

SYNTHESIS AND ANALYSIS OF ASPIRIN

LAB ADV COMP 22

From *Advanced Chemistry with Vernier*, Vernier Software & Technology, 2004

INTRODUCTION

Aspirin, the ubiquitous pain reliever, goes by the chemical name acetylsalicylic acid. One of the compounds used in the synthesis of aspirin is salicylic acid, which is itself a pain reliever that was known to many ancient cultures, including the Native Americans who extracted it from willow tree bark. Salicylic acid is extremely bitter tasting, and frequent use can cause severe stomach irritation. The search for a milder form of this pain reliever led to the successful synthesis of acetylsalicylic acid by the German chemist Felix Hoffmann in 1893.

Your two primary objectives in this experiment will be to synthesize and analyze aspirin. There is more than one way to synthesize aspirin; in this experiment, you will react acetic anhydride with salicylic acid in the presence of phosphoric acid (which acts as a catalyst). A drawing of the aspirin molecule is shown below.

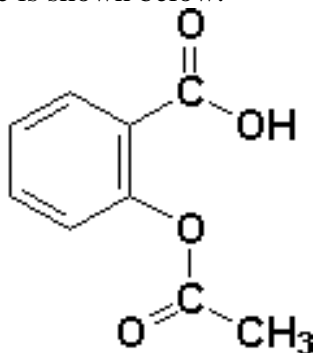


Figure 1

You will conduct two tests of your synthesis to verify that you did indeed make aspirin, and to determine its relative purity. First, you will measure the melting point of a sample of your product. Second, you will use a spectrometer to test the absorbance of your aspirin after it has been “prepped” with an iron solution to give it color.

OBJECTIVES

In this experiment, you will

- Synthesize a sample of acetylsalicylic acid (aspirin).
- Calculate the percent yield of your synthesis.
- Measure the melting temperature of your aspirin sample.
- Conduct a spectrophotometric analysis of your aspirin sample.

MATERIALS

PART I SYNTHESIS MATERIALS

50 mL Erlenmeyer flask	Solid salicylic acid
two 10 mL graduated cylinders	85% phosphoric acid solution, H_3PO_4
25 mL graduated cylinder	liquid acetic anhydride
Büchner funnel, filter, and filter paper	distilled water
spoon, spatula, or rubber policeman	cold distilled water
ice bath	small rubber band
hot plate	fume hood
plastic Beral pipet or eyedropper	balance

PART II MELTING TEMPERATURE TEST MATERIALS

Vernier computer interface	aspirin crystals (from Part I)
computer	hot plate
Temperature Probe	mineral oil
capillary tubes	ring stand, ring, and wire gauze
150 mL beaker or Thiele melting-point tube	cork or split stopper
mortar and pestle	small rubber band
glass stirring rod	utility clamp

PART III COLORIMETER TEST MATERIALS

Vernier computer interface	olid salicylic acid
computer	aspirin crystals (from Part I)
Vernier Spectrometer or Spec 20	95% ethanol
plastic cuvette with lid	0.025 M iron (III) nitrate solution, $Fe(NO_3)_3$
250 mL beaker	distilled water
100 mL beaker	100 mL volumetric flask
50 mL graduated cylinder	250 mL volumetric flask

PROCEDURE

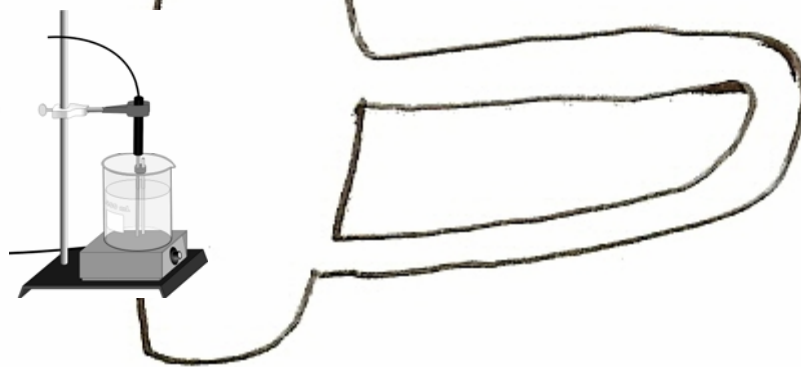
PART I Synthesize Aspirin

1. Obtain and wear goggles. **Note:** Conduct this reaction in a fume hood or a well-ventilated area of the room.
2. Measure out 2.0 grams of salicylic acid into a 50 mL Erlenmeyer flask.

3. Add 5.0 mL of acetic anhydride and 5 drops of 85% phosphoric acid. Swirl the mixture. If necessary, use a sparingly small amount of distilled water to rinse down any bits of solid that may be on the inner walls of the flask. **CAUTION:** *Handle the phosphoric acid and acetic anhydride with care. Both substances can cause painful burns if they come in contact with the skin.*
4. Heat the mixture on a hot plate, at 75°C, for 15 minutes, or when the mixture ceases releasing vapors. Stir the mixture occasionally during heating. After about 10 minutes, add 2 mL of distilled water to the flask. Set up a Büchner funnel and filter flask so that you are ready to filter the reaction mixture after it has cooled.
5. When you are confident that the reaction has reached completion (no vapors appearing), carefully remove the flask from the hot plate and add 20 mL of distilled water. Allow the mixture to cool to near room temperature. Transfer the flask to an ice bath for about five minutes. As the mixture cools, crystals of aspirin should form in the flask.
6. Transfer the contents of the cooled flask to a Büchner funnel assembly. Filter the mixture with vacuum suction. When most of the liquid has been drawn through the funnel, turn off the suction and wash the crystals with 5 mL of cold, distilled water. After about 15 seconds, turn the suction back on. Wash the crystals with cold, distilled water twice more in this manner.
7. Store the aspirin crystals in a safe place and prepare to test their purity.

PART II Test the Melting Temperature of an Aspirin Sample

8. Connect the Temperature Probe into Channel 1 of the Vernier computer interface. Connect the interface to your computer using the proper cable.
9. Start the *Logger Pro* program on your computer. Open the file “Exp 22 Aspirin Melt” from the *Advanced Chemistry with Vernier* folder.
10. Use a mortar and pestle to pulverize a small amount (about 0.2 g) of aspirin and place it in a small pile in the mortar. Push the open end of a capillary tube into the pile of aspirin powder. Pack aspirin into the capillary tube to a depth of about 1 cm by tapping the tube lightly on the table top.
11. Use a rubber band to fasten the capillary tube to the Temperature Probe. The tip of the tube should be even with the tip of the probe. Use a utility clamp to connect the Temperature Probe to a ring stand. If necessary, place the probe in a split stopper or a cork to secure it in the clamp (see Figure 1).




12. Prepare a oil bath to be heated by a hot plate or a bunsen burner. Your instructor may also direct you to use a Thiele tube. If you do not use a Thiele tube, stir the mineral oil bath throughout the testing to maintain a consistent bath temperature.
13. Click to begin data collection or select “start” if using a calculator. Immerse the capillary tube-Temperature Probe in the oil bath. Warm the aspirin sample at a gradual rate so that you can accurately determine the melting point. The white powder will become clear when it is melting. Observe the temperature readings on the computer screen and record the melting point as precisely as possible.
14. Conduct a second trial with a new sample of aspirin in a new capillary tube.

PART III Test the Colorimetric Absorbance of an Aspirin Sample

Your synthesis converted most, but not all, of the salicylic acid into acetylsalicylic acid. You will mix iron (III) nitrate with salicylic acid and your aspirin sample to complex the salicylic acid, which is a bluish-purple color. You will analyze several samples to determine the amount of salicylic acid in your synthesized aspirin. You can use this information to calculate the purity of your aspirin sample. Follow Steps 15-17 to prepare a set of salicylic acid standard solutions, if not provided and conduct testing to develop your own Beer’s law plot of the standards. If your instructor supplies you with the Beer’s law standard data, start at Step 18.

15. Quantitatively prepare the stock salicylic acid solution.
 - a. Measure out about 0.20 g of salicylic acid. Record the precise mass that you use.
 - b. Transfer the salicylic acid to a 250 mL beaker and add 10 mL of 95% ethanol. Swirl the beaker to dissolve the solid.
 - c. Add 150 mL of distilled water to the beaker. Mix the solution.
 - d. Quantitatively transfer the solution from the beaker to a 250 mL volumetric flask. Thoroughly rinse the beaker with several portions of distilled water, and transfer the rinse water to the volumetric flask. Add distilled water, as needed, to fill the flask to the 250 mL mark. Mix the solution thoroughly. Calculate the precise molar concentration of your stock solution and record it in your data table.
16. Prepare four standard solutions of varying concentrations of salicylic acid.
 - e. To prepare 100 mL of your first standard solution, quantitatively transfer precisely 10 mL of the stock salicylic acid solution to a 100 mL volumetric flask.
 - f. Add 10 mL 0.025 M $\text{Fe}(\text{NO}_3)_3$ solution to the flask and fill to mark with distilled water.
 - g. Calculate the precise molar concentration of your first stock solution and record it in your data table.
 - h. Prepare the remaining three salicylic acid standard solutions by diluting the stock solution that you prepared in Part a of this step. Decide on a suitable set of dilutions for your Beer's law plot.
 - i. Calculate the precise molar concentration of each dilution and record it in your data table.
17. Connect a Colorimeter to Channel 1 of the Vernier computer interface. Connect the interface to your computer using the proper cable.
18. Open the file "Exp 22 Aspirin Color" from the *Advanced Chemistry with Vernier* folder.
19. Calibrate the Colorimeter.
 - a. Prepare a *blank* by filling an empty cuvette $\frac{3}{4}$ full with distilled water. Place the blank in the cuvette slot of the Colorimeter and close the lid.
 - b. Set the wavelength on the to 565 nm, press the zero, and proceed directly to Step 20.
20. You are now ready to collect absorbance-concentration data for the four standard solutions.
 - a. Click .
 - b. Remove the cuvette from your Colorimeter and pour out the water. Using the solution in the first 100 mL volumetric flask of salicylic acid, rinse the cuvette twice with ~1 mL amounts and then fill it $\frac{3}{4}$ full. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid.
 - c. After closing the lid, wait for the absorbance value displayed on the monitor to stabilize, then click , type the molar concentration in the edit box, and press the ENTER key. The data pair should now be plotted on the graph.
 - d. Discard the cuvette contents as directed by your instructor. Using the solution in the second 100 mL volumetric flask, rinse the cuvette twice with ~1 mL amounts, and then fill it $\frac{3}{4}$ full. Wipe the outside, place it in the Colorimeter, and close the

- lid. When the absorbance value stabilizes, click , type the molar concentration in the edit box, and press the ENTER key.
- e. Repeat the procedure for the remaining salicylic acid solutions that you prepared.
- f. When you have finished with the last salicylic acid solution, click . Record the absorbance and concentration data pairs for the standard solutions in your data table.
- g. Examine the graph of absorbance vs. concentration. To calculate the best-fit line equation, click the Linear Regression button,  . Record this equation in your data table.
21. Prepare the aspirin sample for testing. Complete this step quickly.
- Measure out about 0.20 gram of aspirin and transfer it to the 250 mL beaker. Record the precise mass of aspirin that you use.
 - Add 10 mL of 95% ethanol to the beaker of aspirin sample. Swirl the mixture to dissolve the solid.
 - Add 150 mL of distilled water to the beaker. Mix the solution.
 - Quantitatively transfer the solution from the beaker to a 250 mL volumetric flask. Thoroughly rinse the beaker with several portions of distilled water, and transfer the rinse water to the volumetric flask. Add distilled water, as needed, to fill the flask to the 250 mL mark. Mix the solution thoroughly.
 - Transfer 5 mL of the aspirin solution from the 250 mL volumetric flask to a clean and dry 100 mL volumetric flask. Add 0.025 M $\text{Fe}(\text{NO}_3)_3$ solution to the flask to make precisely 100 mL. Mix the solution thoroughly.
22. Measure and record the absorbance of the treated aspirin sample. This must be done within 5 minutes of completing Step 21.
- Transfer about 1 mL of the treated aspirin sample to a clean and dry plastic cuvette.
 - Rinse and fill the cuvette $\frac{3}{4}$ full with the sample. Cap the cuvette and place it in the Colorimeter.
 - If the absorbance value falls within the range of the salicylic acid standard solutions, record it in your data table. If it does not, repeat Step 21d with a more dilute, or more concentrated sample.
 - Repeat Parts a-c of this step twice with new aliquots of the treated aspirin sample.
23. Discard all solutions as directed.

DATA TABLES

PART I Synthesis of Aspirin

Mass of salicylic acid used (g)	Trial 1
Volume of acetic anhydride used (mL)	
Mass of acetic anhydride used (vol. \times 1.08 g/mL)	
Mass of aspirin synthesized (g)	

PART II Melting Temperature Data

	Trial 1
Melting Temperature ($^{\circ}$ C)	

PART III Salicylic Acid Standard Stock Solution

Initial mass of salicylic acid (g)	
Moles of salicylic acid (mol)	
Initial molarity of salicylic acid (M)	

PART III Beer's Law Data for Salicylic Acid Standard Solutions

Trial	Concentration (M)	Absorbance
1		
2		
3		
4		

Best- fit line equation for the salicylic acid	
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Test of the Purity of the Synthesized Aspirin

Initial mass of aspirin sample (g)	
Absorbance of aspirin sample	
Moles of salicylic acid in aspirin sample (mol)	
Mass of salicylic acid in aspirin sample (g)	
Mass of aspirin in sample (g)	
Percent aspirin in sample (%)	

DATA ANALYSIS

1. What is the theoretical yield of aspirin in your synthesis? The mole ratio is 1:1 between salicylic acid and acetic anhydride in this reaction.
2. The melting temperature of pure acetylsalicylic acid is 135°C. Based on the results of the melting temperature test, what is the percent purity of your sample of aspirin?
4. Based on the results of the absorbance testing with the Colorimeter, what is the percent purity of your sample of aspirin? Does this percent purity compare well with the results of the melting temperature test? Explain.
5. Use your percent purity calculations to determine the percent yield of your synthesis of aspirin.
6. Use your text, or another suitable resource, to find the structural formulas for salicylic acid, acetic anhydride, and aspirin. Use these structural formulas to construct a reaction equation describing the synthesis of aspirin.