Acylation of Ferrocene

M. Jones: Ferrocene, 12.7, structure on page 572.

J.R. Mohrig, Technique 15, 15.1 – 15.8, pgs 177 – 189
C.N. Hammond, and P.F. Schatz: Technique 17, 17.1 – 17.7, pgs 190 – 226

This procedure has been adapted from the microscale procedure described in the third edition of *Macroscale and Microscale Organic Experiments* by Kenneth L. Williamson (Houghton Mifflin, Boston, 1999).

Background

**Ferrocene.** In this laboratory, you will acylate ferrocene (Figure 1). Ferrocene is an organometallic compound, which behaves like an aromatic compound. As one would suppose, an organometallic compound contains both a hydrocarbon and a metal. Sometimes this molecule is referred to as a “sandwich” complex because the iron is “sandwiched” between two rings.

![Figure 1. The overall reaction for the acylation of ferrocene.](image)

One way to look at this molecule is to think of it as containing two cyclopentadienyl anions (formal -1 charge per each ring) and an iron atom with a +2 charge. Cyclopentadienyl anion is an aromatic compound, and its $\pi$ electrons bond to the iron to yield an overall neutral complex.
The reactivity of ferrocene is similar to other aromatic compounds. Therefore, it can undergo electrophilic aromatic substitution in a very similar mechanism to that of benzene.

In this experiment, ferrocene is acylated using acetic anhydride with a catalytic amount of phosphoric acid. There are two possible products, acetylferrocene and 1,1’-diacetylferrocene, which will be identified at the end of this reaction.

Cautions:
- Take extra care when handling the acetic anhydride and phosphoric acid.
- Make sure to use a clean spatula and reaction tube. The reaction tubes should be cleaned with soap, water and a brush first, rinsed thoroughly, and dried (if needed rinse with acetone).
- Make sure to return the top to the bottles.

Experiment

Preparing a TLC Plate. Obtain a TLC plate from your TA. Handle the plate carefully so that you do not disturb the adsorbent coating or get it dirty. As in Figure 2 at the end of this document, use a ruler and pencil to measure 0.5 inches from the bottom of the plate, and gently draw a line across the plate. This is the origin line where you will spot your samples on the plate. On the origin line, starting 0.5 cm from the end of the plate, make a small tick mark every 1 cm. You will be spotting a different sample on each tick mark: 1) pure ferrocene, 2) your product before running the column, 3) the yellow fraction, 4) the orange fraction, and 5) the red fraction (if you collect one). Mix a small amount of pure ferrocene with a minimal amount of methylene chloride (CH₂Cl₂). Using a microcapillary, spot the pure ferrocene on the first tick mark of the TLC plate. The remaining spots will be added later.

Reaction Workup. Add 200 mg of ferrocene, 1.0 mL of acetic anhydride, and 0.3 mL of phosphoric acid to a large reaction tube and stir. Heat the tube to a gentle reflux using a water bath with constant stirring for 10 minutes. Note the color during the reaction. Cool the reaction tube to room temperature. Add dropwise 1.5 mL of ice water, followed by 3M NaOH solution until the resulting product mixture tests neutral (pH paper). Collect the solid via vacuum filtration. You will be purifying your product using column chromatography with alumina as your stationary phase.

Making the Column. Obtain a micro-column that is fitted with a fritted disc (frit), column tip, and small funnel. Clean the column with a small amount of acetone. If your column does not have a frit, you may pack it with a small cotton plug at the tip. Assemble to column, tip and funnel. Weigh 3 g of alumina and pour into the column. Gently tap the sides of the column to pack the alumina.
Weigh out an additional 500 mg of alumina. Dissolve your reaction product in a minimal amount of methylene chloride. Using a different microcapillary (to avoid contamination), spot your reaction product on the second tick mark of the TLC plate. Next, take your product dissolved in methylene chloride and add the 500 mg of alumina to it. Gently evaporate off the methylene chloride to a dry residue by stirring. Add your product residue to the top of the column. You will first start with hexanes as your eluent. Add hexanes to the column until the liquid level covers the solid alumina. Do not let the column go dry! Note the colors of the fractions on the column. After the yellow fraction is completely through the column, switch to 50:50 hexanes:tert-butyl methyl ether as your eluent. Start adding the 50:50 hexanes:tert-butyl methyl ether mixture before the level of the hexanes eluent falls below the top of the alumina. Collect each of the fractions (yellow, orange, and red) into separate, labeled, preweighed vials. Using different microcapillaries, spot your yellow, orange and red (if you collected it) fractions onto the third, fourth, and fifth tick marks, respectively, on the TLC plate. Add a boiling stick to each vial and evaporate off the solvent. Reweigh each vial. Take a melting point of each product.

**Developing a TLC Plate:** You will now perform a TLC of your products against your starting material using the silica plates as your stationary phase and 95:5 hexanes:ethyl acetate as your mobile phase. Start by adding 10 mL of 95:5 hexanes:ethyl acetate to a 50 mL beaker. Place the prepared TLC plate into the developing beaker, cover with an inverted 400 mL beaker, and leave it undisturbed on your bench top. Make sure the solvent does not cover the origin line! The solvent will gradually rise up the TLC plate by capillary action. Allow the plate to develop until the solvent is about a 0.5 cm below the top of the plate. Remove the plate from the beaker and immediately mark the solvent front with a pencil. Allow the plate to dry. If there are any colored spots, circle them lightly with a pencil. Most samples are not colored and need to be visualized with a UV lamp. Hold a UV lamp over the plate and circle any spots you see. Keep your TLC plate and turn it in stapled to the front of your post lab.

![Figure 2: TLC Plate.](image)