

# Nitration Reactions and HPLC Analysis

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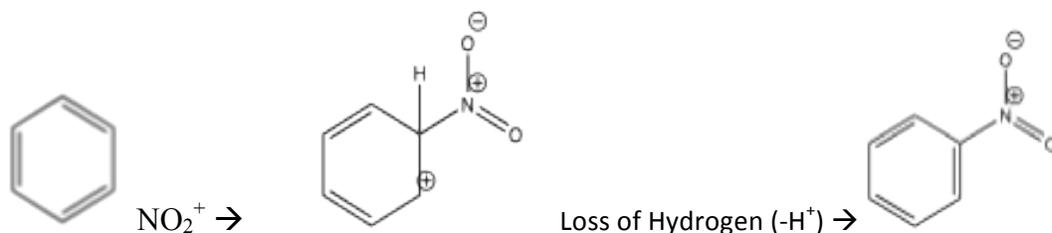
## Abstract:

In this project, twenty-one monosubstituted benzene derivatives were nitrated under the same general set of conditions<sup>1</sup> in order to design a new organic chemistry laboratory experiment. Ten of the reactions were further investigated using HPLC analysis in order to determine how much of three potential isomeric products were made. Six of those ten starting materials have been separated on at least one type of column. Once the last four reactions are run on HPLC, the reactions can be quantified so that students can determine themselves what percentage of products are made from different nitration reactions.

## Introduction:

An aromatic nitration is a reaction where a positively charged nitronium ion ( $\text{NO}_2^+$ ) reacts with the electron rich pi system of an aromatic ring. A hydrogen atom is then pulled off of the ring to restore the pi system of the aromatic compound as shown below.

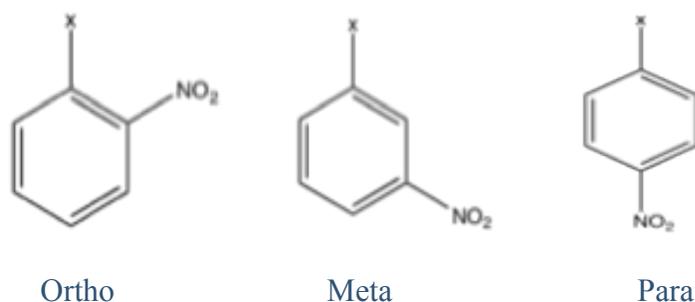
**Figure 1: General Nitration Reaction**



When there is a functional group, also known as a substituent, on the aromatic ring, the rate of the reaction and the location where the nitronium ion adds to the ring are both affected depending on the substituent on the ring. There are two main categories of substituents: electron withdrawing groups and electron releasing groups. Electron withdrawing groups pull electron density away from the ring, making the already unstable carbocation intermediate even more unstable. This leads to the reaction progressing slower than that of an unsubstituted aromatic ring. Electron releasing groups donate electron density to the ring which stabilizes the carbocation making the reaction progress faster than an unsubstituted aromatic ring.

During a nitration reaction on a monosubstituted benzene ring, also known as a benzene derivative, the nitronium ion can add to one of three different spots on the ring: ortho, meta, or para. When the nitronium ion adds to the carbon next to the substituent, it is considered to have added ortho. When the ion adds two carbons away, it is considered meta. Lastly, when the ion adds to the carbon opposite of the substituent, it is considered to have added in the para position. All three possibilities are shown below in Figure 2.

**Figure 2: Three Possible Nitration Reaction Configurations**



Electron releasing groups, or activating groups, stabilize the ortho and para positions so the ortho and para products form faster than the meta product. Since the ring is stabilized by the donation of electrons, activating groups speed up the rate of the reaction. Electron withdrawing groups, or deactivating groups, destabilize the ring tremendously on the ortho and para positions, making it

faster to add to the meta position because it is more stable than. The halogens, however, destabilize the ring and slow the reaction, but direct the nitronium ion to add ortho and para instead of meta.

Electron releasing groups generally direct the ion to add ortho or para while electron withdrawing groups usually direct the ion to add meta; however, there will be a small percent of the meta addition with an electron releasing group along with some ortho and para addition with an electron withdrawing group. The precise amounts of each configuration are important not only to understand where the groups generally add, but also how much of each of the three configurations are present in a mixture of products generated from a reaction. There is a technique used to separate molecules so that they can be quantified known as high performance liquid chromatography or HPLC. The molecules are pushed through a column with a polar mobile phase, while the walls of the column are nonpolar. When a group of molecules, after going through the column, reach the ultraviolet detector, a peak shows up in the software which gives a corresponding time of elution and a curve that can be integrated to find the area of the peak, or exactly how much of a substance came through at that particular time. Once the conditions such as the type of column, flow rate, and mobile phase strength are optimized, separate peaks will show up corresponding to each unique compound with different areas. By running standards of known compounds one at a time, each peak can be identified as a certain isomer of the product. Therefore, a crude sample of products can be separated, identified, and quantified by this instrument.

**Results:**

Table 1 shows which reactions were successful, which were problematic, and which were disastrous. It also shows which starting materials were activating and which were deactivating.

**Table 1**

| Successful Starting Materials<br>(Activating or Deactivating) | Mediocre Starting Materials<br>(Activating or Deactivating) | Problematic Starting Materials<br>(Activating or Deactivating) |
|---------------------------------------------------------------|-------------------------------------------------------------|----------------------------------------------------------------|
| Methyl Benzoate (D)                                           | Nitrobenzene (D)                                            | Biphenyl (A)                                                   |
| Acetanilide (A)                                               | Toluene (A)                                                 | Phenol (A)                                                     |
| Bromobenzene (D)                                              | $\alpha, \alpha, \alpha$ -trifluorotoluene (D)              | Anisole (A)                                                    |
| Benzoic Acid (D)                                              | Benzene (Standard)                                          | Acetophenone (D)                                               |
| Benzonitrile (D)                                              | Phenetole (A)                                               | Styrene (A)                                                    |
| Tert-butyl Benzene (A)                                        |                                                             | Phenyl Acetate (A)                                             |
| Ethyl Benzene (A)                                             |                                                             | Isopropyl Benzene (A)                                          |
| Chlorobenzene (D)                                             |                                                             | Benzaldehyde (D)                                               |

Table 2 shows all the starting materials that yielded products and lists their yields.

**Table 2**

| Starting Materials that Yielded Products   | Percent Yield |
|--------------------------------------------|---------------|
| Methyl Benzoate                            | 62.1%         |
| Acetanilide                                | 47.1%         |
| Nitrobenzene                               | 73.8%         |
| Bromobenzene                               | 36.8%         |
| Anisole                                    | 9.58%         |
| Toluene                                    | 5.60%         |
| $\alpha, \alpha, \alpha$ -trifluorotoluene | <1%           |
| Benzoic Acid                               | 55.8%         |
| Benzonitrile                               | 75.2%         |
| Isopropyl Benzene (crude)                  | 84.9%         |
| Tert-butyl Benzene (crude)                 | 84.5%         |
| Benzaldehyde                               | 2.89%         |
| Ethyl Benzene (crude)                      | 78.8%         |
| Benzene                                    | 58.3%         |
| Chlorobenzene                              | 20.6%         |

Table 3 shows the starting materials and their products' separation ability in the column.

**Table 3**

| Starting Materials + Products | C8 Column (Separation) | Phenyl Column (Separation) |
|-------------------------------|------------------------|----------------------------|
| Benzoic Acid                  | Success                | Failure                    |
| Nitro Benzene                 | Success                | Failure                    |
| Methyl Benzoate               | Success                | In Progress                |
| Toluene                       | Failure                | Success                    |
| Acetanilide                   | In Progress            | Success                    |
| Bromobenzene                  | Not Experimented Yet   | Success                    |

Table 4 shows the starting materials used and their products' detailed information in regard to the successful HPLC runs. It shows the column that worked for each starting material, the mobile phase composition, the flow rate, and in what order compounds eluted from the column ("o" is ortho, "m" is meta, "p" is para, and "sm" is starting material).

**Table 4**

| Starting Material | Column Type   | Mobile Phase (%)                | Flow Rate    | Elution Order |
|-------------------|---------------|---------------------------------|--------------|---------------|
| Benzoic Acid      | C8 column     | 80/20 aq/MeOH<br>aq had 1% acid | 0.800 mL/min | o, m, p, sm   |
| Nitrobenzene      | C8 Column     | 54/46 aq/MeOH                   | 1.000 mL/min | p, o, m, sm   |
| Methyl Benzoate   | C8 Column     | 50/50 aq/MeOH                   | 0.800 mL/min | m, sm*        |
| Toluene           | Phenyl Column | 50/50 aq/MeOH                   | 1.000 mL/min | sm, o, p, m   |
| Acetanilide       | Phenyl Column | 50/50 aq/MeOH                   | 1.000 mL/min | sm, o, m, p   |
| Bromobenzene      | Phenyl Column | 50/50 aq/MeOH                   | 1.000 mL/min | o, sm, p, m   |

\*: Only starting material and meta product were separated

**Discussion:**

In total, twenty-one reactions were run in order to see which would nitrate once and be easily to work with. Table 1 shows that eight starting materials were successful, five starting materials were mediocre, and eight starting materials were problematic. Most of the starting materials that worked well were deactivating groups. This is likely due to the fact that benzene derivatives with deactivating substituents will nitrate but will only nitrate once, giving a maximum of three products (ortho, meta, and para isomers). Most of the reactions that did not work were activating; this is mostly because the starting material would dinitrate or even trinitrate readily, yielding many different products. With so many products, it is hard to dissolve let alone recrystallize a product. There were a couple starting materials that did not work for other reasons. Styrene, for example, did not work because when the starting material was added to the sulfuric acid, the double bond in the styrene sulfonated before the nitration reaction had begun.<sup>2</sup>

There were fifteen products that had yields ranging from less than 1% to 85% (Table 2). Solid products were usually analyzed by determining the melting point, performing infrared radiation spectroscopy (IR) and nuclear magnetic resonance spectroscopy (NMR), while the liquids are still in their crude form because separation of liquids requires flash chromatography whereas solid products require only recrystallization. Since the liquids are in their crude forms, they generally had the higher yields when compared to solids.

After the twenty-one reactions were run, the ones that worked well were then used to make 250 mg/L solutions to run on the HPLC. A total of six compounds and their products have been tested and separated on at least one column so far. Generally, a sample would be made of the starting material and the ortho, meta, and para products dissolved in methanol and water.

About 50  $\mu\text{L}$  would be injected into the HPLC in order to see if the four products separated under a specific flow rate and mobile phase composition. If all the peaks separated, then the separation would be deemed successful and a new mixture of known compounds would be run. If the peaks did not separate then the polarity of the mobile phase would be increased and then the sample would be injected again. Table 3 shows which compounds worked on each column. Generally if the trials lasted longer than fifteen minutes without good separation they were deemed failures, while the ones that had clean separation were deemed successful. So far in the six compounds that have been run, each has separated on one type of column but not on the other. Once a mixture of a starting material and products has separated well, a sample of crude product from a reaction can be injected into the HPLC to get a general idea of the magnitudes of the peaks for each of the products. This is important because this is the first step to quantifying exactly how much of each product was created in the reaction. Crude samples have not been run yet; however, purified samples of a single product synthesized in lab has been placed into the HPLC and showed about 99% purity of a single compound.

Future research includes running more standards that will be separated on HPLC and then crude sample of reactions will be run and the percentages of products will be quantified. Once this information is collected a new organic chemistry lab can be designed to help students critically think about aromatic substitution reactions and deduce the rules of functional group directing affects for themselves instead of being lectured or learning from a textbook.

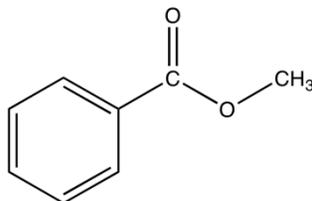
**Conclusions:**

Out of twenty-one reactions run this summer, about ten worked well enough to consider running HPLC analysis. So far six sets of compounds and their products have been separated on

at least one HPLC column. After the next four sets of compounds are separated, quantification will begin using known standard samples.

### Experimental Section:

#### Methyl Benzoate



3.0661 grams (22.5 mmol) of methyl benzoate was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the methyl benzoate mixture over a period of fourteen minutes with periodic stirring. The reaction turned yellow and seemed to form two layers in the flask. Thirty minutes later, the reaction was poured onto 25 grams of ice to quench. The solution turned cloudy and bubbly with a whitish yellow precipitate. TLC analysis showed starting material and product in the crude solid. The crude product was recrystallized in methanol to yield 2.5193 grams methyl-3-nitrobenzoate as a light white solid.

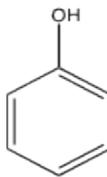
Percent yield: 62.1%

Melting point: 76-78°C

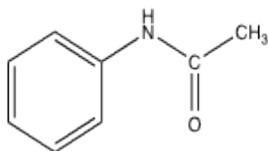
IR: (cm<sup>-1</sup>) 1718.27, 1527.23, 1351.63, 1291.65, 1269.57, 1135.86, 977.07, 727.75

NMR:  $\delta$  4.0 (3H, s), 7.5-9.0 (4H, m)

## Phenol



2.1121 grams (22.4 mmol) of phenol was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the phenol solution over a period of fifteen minutes with periodic stirring. The solution turned from blackish-green to blackish purple during the reaction. TLC analysis showed that all the starting material had been used up and fifteen minutes after the end of the nitration, the solution was quenched on 25 grams of ice. This produced a black solid that looked like tar. Further TLC analysis showed that many products were formed instead of just the three single nitration products. It seems that phenol dinitrated and even trinitrated during the reaction instead of the ideal single nitration. This reaction was run a second time with a lower amount of nitric and sulfuric acid, but the same results were observed.

**Acetanilide**

4.0511 grams (30.0 mmol) of Acetanilide was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the acetanilide mixture over a period of thirteen minutes with periodic stirring. During the reaction, the solution turned yellow and later brown also. TLC analysis showed that most of the starting material was exhausted, so the reaction was quenched with 25 grams of ice about thirty minutes after the addition of nitric acid. The crude product was recrystallized in ethanol to produce 2.5460 grams of 4-nitroacetanilide as a yellow solid.

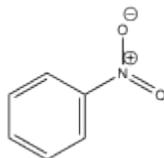
Percent yield: 47.1%

Melting point: 197-202° C, 195-199° C

IR: (cm<sup>-1</sup>) 3277.04, 1681.21, 1618.08, 1597.94, 1567.15, 1503.33, 1347.29, 1302.95, 1269.6, 1113.56, 849.14, 750.04

NMR:  $\delta$  2.1 (3H, s), 4.0 (1H, s), 8.0 (4H, m)

## Nitrobenzene



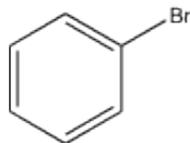
2.7686 grams (22.5 mmol) of nitrobenzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the nitrobenzene solution over a twelve minute period with periodic stirring. The reaction vessel was golden yellow in color, but solidified 5 minutes after the end of nitration. The vessel was heated in order to liquefy the reaction but it did not work. The chunk of solid was taken out and recrystallized in ethanol which produced 2.7833 grams of 1,3-dinitrobenzene.

Percent yield: 73.8%

Melting point: 81-84° C

IR: (cm<sup>-1</sup>) 1616.16, 1540.16, 1528.05, 1347.03, 1068.11, 913.26, 817.06, 711.7

NMR:  $\delta$  7.5-8.3 (4H, m), 8.5-9.5 (4H, m)

**Bromobenzene**

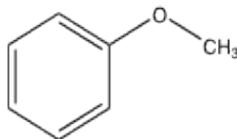
3.4519 grams (22.0 mmol) of bromobenzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of concentrated sulfuric acid was added drop-wise over a ten minute period to the bromobenzene solution with periodic stirring. After the addition of the acids, the reaction was stirred for about an hour and a half before being quenched on 25 grams of ice. The crude product was recrystallized in methanol to produce 1.6352 grams of 4-nitrobromobenzene as a whitish-yellow product.

Percent yield: 36.8%

Melting point: 105-108° C

IR: (cm<sup>-1</sup>) 1600.13, 1517.29, 1354.81, 1105.89, 1066.45, 839.66, 738.36

NMR:  $\delta$  7.5-9.1 (4H, m)

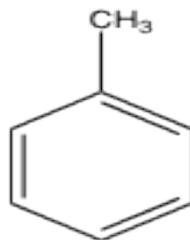
**Anisole**

3.2435 grams (30.0 mmol) of anisole was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a seventeen minute period to the anisole solution with periodic stirring. TLC analysis showed many products with no starting material left in the reaction flask, so the reaction was quenched on 25 grams of ice about 20 minutes after the end of the manual nitration. Brownish black crystals were obtained via suction filtration. These crystals were then recrystallized in methanol to produce brown crystals which were later determined to be a mixture of products.

Percent yield: 9.60%

Melting point: 71-73° C

IR: n/a

**Toluene**

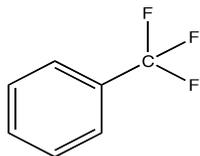
2.7778 grams (30.1 mmol) of toluene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a sixteen minute period to the toluene solution with periodic stirring. The solution turned yellow and orange throughout the addition of the acid mixture. TLC analysis did not work on this starting material because toluene would not show up even with a stain on the TLC plate. The reaction was quenched about an hour and twenty minutes after the completion of the addition of the acids. The solution was quenched on 25 grams of ice to yield yellow white crystals. The crystals were recrystallized with an ethanol/water mixture to produce 0.2301 grams of 4-nitrotoluene.

Percent yield: 5.60%

Melting point: 68-70° C, 67-69° C

IR: (cm<sup>-1</sup>) 3103.72, 1608.21, 1347.56, 912.92, 835.83, 733.08

NMR:  $\delta$  2.8 (3H, s), 7.0-9.0 (4H, m)

**$\alpha,\alpha,\alpha$ -trifluorotoluene**

3.2872 grams (22.5 mmol) of  $\alpha,\alpha,\alpha$ -trifluorotoluene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a fifteen minute period to the  $\alpha,\alpha,\alpha$ -trifluorotoluene solution with periodic stirring. The resulting solution was a light lemonade color. TLC analysis showed that most, if not all, of the starting material was exhausted and the reaction was quenched with 25 grams of ice about one hour and twenty minutes after the end of the addition of acids. Upon quenching, the reaction was mostly white with some yellow at the bottom. The yellow product at the bottom was extracted with ether and after the ether evaporated off left specs of yellow liquid. This yellow liquid was probably 3-nitro- $\alpha,\alpha,\alpha$ -trifluorotoluene but could not be tested sufficiently because of how little product was produced.

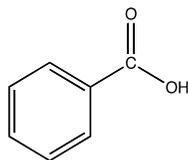
Percent yield: <1%

Melting point: n/a

IR: ( $\text{cm}^{-1}$ ) 3099.62, 1625.59, 1542.94, 1488.44, 1325.02, 1282.76, 1137.47, 1067.89, 911.4, 814.03, 785.16, 741.05, 699.33

NMR:  $\delta$  7.2-8.7 (4H, m)

## Benzoic Acid



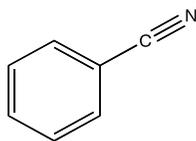
2.7434 grams (22.5 mmol) of benzoic acid was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a thirteen minute period to the benzoic acid solution with periodic stirring. The reaction mixture was cloudy and slightly yellow after the addition of the acids. TLC analysis showed that the starting material was exhausted and the reaction was quenched on 25 grams of ice an hour and two minutes later. The resulting solution was a milky lime-green color. Suction filtration produced a yellow solid with a green tint. Water was used to recrystallize the solid and produced 2.0925 grams of 3-nitrobenzoic acid as a white fluffy solid.

Percent yield: 55.8%

Melting point: 134-137° C

IR: (cm<sup>-1</sup>) 3093.29, 1705.66, 1618.48, 1529.63, 1482.79, 1352.84, 1302.43, 720.05

NMR:  $\delta$  7.3-9.1 (4H, m)

**Benzonitrile**

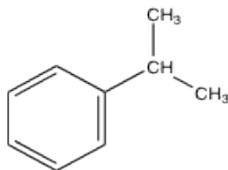
2.3217 grams (22.5) of benzonitrile was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a thirteen minute period to the benzonitrile solution with periodic stirring. The reaction vessel initially turned yellow but in the end turned a slight orange color. TLC analysis showed that most if not all of the starting material was exhausted and the reaction was quenched with 25 grams of ice thirty minutes after the end of the addition of the acids. The solid obtained via suction filtration was recrystallized in ethanol to produce 2.4955 grams of 3-nitrobenzonitrile as an orange-yellow solid.

Percent yield: 75.2%

Melting point: 108-111° C

IR: (cm<sup>-1</sup>) 2237.23, 1539.7, 1534.13, 1356.12, 817.35, 789.66, 784.45, 668.56

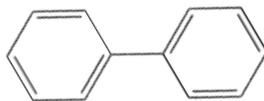
## Isopropyl Benzene



2.8892 grams (24.0 mmol) of isopropyl benzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the isopropyl benzene solution over a fifteen minute period with periodic stirring. TLC analysis showed that all the starting material had been exhausted and the reaction was quenched on 25 grams of ice twenty minutes after the end of the addition of the mixture of acids. Ether was used to extract the liquid products from the quenched solution. The resulting solution was reddish-brown in color. This solution is still a mixture of products because flash chromatography has not been performed on it to separate its components.

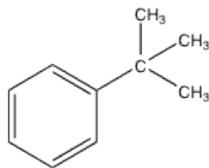
Percent yield (crude): 85.0%

## Biphenyl



2.0988 grams (13.6 mmol) of biphenyl was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the biphenyl solution over a fifteen minute period with periodic stirring. The reaction vessel went from yellow to golden brown during the addition of the acids. TLC analysis showed that no starting material was present so the reaction mixture was quenched with 25 grams of ice thirty minutes after the end of the addition of acids. However, visually there seemed to be starting material on the sides of the reaction flask. The reaction did not seem to work because too much of the nitric acid was added. It seemed like many products were produced but could not be recrystallized even when the starting material had to be physically taken out of the reaction flask. This reaction did not seem to work or make a lot of sense.

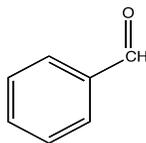
### Tert-butyl Benzene



3.2327 grams (24.1 mmol) of tert-butyl benzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a twelve minute period to the tert-butyl benzene solution with periodic stirring. The reaction flask turned yellow and the reaction was quenched fifteen minutes after the end of the nitration. The reaction was extracted with ether to separate the products from the water. The ether then evaporated to yield 3.6316 grams of the crude liquid product. Since the products are liquid they must be separated by flash chromatography, which did not happen over the summer.

Percent yield (crude): 84.5%

## Benzaldehyde

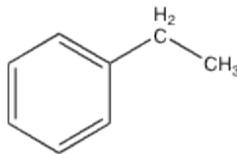


2.3469 grams (22.1 mmol) of benzaldehyde was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a ten minute period to the benzaldehyde solution with periodic stirring. The reaction flask turned a blood-orange in color throughout the addition of the acids. TLC analysis was vague in determining if there was any starting material left in the reaction flask, so thirty-five minutes later the reaction was quenched with 25 grams of ice leaving a huge chunk of orange solid and some white solid. The orange solid was unexpected and was taken out of the reaction flask so that the white solid could be recrystallized in water. This produced 0.0959 grams of a white solid that is 3-nitrobenzaldehyde. The orange solid is speculated to be the dinitrated product.

Percent yield: 2.88%

Melting point: 57-59° C

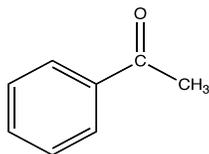
### Ethyl Benzene



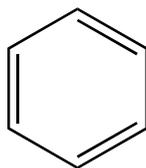
2.7592 grams (26.0 mmol) of ethyl benzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a thirteen minute period to the ethyl benzene solution with periodic stirring. The reaction flask was yellow in color after the addition of the acids. TLC showed a mixture of products with little to no starting material left in the reaction, so the reaction was quenched on 25 grams of ice thirty minutes after the end of the addition of acids. Upon quenching the reaction vessel turned a whitish yellow color. Ether was used to extract the product out of the water and when the ether evaporated, it left 3.0973 grams of what should be a mixture of the three single nitrated products. Since all the products are a liquid, flash chromatography must be used to separate the products, which was not done this summer.

Percent yield (crude): 78.8%

### Acetophenone



2.8808 grams (24.0 mmol) of acetophenone was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a ten minute period to the acetophenone solution with periodic stirring. After the adding of the acids, the reaction flask turned black and bubbly and a gas fuming out of it. TLC analysis showed a multitude of products with starting material still left in the reaction flask. Quenching on 25 grams of ice yielded a tar that was not workable and therefore no tests have been done on it. This reaction was a failure.

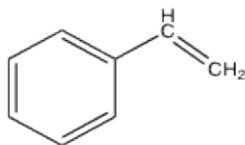
**Benzene**

2.1064 grams (27.0 mmol) of benzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the benzene solution over a thirteen minute period with periodic stirring. The reaction flask turned yellow after the acids had been added; however, about 15 minutes later the reaction flask turned orange. TLC analysis compared the product obtained here versus known dinitrobenzene product; the result was that most of the benzene dinitrated. This was not what was wanted, however, the solid dinitrobenzene product was recrystallized in methanol to yield 1.8670 grams.

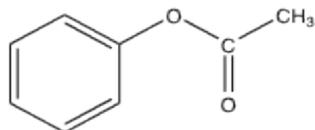
Percent yield (dinitrated product): 58.3%

Melting point: 86-88° C

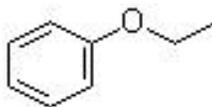
## Styrene



2.7647 grams (26.5 mmol) of styrene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise to the styrene solution over an eleven minute period with periodic stirring. During the addition of the styrene to the 6.00 mL of sulfuric acid, the flask turned into an orange and black tar that looked useless. The reaction was carried out anyways but nothing happened. The styrene was probably sulfonated during the addition of sulfuric acid so that it could not react with the nitric acid mixture. This reaction failed and will not be used again.

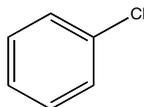
**Phenyl Acetate**

4.0810 grams (30.0 mmol) of phenyl acetate was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over an eleven minute period to the phenyl acetate solution with periodic stirring. The reaction vessel turned from yellow to a dark green to black at the end. TLC analysis showed that there was little starting material left but many products also had formed. The reaction was quenched with 25 grams of ice, which yielded reddish-black crystals. These crystals were not workable and tests could not be run on them. It is thought that since phenyl acetate is a strongly activating group that the phenyl acetate probably got dinitrated and formed many products, resulting in the tar. This reaction also was not used again.

**Phenetole**

3.7310 grams (30.5 mmol) of phenetole was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a fifteen minute period to the phenetole solution with periodic stirring. During the addition of acids, the reaction flask turned yellow to black to green. TLC analysis showed no starting material and three products. The reaction was quenched fifteen minutes after the end of the addition of acids on 25 grams of ice. Upon quenching the reaction flask turned black and red with a deposit of black on the bottom. This reaction also produced unworkable tars because of how strongly activating it is. This reaction will also be discarded and not used again.

### Chlorobenzene



2.5949 grams (23.1 mmol) of chlorobenzene was added to 6.00 ml (113 mmol) of concentrated sulfuric acid on ice. Then, a cooled mixture of 2.00 mL (33.6 mmol) concentrated nitric acid and 2.00 mL (37.7mmol) of sulfuric acid was added drop-wise over a fifteen minute period to the chlorobenzene solution with periodic stirring. TLC analysis showed one product circle but no starting material showed up. The reaction flask showed a solid so the reaction was quenched in 25 grams of ice twenty-five minutes after the end of the addition of acids. This produced yellow-white crystals and these crystals were recrystallized in ethanol to produce 0.7486 grams of 3-nitrochlorobenzene.

Percent yield: 20.6%

Melting point: 87-89° C

IR: (cm<sup>-1</sup>) 1603.84, 1537.97, 1519.74, 1344.09, 1093.46, 845.8, 740.34

## References

1. Pavia, Donald L. *Introduction to Organic Laboratory Techniques: a Microscale Approach*. Fort Worth: Saunders College Pub., 1999.
2. Carey, Francis A. *Organic Chemistry*. 6th ed. New York, NY: McGraw-Hill, 2006.