Lab Six: Regioselective Nitration of Acetanilide

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Lab Section: Z05

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Date: Wednesday April 3, 2019

Introduction

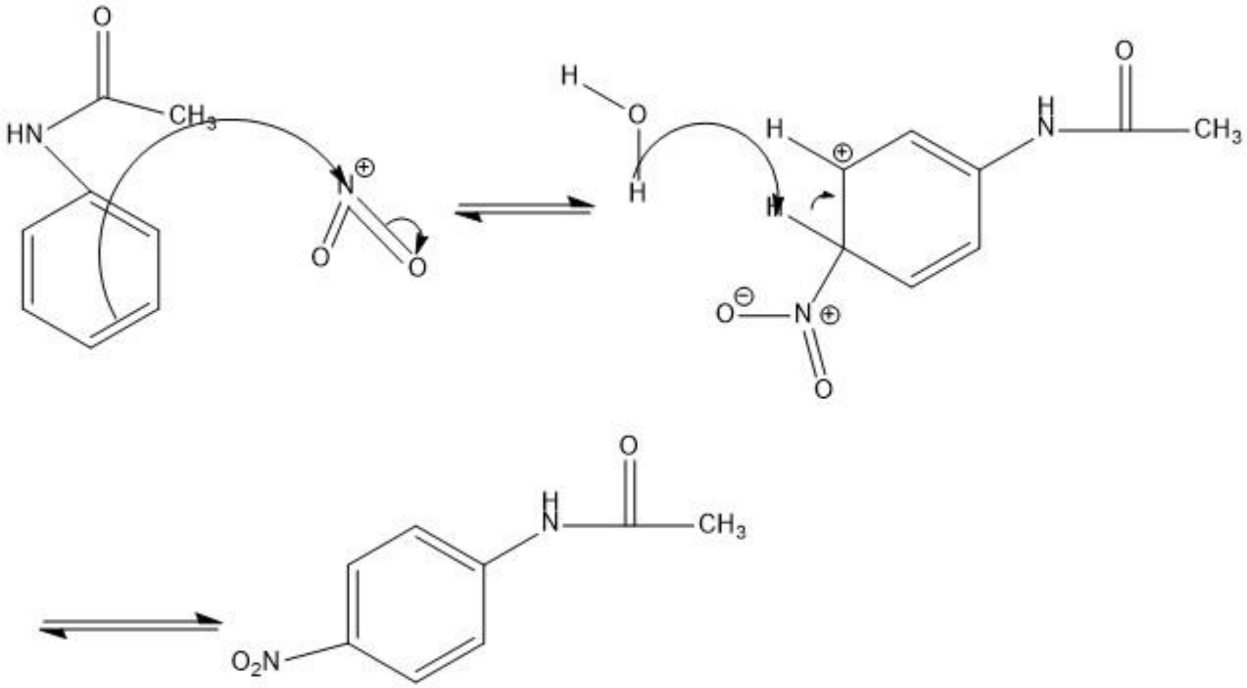


Figure 1.0: mechanism for the para product of the nitration of acetanilide

Procedure

The procedure is as described in the lab manual*

*with additional steps of boiling off approximately 20 mL of Ethanol and then placing the reaction mixture in an ice bath for 10 minutes during recrystallization

(Durst, R. et al. Regioselective Nitration of Acetanilide, 2019, Exp. 6, p.7)

Table of Reagents

Reagents	Molar Mass (g/mol)	Amount Used	Density (g/mL)	Number of Moles (mol)
Acetanilide	135.17	1.0 g	1.22	0.0074
Sulfuric Acid	98.079	5.8 mL	1.84	0.1090
Nitric Acid	63.01	0.6 mL	1.51	0.0144

Figure 1.1: table demonstrating the reagents and their properties used in the experiment six

Observations

- Acetanilide was a white, granulated powder
- H2SO4 was clear, colourless without odour
- Reaction mixture had a foamy layer of acetanilide sitting at the bottom of flask once it was submerged in an ice bath
- On addition of the nitric and sulfuric acids, the reaction mixture turned an opaque yellow, then brown, then black with a foggy vapour being released
- EtOAc:hexanes 5:5 is clear, colourless with a strong odour
- On addition of the reaction mixture to the flask with ice water, the reaction mixture became bright yellow and cloudy, remaining opaque and a precipitate was produced
- Solid crude product was yellow with a clay-like texture
- On addition of boiling ethanol, crude product dissolved and solution was amber, clear
- After recrystallization and drying through gravity filtration and suction filtration, the final pure product was a red/orange powder

TLC Plate	**Lanes (left to right)** _*Rf measurements in cm_		
1	???? R_{f1}=2.3/4.1 =0.561	Reaction Mixture ???? R_{f2}=2.2/4.1 =0.537 R_{f3}=0.2/4.1 = 0.049	Reaction Mixture R_{f4}=0.2/4.1 =0.049
2	Ortho R_{f1}= 2.4/4.3 = 0.558	Crude Product Ortho R_{f2}= 3.0/4.3 = 0.698 R_{f3}= 2.4/4.3 = 0.558 R_{f4}= 0.8/4.3 = 0.186	Crude Product R_{f5}= 3.0/4.3 = 0.698 R_{f6}= 0.8/4.3 = 0.186
3	Meta R_{f1}= 1.4/4.7 = 0.298	Crude Product Meta R_{f2}= 3.2/4.7 = 0.681 R_{f3}= 1.4/4.7 = 0.298 R_{f4}= 1.1/4.7 = 0.234	Crude Product R_{f5}= 3.2/4.7 = 0.681 R_{f6}= 1.1/4.7 = 0.234
4	Para R_{f1}= 1.2/4.5 = 0.267	Crude Product Para R_{f2}= 3.6/4.5 = 0.800 R_{f3}= 1.2/4.5 = 0.267	Crude Product R_{f4}= 3.6/4.5 = 0.800 R_{f5}= 1.2/4.5 = 0.267
5	2,4-dinitro R_{f1}= 2.1/4.4 = 0.477	Crude Product 2,4-dinitro R_{f2}= 2.1/4.4 = 0.477 R_{f3}= 0.2/4.4 = 0.045	Crude Product R_{f4}= 0.2/4.4 = 0.045
6	Mother Liquid R_{f1}= 1.9/4.6 = 0.413 R_{f2}= 1.2/4.6 = 0.261 R_{f3}= 0.8/4.6 = 0.174	Pure Product Mother Liquid R_{f4}= 3.0/4.6 = 0.652 R_{f5}= 1.9/4.6 = 0.413	Pure Product R_{f9}= 3.0/4.6 = 0.652 R_{f10}= 0.9/4.6 = 0.196

		R_{f6}= 1.2/4.6 = 0.261 R_{f7}= 0.9/4.9 = 0.196 R_{f8}= 0.8/4.6 = 0.174	

Figure 1.2: table demonstrating results of the TLC plates taken throughout the lab

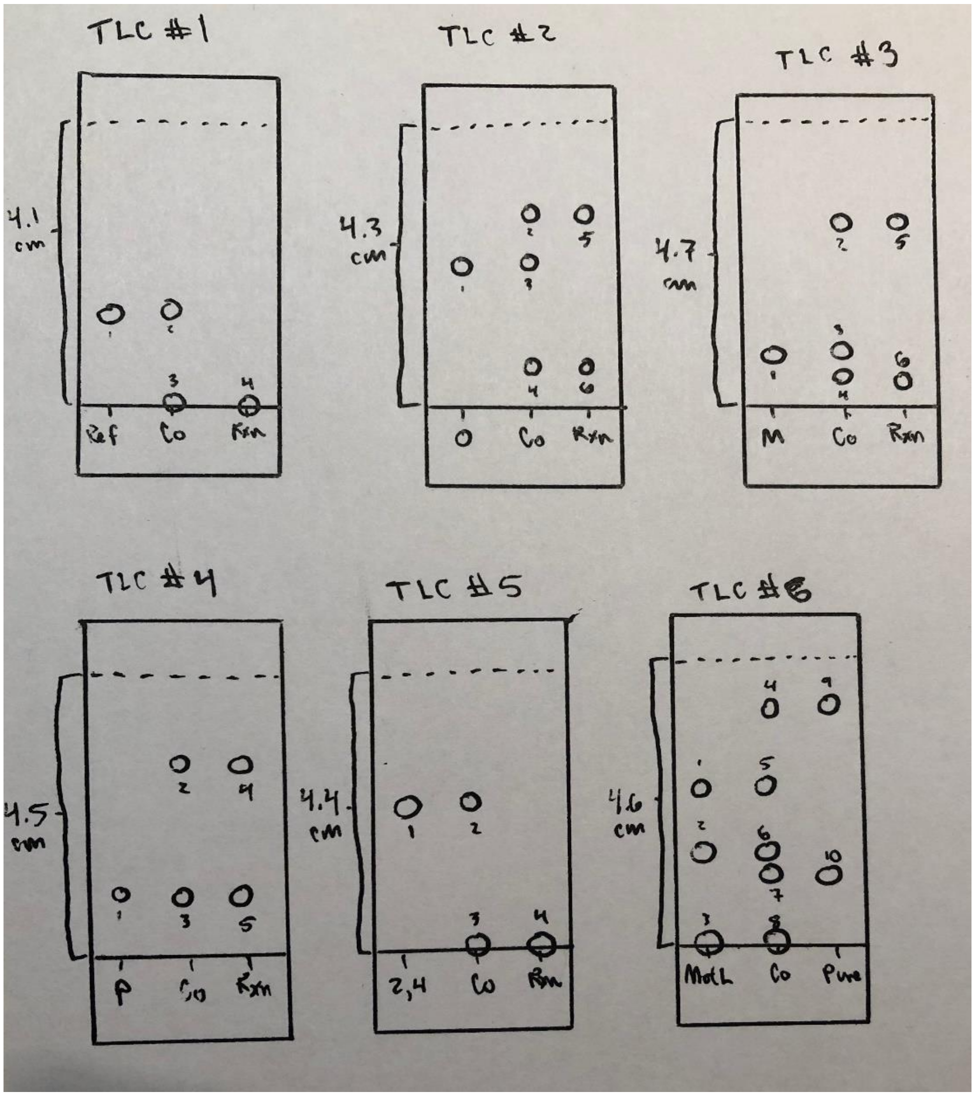


Figure 1.3: TLC plates taken throughout the lab

Calculations

Percent yield:

% yield = $\frac{actual\ yield}{theorectical\ yield} = \frac{0.68g}{1.0g} * 100\% = 68\%$

Image J absorbance:

Absorbance of para = 10429
Absorbance of meta = 3804
%Absorbance (para) = (10429/(10429+3804))x100% = 73%

%Absorbance (meta) = (3804/(10429+3804))x100% = 27%

Table of Results

Product	Amount	Molar Mass (g/mol)	Number of Moles (mol)	Melting Point (°C)	Percent Yield (%)
nitroacetanilide	0.68 g	180.16	-	-	68%

Figure 1.4: table demonstrating the properties found of the final product obtained

Discussion

- This experiment was designed to demonstrate an electrophilic aromatic substitution through the regioselective nitration of acetanilide
- The sulfuric acid was added twice, 5mL in step 3 and 0.8mL in step 5. This is because the first addition of H2SO4 is dissolve the acetanilide, and the second addition is to protonate the nitric acid
- After taking the initial TLC, the reaction was complete because acetanilide is less polar than the reaction mixture and thereby rose more with the nonpolar 5:5 solvent in the reference lane and had a higher Rf value, but the reaction mixture had a very low Rf value, indicating the starting materials had been consumed
- During recrystallization, too much boiling ethanol was added and barely any crystals were forming which would have greatly impacted our yield. To prevent the lack of crystals, approximately 20 mL of ethanol was boiled off since the reaction mixture had such a high boiling point/melting point the crystals already formed were not at risk of melting back into the boiling ethanol
- Once enough ethanol was boiled off, the reaction mixture was then placed into an ice bath to speed of the recrystallization process, and as a result produced substantially more precipitate
- The final product obtained was nitroacetanilide, an electrophilic aromatic compound which can be broken down into its three isomer products: para, ortho and meta
- The major and minor products can be determined through its stability in resonance structures, with the most abundant and most stable being the para product → ortho → meta
- EtOAc:Hexanes 5:5 was used as the solvent, this is a nonpolar solvent making the polar compounds less attracted to it, p-dinitroacetanilide is polar and therefore had smaller Rf values, this can be seen in the TLC plates
- As anticipated, the para isomer was the most abundant making up 73% of our final product, with the remaining 27% being composed of meta
- The lack of ortho could be due to the addition of too much ethanol during recrystallization and a lot of the ortho isomer dissolved and became a liquid instead of a

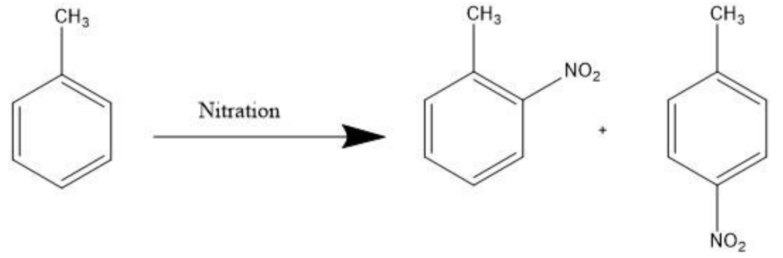
solid crystal, then when the ethanol was boiled out, the ortho isomer was boiled out of the reaction mixture with it, leaving primarily para and meta isomers

- The TLC plate comparing the crude product with the final product was contaminated and therefore not included in the lab results, however it would have been expected to see TLC demonstrating which isomer products crystallized out and which didn't. The meta Rf value would be present in the crude reference lane and Co-spot however the spot wouldn't have been present in the pure product lane, indicating the meta isomer is no-longer or barely present in the pure product as the absorbance results indicated

Questions

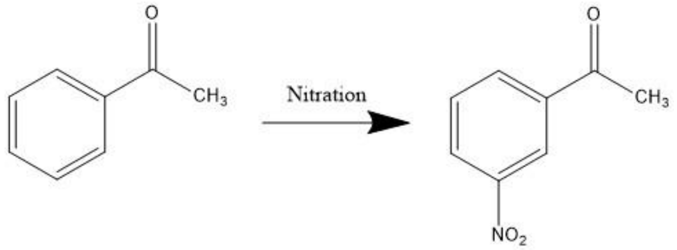
1. The addition of the second nitro group occurs much more slowly because the addition of the first nitro group will remove electron density and causes the second nitro addition to require more energy, thus proceeding more slowly.

2. a)



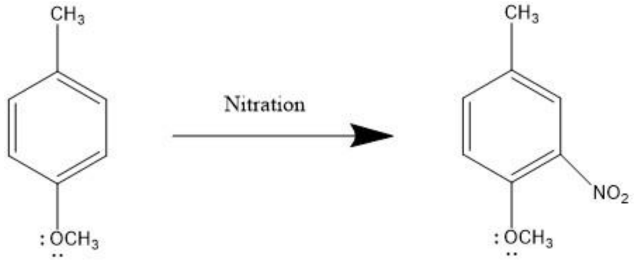
The preferred position of nitration in this compound is the para position. As the methyl group increases electron density at ortho (left product) and para (right product) position, and due to steric interactions at the ortho position, the para position is preferred for this nitrate.

b)



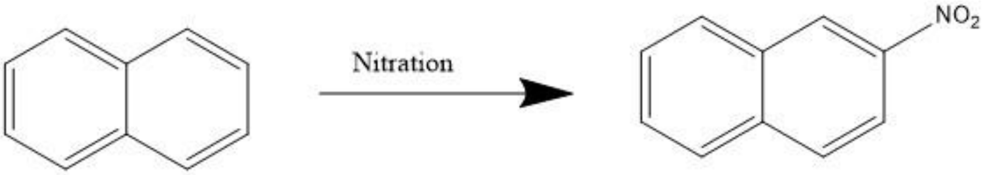
Because of the presence of the functional group, electron density is decreased at the ortho and para position, making the meta position preferred for this nitration.

c)



The extra oxygen on the methyl group in this compound adds a lone pair of electrons which will increase electron density in the ortho position, making it the preferred position for the nitration.

d)



The favourable position in this compound is the beta position.

3. The first reaction of cyclohexane to 1,2-dibromocyclohexane is an electrophilic addition reaction because of the pi bond creating an area of high electron density. The second reaction of benzene to bromobenzene is an electrophilic substitution reaction since benzene doesn't have a high electron density, it needs the hydrogen for a halogen carrier.

4. a) Number of moles of Benzene = 0.128
   Number of moles of HNO_3=0.144
   Number of moles of H_2SO_4=0.162
   Number of moles of Nitrobenzene=0.066

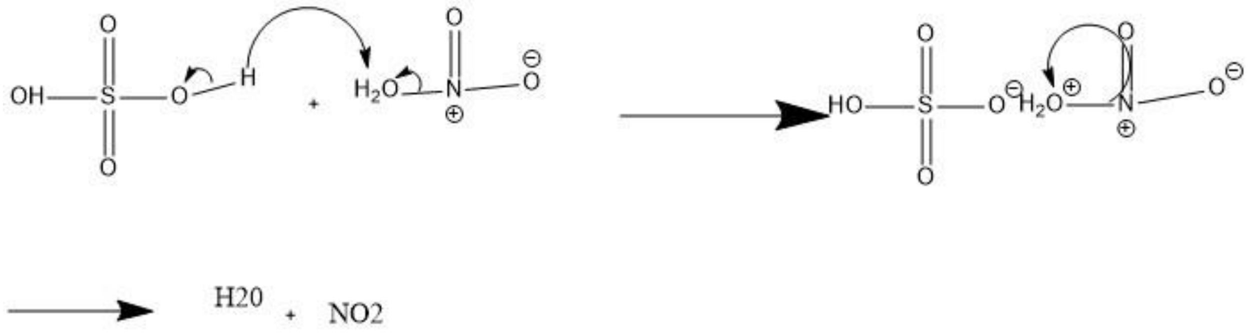
Therefore, since benzene is the reactant that is present in the least amount of moles it is the limiting reactant

b) To find the percent yield, first we need our theoretical yield of nitrobenzene, if we use up all 0.128 mol of our limiting reactant, we'll make (0.128)(123g/mol)=15.74g of nitrobenzene. Since in our original question the weight we got was 8.1g of nitrobenzene the percent yield is:
8.1g15/74gx 100% = 51.5%
Therefore our percent yield is 51.5%

c)

The most probable side product is meta-dinitrobenzene with a melting point of 90°C.

d)

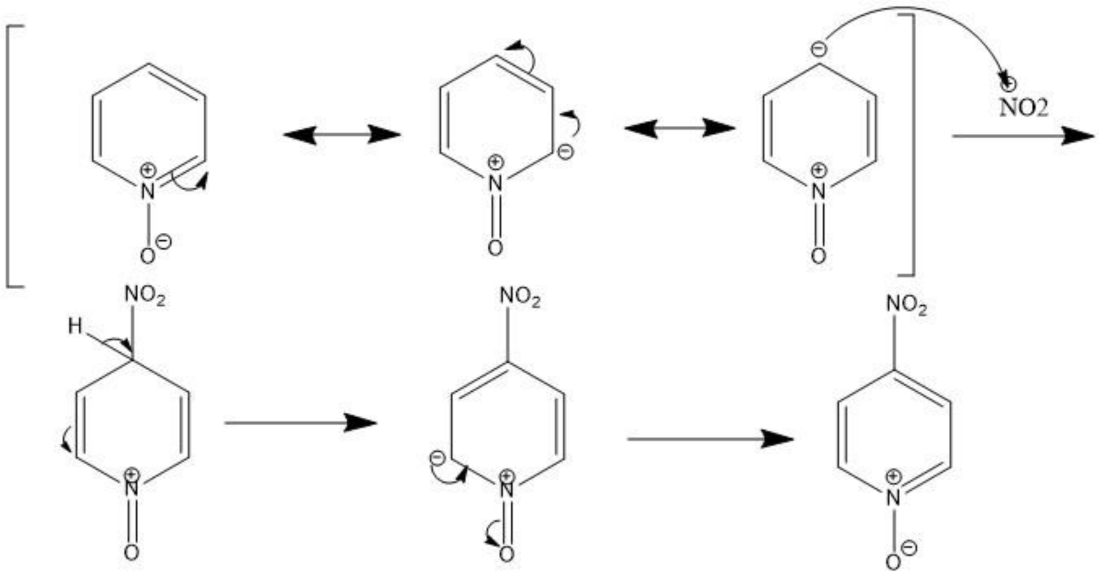


The role of sulfuric acid in this reaction is to protonate the nitric acid so that it can form a nitronium which is then attacked by the aromatic ring, essentially making the sulfuric acid a nitration reaction

e) In order to first find our theoretical yield of the crystalline compound, we again use the number of moles of benzene times the molar mass: (0.128)(268.31g/mol)=34.34g of the crystalline compound, giving us Percent yield=1.2g34.34g x 100% =3.5%

5. The 1-nitrofuran isomer is preferred because there are only two resonance structures formed at the o-position compared to the 3 formed at the m or 2-position, therefore 1-nitrofuran forms preferentially because it is more stable.

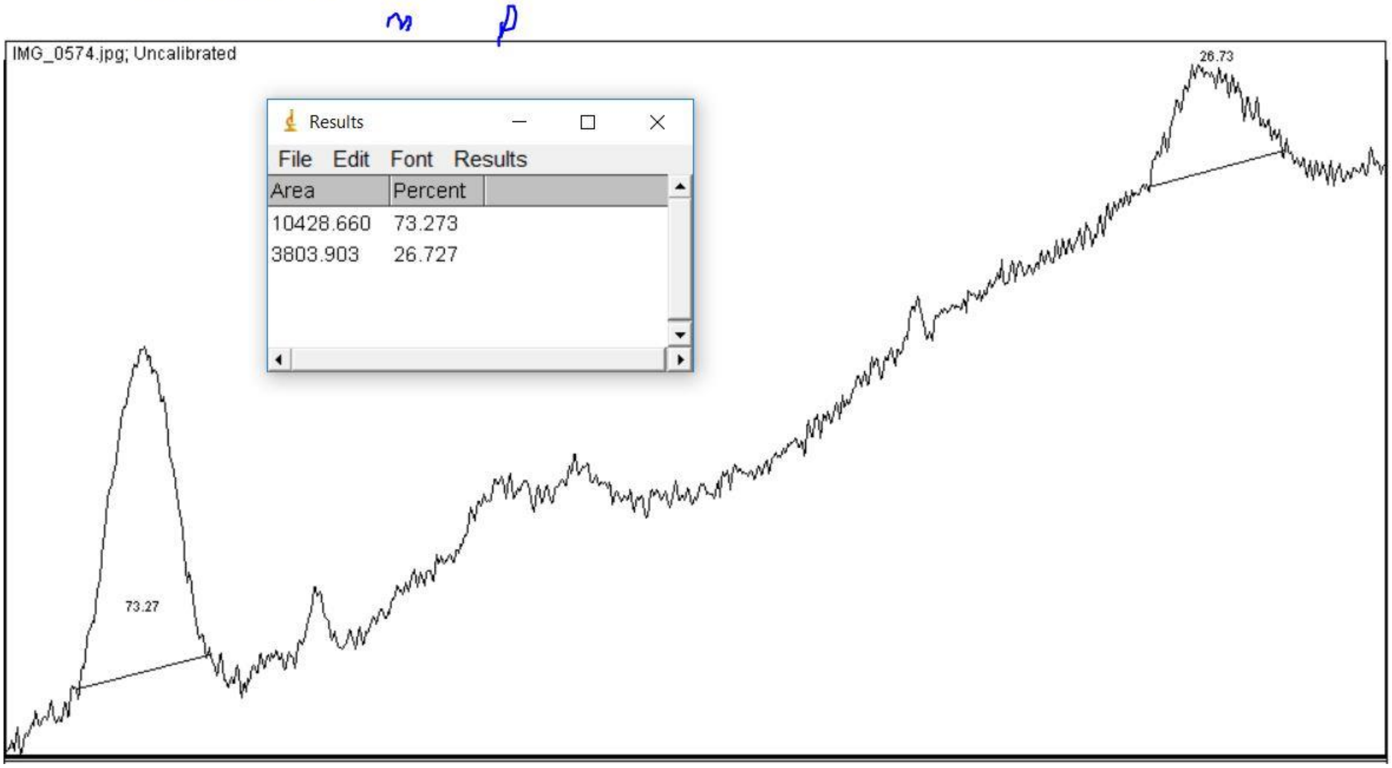
6.



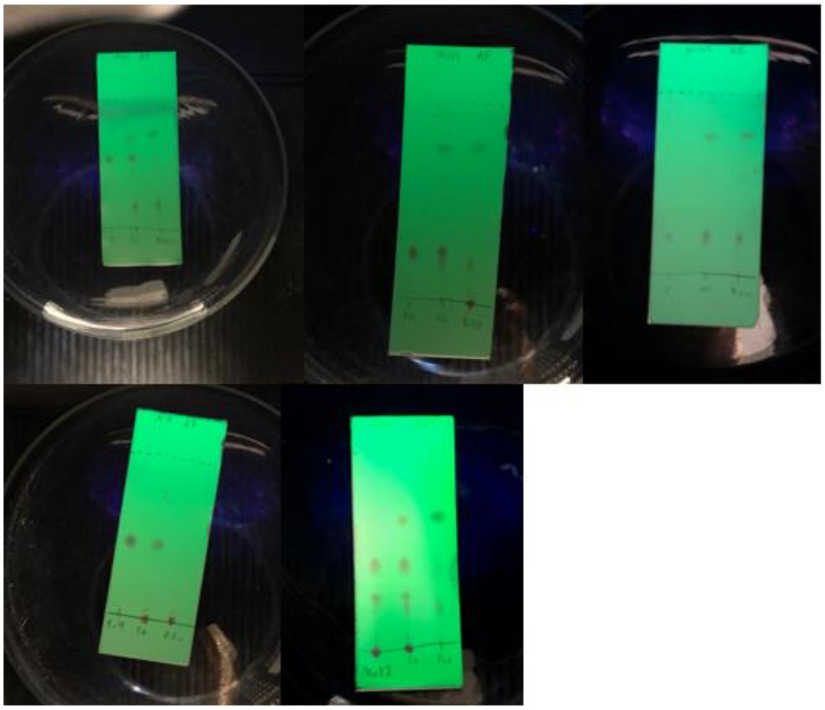
As shown above in the resonance structures, the electrophile can be attacked at the 4th position of pyridine N-oxide.

Raw Data

27 : 73
m p



Area	Percent
10428.660	73.273
3803.903	26.727



Experiment 6

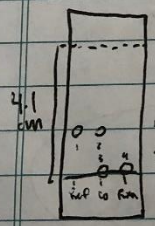
Step 3 → volume of sulfuric acid: 5 mL
Amount of nitronium ion: 0.015 mol
Step 5 { volume of nitric acid: 0.6 mL
volume of sulfuric acid #2: 0.8 mL

Observations

[redacted]

- Acetanilide is white, granulated powder
- H_2SO_4 is clear, colourless, no odour
- Reaction mixture had foamy layer on top when acid was added
- Foam became undissolved granules of acetanilide sitting at bottom of flask once rxn mixture was submerged in an ice bath
- On addition of 0.6 mL of nitric acid and 0.8 mL of H_2SO_4, rxn mixture turned yellow → brown → black with a foggy ~~gas~~ vapour being released, mixture is opaque

TLC #1



1. $\frac{2.3\text{cm}}{4.1\text{cm}}$
2. $\frac{2.2\text{cm}}{4.1\text{cm}}$
3, 4. $\frac{0.2\text{cm}}{4.1\text{cm}}$

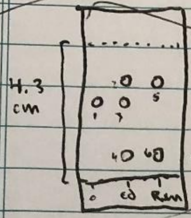
- EtOAc : hexanes 5:5 is clear, colourless with strong odour

- On addition of the reaction mixture to the flask with ice water, the RM became bright yellow and cloudy, remaining opaque
  - ↳ a precipitate was produced
- Solid product is yellow with a clay-like texture
- When boiling Ethanol was added, crude product dissolved and solution was amber, clear

* Procedure change: boiled off excess ethanol (~20 mL) then chilled solution in ice bath for 10 mins

Experiment 6

ortho TLC #2

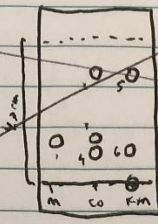


1,3: $\frac{2.4cm}{4.3cm}$

2,5: $\frac{3.0cm}{4.3cm}$

4,6: $\frac{0.8cm}{4.3cm}$

meta TLC #3

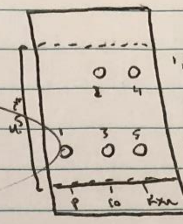


1,3: $\frac{1.4cm}{4.7cm}$

2,5: $\frac{3.2cm}{4.7cm}$

4,6: $\frac{1.1cm}{4.7cm}$

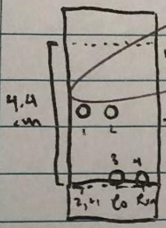
para TLC #4



1,3,5: $\frac{1.2cm}{4.5cm}$

2,4: $\frac{3.6cm}{4.5cm}$

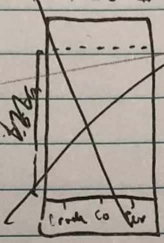
2,4 TLC #5



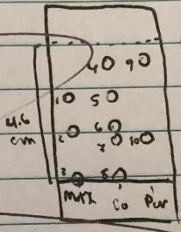
1,2: $\frac{2.1cm}{4.4cm}$

3,4: $\frac{0.2cm}{4.4cm}$

TLC #6



TLC #7



1,5: $\frac{3.9cm}{4.6cm}$

4,9: $\frac{3.0cm}{4.6cm}$

2,6: $\frac{1.2cm}{4.6cm}$

7,10: $\frac{0.9cm}{4.6cm}$

3,8: $\frac{0.8cm}{4.6cm}$

- 0.68g of solid pure product was obtained
  ~~to~~ red/orange powder