

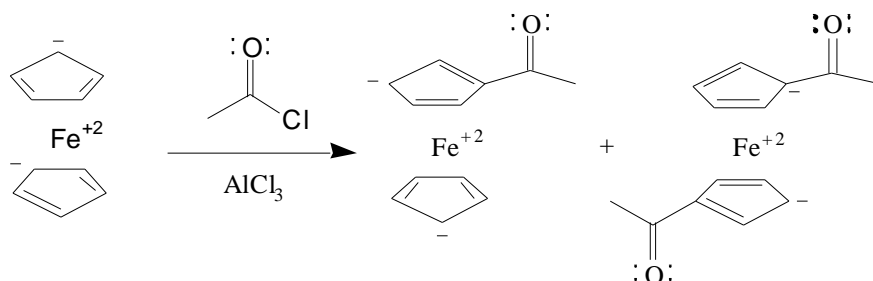
Friedel-Crafts Acylation of Ferrocene

Introduction

In this reaction, a compound containing two aromatic rings will undergo Friedel-Crafts acylation. Since it has two rings, it can either react once or twice, creating two products, which we will separate by column chromatography. You will calculate the yield of both products separately, as if each were the only product.

The aromatic starting material is ferrocene, an ionic compound made from an Fe^{+2} cation and two cyclopentadiene anions put together like a sandwich (the rings are the bread, the iron is the meat). Both of the rings are aromatic and can undergo electrophilic aromatic substitution reactions (such as Friedel-Crafts acylation) just like benzene rings can. If only one ring reacts, then the product is monoacetylferrocene, which is orange in color. If both rings react, then the product is diacetylferrocene, which is red-orange in color. The colors will make it possible to see the separation occurring during the column chromatography.

The reagents needed for a Friedel-Crafts reaction are AlCl_3 and an acid chloride, in this case acetyl chloride. Both AlCl_3 and acetyl chloride react with water. You will need to weigh the AlCl_3 out quickly to prevent it from having a chance to react with water in the air. You will also use a drying tube to protect the reaction from water vapor while the reaction is running.



To run the reaction, you will first prepare a solution of AlCl_3 and acetyl chloride to create the strong electrophile, an acylium ion. You will then prepare a solution of ferrocene and add it to the reaction. After the reaction is done, it will be quenched, and the organic products and starting material will be extracted out. The products will then be separated by chromatography. Finally, the products will be characterized.

reagents	volume	density	mass	MW	mmoles	eq
ferrocene	x	x	100 mg			1.00
acetyl chloride	0.080 ml					
AlCl_3 (anhydrous)	x	x	150 mg			
dichloromethane	3.5 ml	x	x	x	x	solvent
monoacetylferrocene	x	x				1.00
diacetylferrocene	x	x				1.00

Procedure

Before coming to lab:

- Review the Friedel-Crafts acylation reaction in your lecture notes.
- Read the entire procedure to make sure you understand what you will be doing.
- Review the following techniques. Make sure to read the ones we have not done recently!
 - Extraction and Washing
 - Drying an Organic Solution
 - Evaporating an Organic Solution
 - Analysis of a Mixture by TLC
 - Measuring a Melting Point
 - Separating Compounds by Column Chromatography
- Do the calculations needed to fill out the reagent table above.
- Write an introduction to this lab in your lab notebook, making sure to include the reaction and the reagent table.
- Answer the pre-lab questions on-line.

During lab:

Set up and run the reaction –

- Set up a calcium chloride drying tube. Get out two yellow clips, a septum and cap, and two clean, air-dried conical vials and a spin vane. (If you need to clean a vial, make sure to rinse it with acetone and dry it well.) Get a Claisen adapter from the front desk.
- Quickly weigh out the anhydrous AlCl_3 and add it to the conical vial. Then add 2.0 ml of dichloromethane. Put in the spin vane, top it with a Claisen adapter, and add the drying tube (on the curved branch) and a cap and septum (on the straight branch). Use yellow clamps to secure the joints.
- Clamp it above your stirrer/hot plate. While stirring, add the acetyl chloride with the a graduated pipet (open the top briefly). This should cause the the acylium ion to form.
- In the other conical vial weigh out the ferrocene. Then add 1.5 ml of dichloromethane. Swirl it around until all of the solid has dissolved, then transfer this solution to the reaction mixture using a plastic pipet (open the top again briefly). Make sure to record what you observe.
- Stir the reaction at room temperature for 15 minutes.

Quench the reaction and isolate the products –

- Fill a sep funnel about 1/3 full of ice (you will probably have to crush them with a mortar and pestle to get them to fit into the opening). Quench the reaction by pouring it into the sep funnel. Rinse the vial with dichloromethane and add it to the sep funnel.
- Neutralize the mixture by adding 25% NaOH dropwise until pH paper indicates that the solution is basic (dip in a spatula or pipet into the water layer and touch it to the paper to test it). Make sure to shake the mixture gently so that the base interacts with all of the solution.
- Drain off the dichloromethane containing the colored products into a beaker. Extract the remaining water phase three times with dichloromethane, adding the extracts to the original dichloromethane solution.
- Add enough sodium sulfate to dry the solution (if you have water droplets, remember to pour it into a new beaker to leave the water behind before adding sodium sulfate).
- Analyze the solution by TLC, comparing it to a solution of ferrocene. Use 5% methanol in dichloromethane as the eluting solvent (make this solution in your 10 ml graduated cylinder and pour it into a beaker to mix it before using). Determine what approximate ratio of products you have.

Separate and purify the products by column chromatography:

- Transfer the solution containing the products to a round bottom flask, rinsing the sodium sulfate with dichloromethane until most of the colored products are removed.
- Add 500 mg of alumina and rotovap to dryness.
- Prepare a chromatography column according to the instructions in "Separating Compounds by Column Chromatography," using the alumina provided.
- Add the products/alumina mixture to the top of the column.
- Begin eluting with hexanes. If a yellow ferrocene band appears, elute with hexanes and collect the solvent until the ferrocene has all been removed. (If all of your ferrocene has been consumed, you won't see this band.)
- Begin eluting with 50% hexanes and 50% dichloromethane (prepare about 100 ml of this solution and mix well before using). This should cause both of the product bands to move, with the orange monoacetylferrocene band moving faster than the red-orange diacetylferrocene band. It is important that these bands separate by the time they get to the end of the column – look for a white space to appear between them.
- When the bands are about half way down the column, switch to 25% hexanes and 75% dichloromethane. Continue eluting until the monoferrocene has been removed from the column.

- Change eluting solvents to 10% methanol and 90% dichloromethane. This will cause anything that is left in the column (hopefully just the red-orange band) to be eluted.

Finish isolating the products and characterize them –

- Spot a TLC plate with each of the solutions that you have collected and run it with the same solvent as before. Observe whether your bands contain a pure product or a mixture.
- Rotovap each of the products to dryness in a tared round bottom flask.
- Observe the appearance of the products; authentic monoacetylferrocene is an orange crystalline solid, while diacetylferrocene is a red-orange crystalline solid.
- Obtain a mass of both products. Calculate the % yield of each product. The total should not exceed 100%!
- Obtain a mp of both products and compare them to the mp given in the literature: monoacetylferrocene mp = 82° C, diacetylferrocene mp = 126° C.
- Your conclusion should discuss the observations and interpretations you made during the experiment, the appearance of your products, their mass and % yields, the TLC data that you obtained (ratio of product and whether the separation was complete) and the melting points, comparing them to the literature values and commenting about their purity.

After lab:

- Finish writing up your procedure and observations.
- Print out the questions on the next page and fill them out. Turn in this sheet with the carbon copies of your lab (in 2 separate piles).

Questions for the Friedel-Crafts Reaction

Name _____

- 1) Explain why the organic rings in ferrocene are aromatic. (1 pt)

- 2) Write out all resonance structures for one of the rings. (1 pt)

- 3) Give the mechanism by which the electrophile in this reaction is generated. (1 pt)

- 4) Give the mechanism by which one of the ferrocene rings becomes acylated. Note – it will have the same steps as a normal electrophilic substitution, but since the starting material is already charged, the intermediate will be different. (2 pts)

- 5) Draw the reactions that would occur if you made the following substitutions: (2 pts)
 - a) benzene instead of ferrocene

 - b) benzoyl chloride instead of acetyl chloride (look up or see me for structure)

- 6) Write out the reactions that occur when acetyl chloride and aluminum chloride react with water during the quenching step. (2 pts)
 - a) acetyl chloride

b) AlCl_3

7) No acids were added to this reaction. What was being neutralized when NaOH was added? (hint – look at the answer to the previous question!) (1 pt)

8) Look at the equivalents of acetyl chloride and aluminum chloride that were used in this reaction. (2 pts)

a) What would the product(s) be if the reaction went to completion?

b) Why didn't the reaction go to completion?

9) If these products weren't colored, would IR be a good way to determine if the starting material had reacted to form any products? Why or why not? (2 pts)

Would it be a good way to tell the two products apart?

10) Compare the three mixtures used to elute the column – which was most polar and which was least? (1 pt)

11) Draw a three TLC's predicting what happens if ferrocene, monoacetylferrocene, and diacetylferrocene were run in each of these solvents. (3 pts)