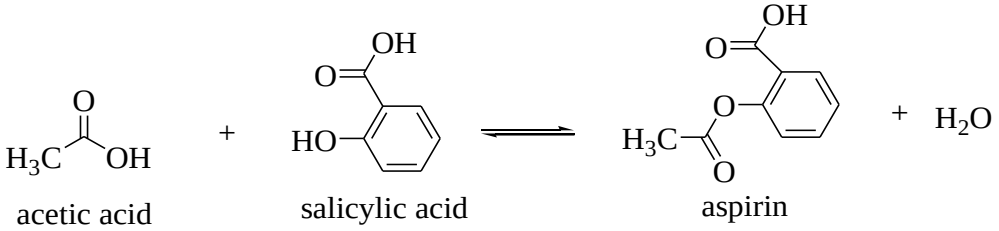
One of the simpler organic reactions that can be carried out is the formation of an ester from an acid and an alcohol. This reaction proceeds as follows:



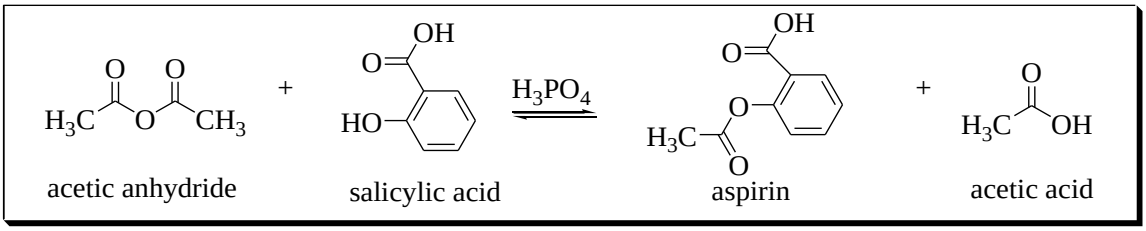
In the equation, R and R' are H atoms or organic fragments like CH_3, C_2H_5, or more complex aromatic groups. There are many known esters in organic chemistry that can be synthesized from organic acids and alcohols. The driving force for the reaction is in general not very great, resulting in an equilibrium mixture of the formed ester, water, acid, and alcohol.

There are some esters which are solids because of their high molecular weight or other properties. Most of these esters are not soluble in water, so they can be separated from the mixture by crystallization. This experiment involves an ester of this type, a substance commonly called aspirin (or acetylsalicylic acid). Aspirin is the active component in headache pills and is one of the most effective, relatively nontoxic, pain killers.

Aspirin can be made by the reaction of the hydroxyl group (–OH group) in the salicylic acid molecule with the carboxylic acid group (–COOH group) in acetic acid. The reaction proceeds as follows:



A better preparative method, which we will use in this experiment, employs acetic anhydride in the reaction instead of acetic acid. The anhydride can be considered to be the product of a reaction in which two acetic acid molecules combine, with the elimination of a molecule of water. The anhydride will react with the water produced in the esterification reaction and will tend to drive the reaction to the right. A catalyst, normally sulfuric or phosphoric acid, is also used to speed up the reaction. The reaction occurs as follows:



The aspirin you will prepare in this experiment is somewhat impure and should certainly not be taken internally, even if the experiment gives you a bad headache. We will attempt to purify the aspirin via recrystallization with ethanol. The purified compound will be characterized by its melting point and by infrared spectroscopy. For further theory on IR spectroscopy, see the "Introduction to IR and NMR Spectroscopy" lab located at the end of this manual.

Safety

During the synthesis steps of the procedure, wear gloves and safety goggles. Both phosphoric acid and acetic anhydride are corrosive and will cause burns if spilled on your skin. Salicylic acid is a skin irritant.

Procedure

Fill a 250 mL beaker approximately 1/4 full of water. Place it on a hot plate and heat to 80 ºC. Watch the temperature, the water should not boil.

Weigh out approximately 500 mg salicylic acid in a 25 mL Erlenmeyer flask. *Perform the next operation in the fume hood*: pipet 1.0 mL of acetic anhydride into the flask in such a way as to wash any crystals of salicylic acid on the walls down to the bottom. Add 5 drops of 85% phosphoric acid to the mixture to serve as a catalyst.

Clamp the flask so that it is immersed in the hot water bath for 10 minutes, stirring the liquid in the flask occasionally with a stirring rod. Once the reaction is complete, remove the flask from the water bath, and CAUTIOUSLY add 10 – 20 drops of water to the mixture to destroy any excess acetic anhydride. There will be some hot acetic acid vapor evolved as a result of the decomposition of any unreacted acetic anhydride.

Let the flask cool for a few minutes in air, during which time crystals of aspirin should begin to form. Put the flask in an ice bath to hasten crystallization and increase the yield of product. If crystals are slow to appear, it may be helpful to scratch the inside of the flask with a glass rod. Collect the aspirin by vacuum filtration. Be sure to wet the filter paper and turn on the vacuum suction before transferring the crystals. Use minimal water. Drop distilled water over the crystals; repeat the washing process, and then draw air through the funnel for a few minutes to help dry the crystals. Determine the mass of your impure aspirin.

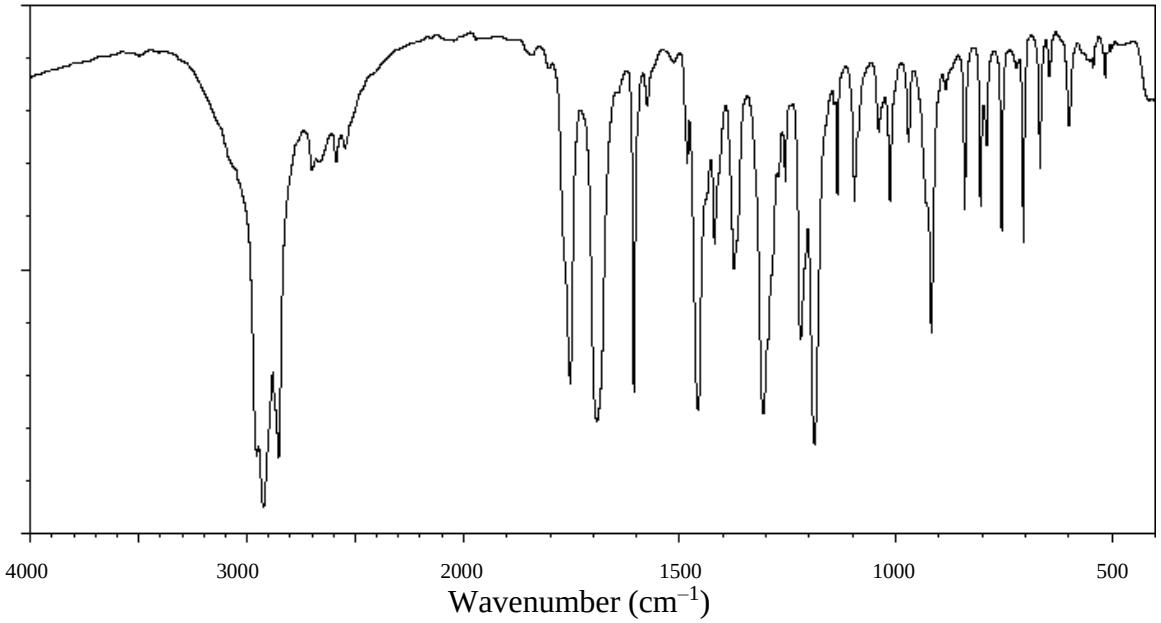
To purify your synthesized aspirin, transfer it to a 10 mL beaker and add approximately 10 to 20 drops of ethyl alcohol using a plastic pipet. Warm the solution to 60 ºC. Cover the solution and allow it to cool undisturbed to room temperature. Then set the beaker in an ice bath and once again scratch the inside of the flask with a glass rod to induce recrystallization. Collect the purified aspirin by vacuum filtration, and let the crystals dry for a few minutes before weighing them. Determine the mass of your dry purified aspirin.

Record the temperature of the melting point range temperature of your synthesized compound using the melting point apparatus. This range extends from the temperature when

the solid begins to soften until the disappearance of the last solid. Make sure your sample is dry before you take this measurement. Place a small amount of your compound in a capillary tube. Place the sample in the melting point apparatus and heat rapidly until 120 °C and then slowly (2 °C / minute) until the sample melts. Find the published value for the melting point of aspirin, and compare it to your obtained experimental value.

Optional, you may be asked to run an IR spectrum of your recrystallized product, where it will be compared to a known spectrum available below. Under the supervision of your instructor, you will take a small sample of your dry purified aspirin and analyze via a Fourier Transform Infrared (FTIR) spectrophotometer. Functional group recognition amongst the various absorption peaks should be noted. Consider the following:

Figure One. IR Spectrum of Acetylsalicylic Acid



C=C (aromatic), 1600 – 1400 cm^{-1}
C=O (ester), 1750 – 1730 cm^{-1}
C=O (carboxylic acid), 1725 – 1700 cm^{-1}
C–O (ester/carboxylic acid), 1300 – 1000 cm^{-1}
O–H (carboxylic acids), 3300 – 2500 cm^{-1}

Name: _____ Section: _____

Data

Weight of salicylic acid added _____

Volume of acetic anhydride _____

Density of acetic anhydride _____

Molecular Weight of acetic anhydride _____

Molecular Weight of salicylic acid _____

Theoretical Yield of aspirin _____

Actual Yield of crude aspirin _____

Actual Yield of recrystallized aspirin _____

Percent Yield of recrystallized aspirin _____

Melting Point of pure aspirin (literature) _____

Melting Point of recrystallized aspirin _____

Discussion Questions:

1. Determine the percentage yield of your crude product.

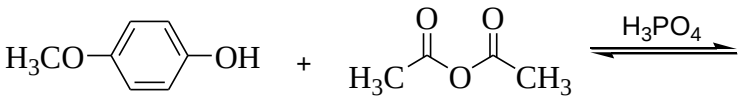
2. As in many organic reactions, the synthesis in this experiment is an equilibrium reaction. What steps could you take to improve the yield of aspirin in this particular experiment?

3. If the aspirin crystals were not completely dried before the melting point was determined, what effect would this have on the observed melting point?

Name: _____ Section: _____

4. *(Optional)* Discuss the purity of your final product. How pure (or impure) is your aspirin based on literature values? Comment on how your IR spectrum parallels the spectrum of pure acetylsalicylic acid, making certain to LABEL and discuss all characteristic absorption peaks. You should turn in the labeled IR spectrum of your product with this report.

5. Consider the reaction shown below. Predict the product(s) of this reaction.



Name: _____ Section: _____

Post-Lab Questions: Synthesis and Characterization of Aspirin

1. Determine the theoretical yield of aspirin that can be obtained from the addition of 2.0 grams of salicylic acid and 5.0 mL of acetic anhydride (density = 1.08 g/mL). What is the limiting reagent?

2. Determine the percentage yield of the reaction if 1.9 g of aspirin is obtained in this experiment.

3. What is the purpose of recrystallization?

4. Draw and name two different structural isomers for esters (RCOOR) with an empirical formula $C_3H_6O_2$.