394/400

Chemistry 2229 (FS17) – Synthesis of Berryflor
Formal Report for the Synthesis Project

Name: [redacted] Section: 3A

****ATTACH THIS GRADESHEET TO THE FRONT OF YOUR PAPER****

TITLE PAGE 10

General/Grammar (40 points):

Paper should be formatted according to handout.

General/Grammar Subtotal (40 points) 38

Abstract (20 points):

Should include:

All pertinent chemicals used for reaction (e.g., reactants, products of each step).
All types of reactions used (e.g., distillation, esterification, acetylation, extraction, etc.).
All methods of characterization used (e.g. MP, IR, NMR, GC, TLC etc.).

Abstract Subtotal (20 points) 16

Introduction (20 points):

Should include:

Background information about "Berryflor," example topics include, but are not limited to:
Commercial importance, sources, uses
Review of reactions used, advantages. & disadvantages
Alternate synthesis routes

Introduction Subtotal (20 points) 20

Procedure (60 points):

Each Step should include:

Balanced Reaction Equations including structures & chemical names.
Chemicals (amounts in grams and moles) used.
Glassware (include size) used.
Labeled diagrams of glassware assemblies.
Methods used to react/isolate the chemicals.
Methods used to characterize the results.

Step 1 Procedure	20	✓
Step 2 Procedure	20	✓
Step 3 Procedure	20	

Procedure Subtotal (60 pts) 60

FTIR Analysis (40 pts):

Should include:

Brand Name and Model of Instrument Used.
NaCl crystals used.
FTIR chromatograms for Steps 1 & 2 attached.
Table with all significant peaks identified & compared to literature values.
Discussion of results.

FTIR Subtotal (40 pts) 40

NMR Analysis (40 pts):

Should include:

Brand Name and Model of Instrument Used.
Type of solvent used.
NMR chromatograms for Steps 1 & 2 attached.
Table with all significant peaks identified & compared to literature values.
Discussion of results.

NMR Subtotal (40 pts) 40

TLC Analysis (30 pts):

Should include:

Type of solvent and TLC plate used.
TLC plates for all 3 Steps for Distillation & Steps 1 & 2.
Table with all Rf values identified & compared to literature values & % Errors.
Discussion of results.

TLC Subtotal (~~20~~ 30 pts) 30

Analysis of Yield / Reaction Success (30 pts):

Should include:

Table listing reactant, amount used, product, theoretical yield, actual yield and % yield for each step and the Overall % Yield for the 2 steps combined.
Discussion of results.

Yield Subtotal (20 pts) 20

Conclusion / Discussion of Overall Results (20 pts):

Should include:

What information/processes were learned during the experiment.
Whether the experiment was successful.
How to improve the experiment.
What information from this experiment could be used to help future experimenters.

Discussion Subtotal (20 pts) 20

References (20 pts):

Should include but not limited to:

Dr. Bone's lecture material. All references cited in the handouts.
Background information in Introduction, Procedure, Adapted Procedure, Chemical Properties, FTIR /NMR/ TLC literature values (including literature values for contaminants)

References Subtotal (20 pts) 20

Chemical Properties Table (20 pts):

Should include:

Chemical Names, Chemical Structure, CAS#, Physical Properties (solid/ liquid, color), Molar Mass, Melting Point, Boiling Point, Hazards

Chemical Subtotal (20 pts) 20

Calculations (*May be handwritten and attached as an appendix.*) (20 pts):

(Calculations found only in the yellow pages will receive no credit.)

Should include:

Theoretical Yield for each step. % Yield for each step. Overall % Yield for the 2 steps.
% Error for the Rf values for the TLC for the distillation, and steps 1 & 2.

Calculations Subtotal (20 pts) 20

Participation/Yellow Sheets (40 points):

Should include:

Chemicals, glassware and procedure used including any modifications.
Raw Data collected: Masses, TLC plates,
TA signature as proof of attendance.

Participation Subtotal (40 points) 40

Late Penalty **-20pt/day** /

Grand Total (400 minus Total of Reduced Points): 394

Berryflor Synthesis from Caprolactone

CHEM 2229: Section 3A

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Submitted

December 8, 2017

Abstract

Caprolactone was purified using vacuum distillation. Caprolactone purity was verified by TLC comparison of distillate and stock. Esterification of caprolactone was performed by refluxing caprolactone with ethanol and a sulfuric acid catalyst to produce 6-hydroxy ethylhexanoate. Excess ethanol was removed via rotovac and 6-hydroxy ethylhexanoate was extracted using a separatory funnel and MTBE. MTBE was removed via rotovac and 6-hydroxy ethylhexanoate isolation was verified by TLC, HNMR, and FTIR. Acetylation of 6-hydroxy ethylhexanoate was performed by refluxing 6-hydroxy ethylhexanoate with acetic anhydride to produce 6-acetoxy ethylhexanoate with acetic acid by-product. 6-acetoxy ethylhexanoate was extracted using a separatory funnel and MTBE. MTBE was removed via rotovac and 6-acetoxy ethylhexanoate isolation was verified by TLC, HNMR, and FTIR.

Introduction

Berryflor is an organic compound with a fruity odor similar to raspberry. Berryflor is also known as 6-acetoxy ethylhexanoate (Bone and Bolon, "Acetylation to Berryflor"). Berryflor does not occur in nature ("Berry Hexanoate"). However, it is synthesised for use in perfumes to add floral and fruity tones. The compound is useful for enriching and softening other smells and its scent complements woody and musky smells nicely ("BERRYFLOR").

Compounds invoke the sense of smell by interacting with olfactory organs. Compounds in the air dissolve in mucous in the nose and then come in contact with the olfactory epithelium membrane (Chundler 2011) . Cells on this membrane detect different chemicals (Chundler 2011). Humans have around 40 million different chemoreceptors on this membrane, allowing for a wide variety of smell sensations (Chundler 2011). These receptors send electrical impulses to the

brain, where their information is interpreted (Chundler 2011). Many of the same structures in the brain that interpret the smell are also involved in emotions and memory, causing some smells to bring back memories (Chundler 2011). For this reason, the smell of raspberries may be very pleasing to some individuals.

In this procedure, berryflor was synthesized from caprolactone. Caprolactone is a cheap material costing approximately $30 per 100 grams or $0.30 per 1 gram from Sigma-Aldrich, Inc. Synthesizing berryflor from caprolactone is cheaper than if it was purchased as 1 oz of undiluted berryflor costs $12.75 from Creatingperfume.com. This would be about $12.75 per 28.35 grams or $0.45 per gram. Other chemicals used in the conversion of caprolactone to berryflor are readily available in most laboratories.

Other sources created berryflor using the same methods used in this synthesis, specifically the one performed by James McCullagh and Sophia Hirakis of Manhattan College. The process contains mostly harmless chemicals and can be completed in relatively few steps. It would be difficult to synthesis in fewer steps from the same starting compound as the caprolactone ring must be opened and compounds added to either side of the break.

The reactions used for this synthesis were esterification and acetylation. They involved refluxing intermediate compounds with ethanol or acetic anhydride for about half an hour each. The intermediate and product were characterized by TLC, FTIR, and HNMR. The process was so simple an undergraduate chemistry student could successfully complete the steps.

Experimental Methods

All glassware was checked for star cracks prior to use. No glassware used possessed cracks but if any had, replacement glassware would have been used. Glassware with cracks can

shatter under vacuum or high heating. Goggles were used in all steps to ensure chemicals did not come in contact with the eyes. Physical properties and hazards of chemicals used are listed in appendix C.

Note: Steps were performed over the course of multiple weeks. Intermediate products do not have to be stored if reactions are performed consecutively. All glassware was cleaned with water and acetone prior to and after use. All glassware setups and chemical structures were drawn using ChemBioDraw Ultra 14.0 unless otherwise noted. The experimental procedure used was taken from Dr. Terry Bone and Dr. Cynthia Bolon's synthesis procedure for "Vacuum Distillation of Caprolactone," "Esterification of Caprolactone," and "Acetylation to Berryflor." All mass measurements were conducted on Denver Instruments XE series Model 300 scales.

Step 1: Distillation

Contaminates were removed from stock caprolactone through vacuum distillation. Equipment used for this step: a distillation apparatus consisting of a 50 mL round bottomed flask, an egg-shaped stir bar, a distillation adapter, a thermometer adapter, a thermometer, a jacketed air condenser, a vacuum adapter, a 25 mL round bottomed flask, a stirring hot plate, a heating mantle, a variable voltage meter, aluminum foil, cotton batting, 3 keck clips, 2 clamps, 2 ring stands, a piece of rubber tubing, and a piece of vacuum tubing; and a TLC chamber consisting of a watch glass, a 500 mL plastic beaker, a piece of filter paper, and a fluorescent silica gel TLC plate.

Glassware was assembled into the vacuum distillation apparatus shown (figure 1). Three Keck clips and two clamps were used to hold the glassware together. The aspirator used was not initially pulling appropriate vacuum but vacuum was obtained after changing the filter trap plug.

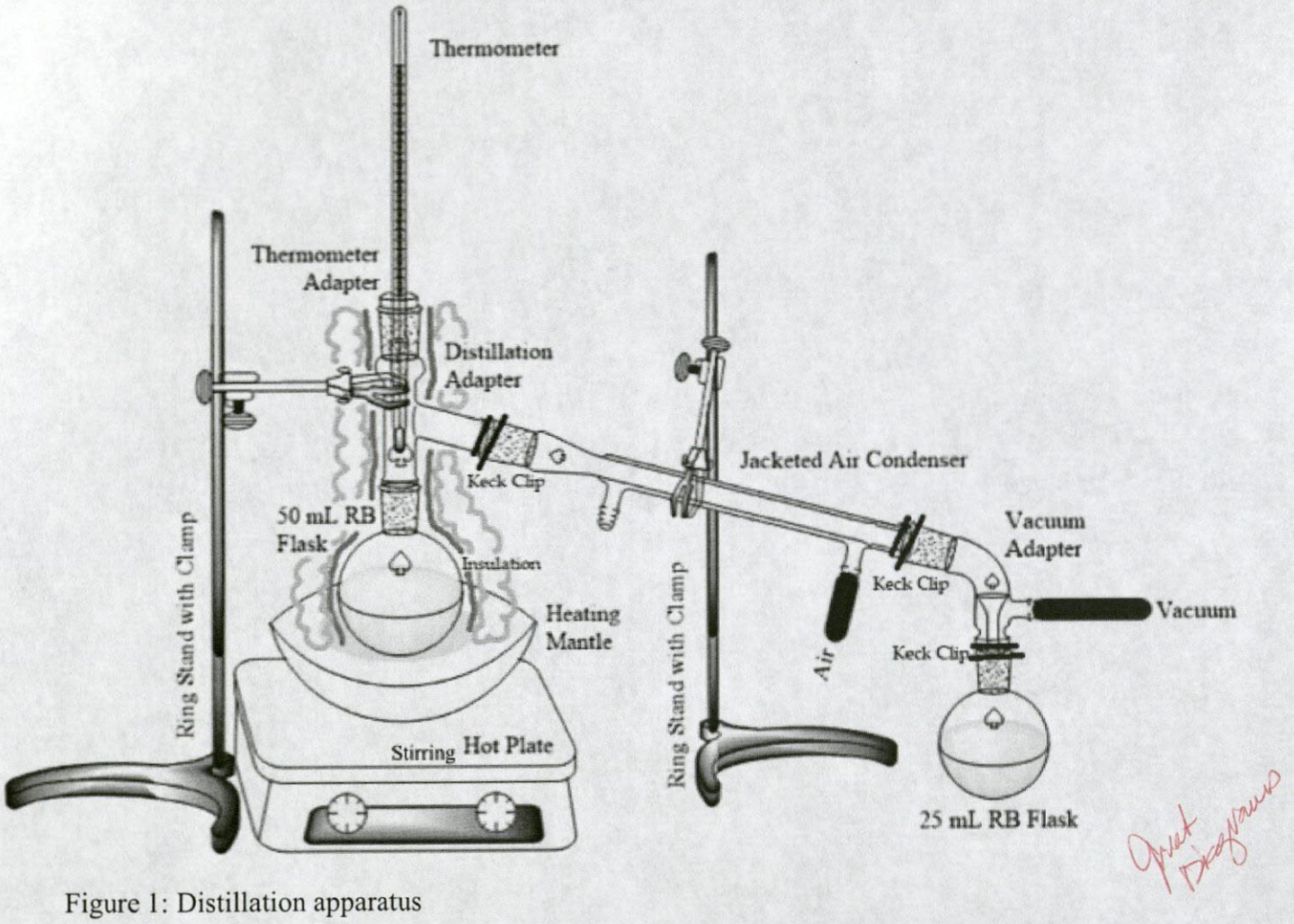


Figure 1: Distillation apparatus

Approximately 10 mL of stock caprolactone and an egg-shaped stir bar were added to a 50 mL round bottomed (RB) flask. A 25 mL RB flask was used for distillate collection. The 50 mL RB and the distillation adapter were insulated using aluminum foil and cotton batting. A small opening near the bottom of the 50 mL RB was left for observation of boiling.

The 50 mL RB was heated using a heating mantle connected to a variable voltage/meter setup. Gas tubing was used to flow pressurized air into the lower portion of the condenser for cooling. Temperature of the distillation was monitored with a glass thermometer. Vacuum was

achieved by connecting the vacuum adapter above the 25 mL RB to an aspirator. The contents of the 50 mL RB were stirred using a stirring hot plate with heating turned off.

The variable voltage source was set to 100 V until boiling of the stock caprolactone was observed. After boiling, the voltage source was reduced to 50 V. The temperature and vacuum pressure were recorded after first distillate was observed and were 128.5°C and -27.0 in Hg respectively.

Stock caprolactone was distilled until approximately half of the 25 mL RB was filled, less than 10 mL. Pot was not distilled to dryness. The heating mantle was removed after it was turned off. The distillation apparatus was allowed to cool and come to atmospheric pressure. Distillate was stored in a labeled, glass, screw-cap vial for storage.

A TLC chamber was prepared using 4:1 hexane:acetone as illustrated in figure 2. A fluorescent, silica gel, TLC plate was spotted with stock caprolactone, still pot residue, and distilled caprolactone (appendix B, figure 1). Plates were allowed to develop in the chamber and spots were visualized by dipping the plate into 0.25% w/v Rhodamine B in water. Spots were circled before they disappeared. All of the following steps used this procedure for TLCs except different compounds were compared.

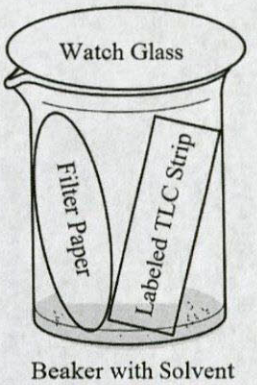
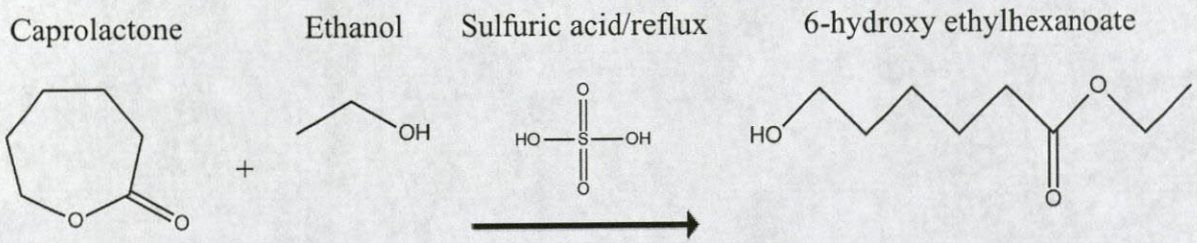


Figure 2: TLC chamber

Step 2: Esterification

Esterification of purified caprolactone with ethanol and sulfuric acid catalyst was performed to produce 6-hydroxy ethylhexanoate.

Equation 1: Esterification Reaction



Equipment used for this step: a reflux apparatus consisting of a 500 mL RB flask, an egg-shaped stir bar, a jacketed water condenser, a ring stand, a clamp, a hot water bath, a stirring hot plate, and two pieces of rubber tubing; a TLC chamber as described previously; a vacuum filtration system consisting of a 500 mL vacuum flask, a filter trap, a 3 cm Hirsch funnel and filter paper, 2 pieces of vacuum tubing, and a ring stand with clamp; a 500 mL beaker in an ice bath; a separatory funnel setup consisting of a 250 mL separatory funnel, a ring stand with ring support, and beakers of various sizes for layer collection; a 500 mL beaker for drying; pH paper; and a 500 mL RB connected to a rotovac.

A stirring hot plate and a water bath were preheated at 250°C. A clean, dry 500 mL RB flask was weighed and determined to be 133.598 g. Distilled caprolactone was added to the tared flask and its mass was determined to be 5.058 g or 0.04431 moles. Approximately 250 mL of absolute ethanol was added to the RB.

The RB was clamped in place in the water bath and a jacketed water condenser was added to the flask (figure 3). The solution was stirred while about 3 mL of sulfuric acid was were added dropwise by pipette. After the water bath began to boil, the hot plate temperature was reduced to 100°C.

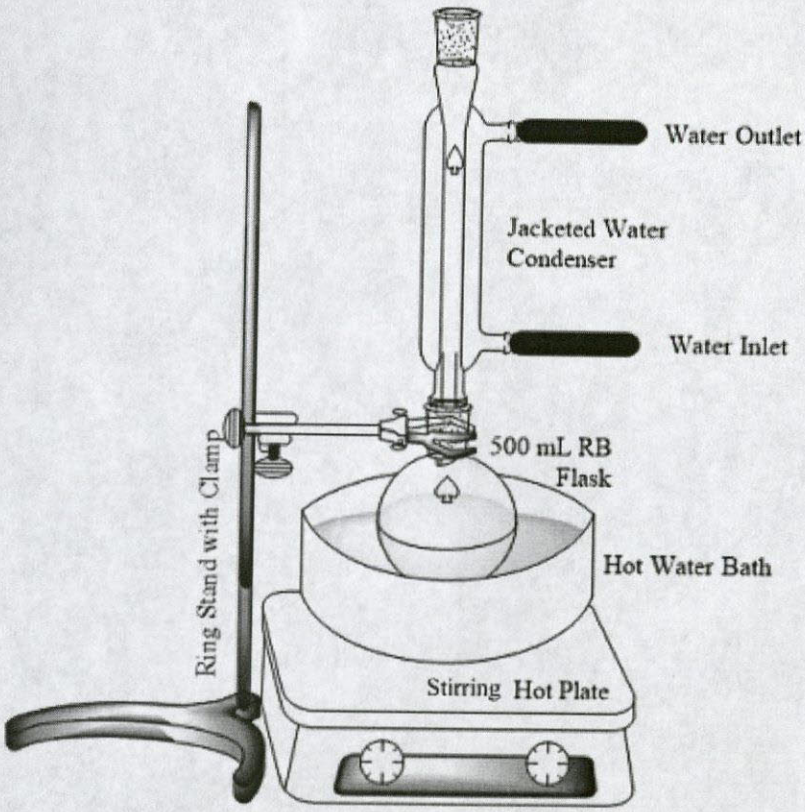


Figure 3: Reflux apparatus for esterification

Solution was refluxed for 30 minutes after observation of condensation. Following the 30 minutes, the RB was raised out of the water, allowed to cool briefly, and a sample was removed for TLC by dipping a pipette in the mixture. Capillary action pulled a small amount of liquid from the solution and this sample was diluted in a small vial with acetone. The 500 mL RB flask was returned to reflux while a TLC chamber was set up with 4:1 hexane:acetone and TLC plates developed. TLC plate was spotted with diluted reflux sample and distilled caprolactone (appendix B, figure 1). TLC plate was visualized with aqueous Rhodamine B. Spots indicated that the esterification was complete and caprolactone had been fully converted. If the caprolactone was still present in the sample, reflux would have been continued until TLC indicated all caprolactone was reacted.

The 500 mL RB flask was removed from the water bath and the solution was cooled. Contents of the flask were transferred to a 500 mL beaker. The flask was rinsed twice with about 5 mL portions of ethanol and rinsings were added to the beaker. A little over 8 g of $NaHCO_3$ was added to the beaker. Solution was stirred on the stirring hot plate with no heat until bubbling stopped.

The 500 mL beaker was chilled in an ice bath to help precipitate solids out of solution. Solution was vacuum filtered to remove solids using the setup shown in figure 4. When transferring the solution to the 3 cm Hirsch funnel, beaker was rinsed twice with about 5 mL portions of ethanol. The pH of the filtrate was determined to be around 5 with pH paper. Filtrate was poured into a dry 500 mL RB flask for storage.

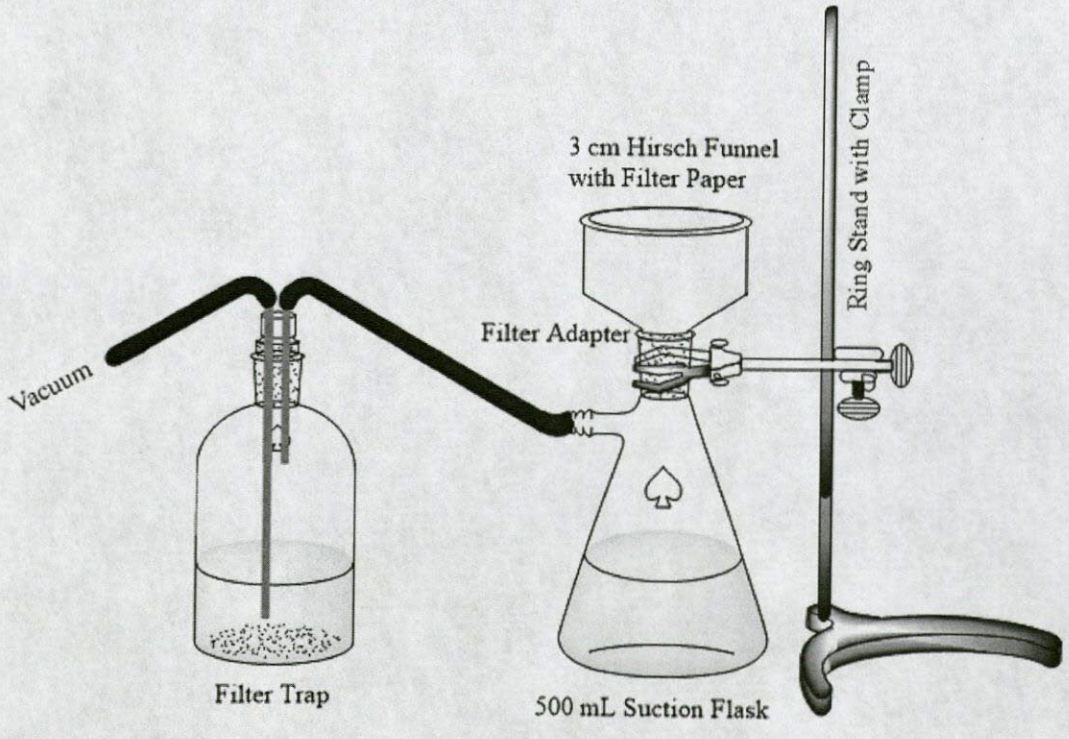


Figure 4: Vacuum distillation apparatus

Ethanol was removed from the esterification product via rotovac. The bath temperature and gauge pressure of the rotovac were 63°C and -26.7 in Hg respectively. The mass of the 500 mL RB flask and the product was 156.460 g.

Approximately 50 mL of water and 50 mL of MTBE were added to the RB flask containing the esterification product. The layers were transferred to a 250 mL separatory funnel after swirling the RB and dissolving the product (figure 5). The RB was rinsed twice with 10 mL portions of Rinsings were added to the funnel MTBE. The separatory funnel was shaken briefly and the layers were allowed to separate. The lower water layer was drained into a labeled beaker and the MTBE was drained into a different labeled beaker.

The water layer was returned to the separatory funnel and the product was re-extracted with 50 mL of MTBE. Water layer was drained into the water beaker and the MTBE layer was drained into the beaker containing the other MTBE layer. This re-extraction was done twice.

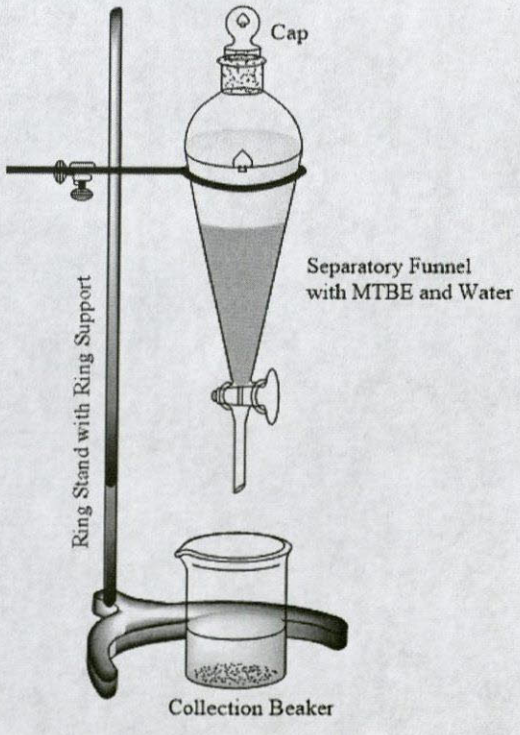


Figure 5: Separatory funnel setup

Combined MTBE extracts were poured back into the separatory funnel and washed with 50 mL of saturated NaCl solution to force out excess water. The lower NaCl layer was drained and discarded. The MTBE layer was drained into a large 500 (600) mL beaker and dried with Na_2SO_4. The Dried MTBE extract was transferred to a dry 500 mL RB flask. The 500 (600) mL flask beaker with drying agent was rinsed twice with 10 mL portions of MTBE. Rinsings were added to the RB flask

The majority of the MTBE was evaporated using a hot water bath and a stirring hot plate under a hood (figure 6). The RB flask was heated in the water bath and stirred using an egg-shaped stir bar on a hot plate set to 250°C. After liquid level in the RB dropped to about a quarter of an inch, the remaining solvent was removed via rotovac. The RB flask with the isolated esterification product was weighed to determine the esterification product yield and its mass was 140.827 g. The product was stored in the 500 mL RB flask.

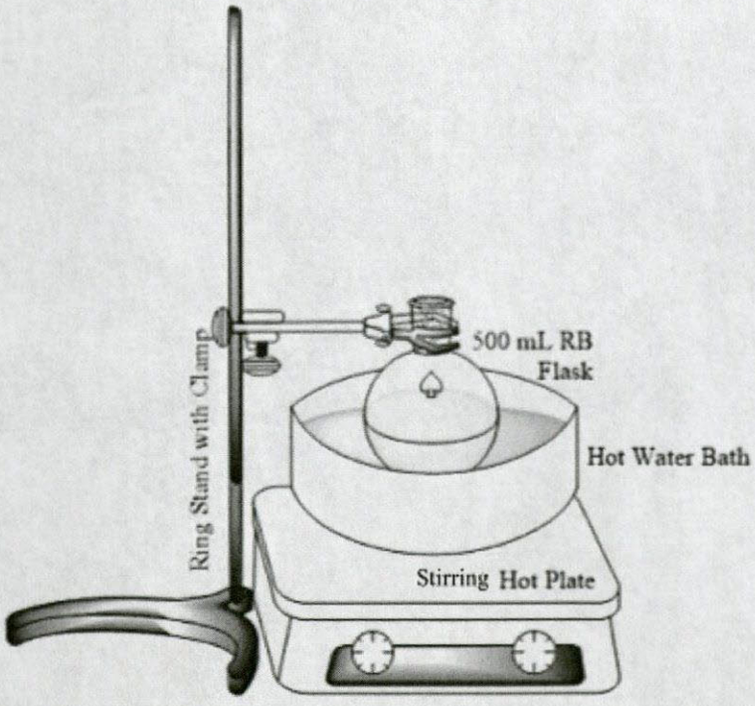
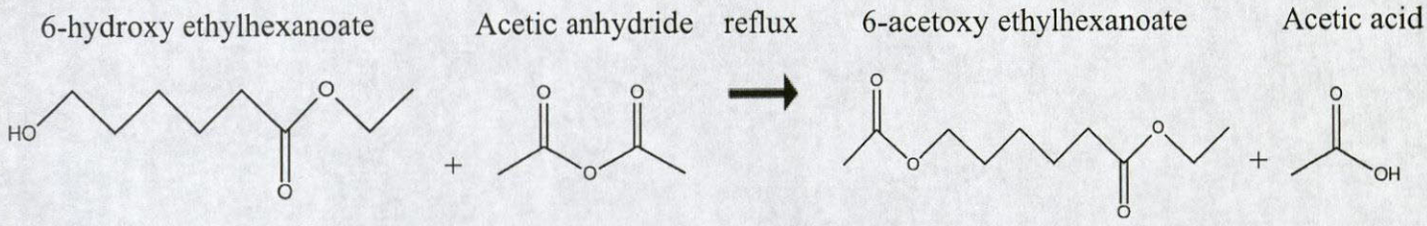


Figure 6: Hot water bath

Step 3: Acetylation

Acetylation of 6-hydroxy ethylhexanoate with acetic anhydride was performed to produce 6-acetoxy ethylhexanoate with acetic acid by-product.

Equation 2: Acetylation to berryflor



Equipment used for this step: a reflux apparatus consisting of a heating mantle, a stirring hot plate, a variable voltage meter, a 250 mL RB flask, an egg-shaped stir bar, a jacketed water condenser, 2 pieces of rubber tubing, and a ring stand with a clamp; a TLC chamber as described previously; an 800 mL beaker with a rod stir bar; a separatory funnel as described previously except the funnel being 500 mL; a 500 mL beaker for drying; pH paper; and a 500 mL RB connected to a rotovac.

A heating mantle was used to heat a 250 mL RB flask during the reaction. A stirring hot plate was used only for its stirring function. The mantle was connected to a variable voltage meter. A small snap cap vial was filled a quarter full with the esterification product to save for characterization. The 500 mL RB flask and the remaining esterification product were reweighed to determine the amount of starting material. The RB flask and esterification product mass was 140.325 g. The same empty RB weighed 133.598 g so the amount of 6-hydroxy ethylhexanoate used was determined to be 6.727 g or 0.04199 moles.

The amount of acetic anhydride needed for the reaction was determined using the following ratio: one g of esterification product per four mL of acetic anhydride. The mass of the esterification product was multiplied by four to give 26.908 mL of acetic anhydride.

Approximately 27 mL of acetic anhydride was added to the 500 mL RB flask and the flask was swirled to mix the acetic anhydride with the esterification product. The solution was transferred to a 250 mL RB flask and an egg-shaped stir bar was added to the flask along with a jacketed water condenser to create the reflux setup shown in figure 7.

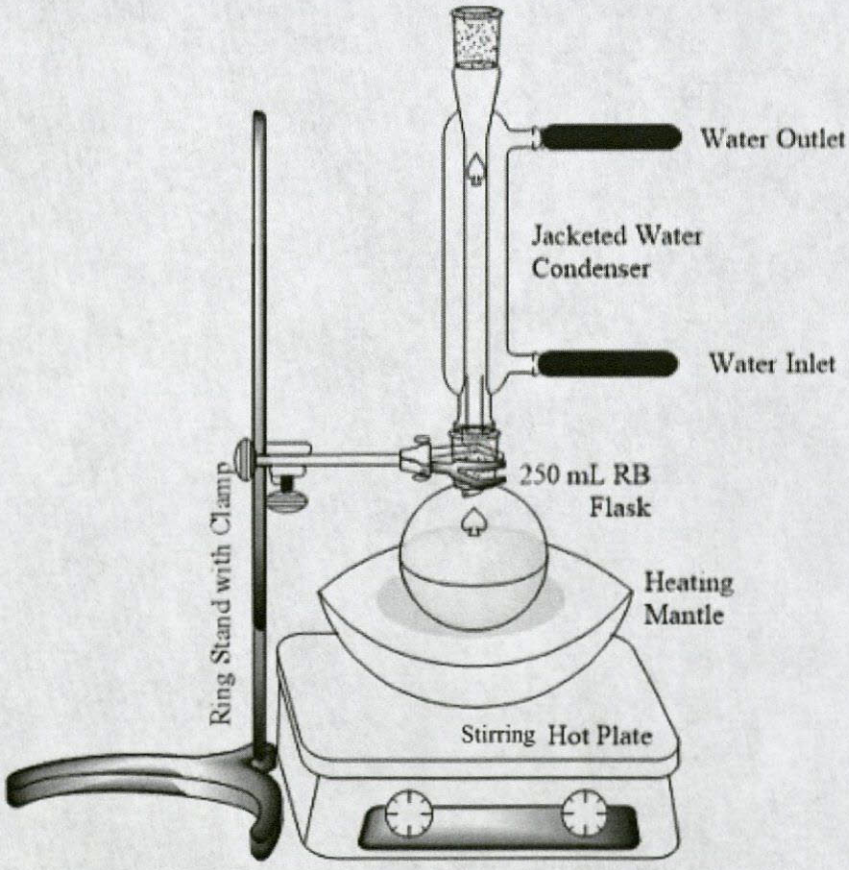


Figure 7: Reflux apparatus for acetylation

The heating mantle was set to 100 V then reduced to 50 V after boiling was observed. The reaction mixture was refluxed for 40 minutes. After 40 minutes, the RB flask was raised and cooled briefly. A pipette was used to remove a small amount of the mixture and the sample was

diluted in acetone. Diluted sample and diluted esterification product were run on a fluorescent, silica gel, TLC strip in a TLC chamber prepared with 4:1 hexane:acetone (appendix B, figure 1).

The reaction mixture was allowed to continue refluxing while the TLC developed. After development and visualization with aqueous Rhodamine B, the TLC strip showed that the reaction was complete. If the spots had indicated that 6-hydroxy ethylhexanoate still remained in the flask, reflux would have been continued until TLC indicated completion.

The heating mantle was removed and the solution in the 500 mL RB flask was allowed to cool to around 70°C. Approximately 10 mL of water was slowly added to the RB to destroy excess acetic anhydride. After addition of the water, the flask was heated via mantle for an additional 5 minutes. The flask was cooled to room temperature by immersing in an ice water bath.

After cooling, the contents of the RB were transferred to an 800 mL beaker. The RB flask was rinsed twice with 5 mL portions of MTBE and with 50 mL of water. All rinsings were added to the 800 mL beaker. Initially, about 24 g of $NaHCO_3$ were slowly added to the beaker and the solution stirred on a stirring hot plate with heating turned off. The solution was stirred until bubbling stopped. The pH of the solution was taken and determined to be too low for storage.

Since bubbling did not stop after a reasonable amount of time and pH was low, excess $NaHCO_3$ was added to speed the bubbling process and raise the pH to around 8. Solution was stored in a 500 mL RB flask. The RB was left unstoppered for several hours to ensure the glass stopper would not be ejected by any remaining gas production.

The stored solution was transferred to a 500 mL separatory funnel. The majority of the excess $NaHCO_3$ was left in the RB. The RB and $NaHCO_3$ were rinsed twice with 50 mL portions

of MTBE and rinsings were added to the separatory funnel. Any $NaHCO_3$ that made its way into the funnel was dissolved with about 200 mL of dH_2O. The funnel was capped and shaken briefly to extract the acetylation project. The separatory funnel was set up the same way as in figure 5.

The water layer was drained into a labeled beaker and the MTBE was drained into a different labeled beaker. The water layer was poured back into the separatory funnel and re-extracted with 50 mL of MTBE. Re-extraction was repeated twice.

The combined MTBE extracts were poured back into the separatory funnel and were washed twice with 50 mL portions of saturated $NaHCO_3$. The lower $NaHCO_3$ layer was discarded both times. The MTBE was washed once with 75 mL of saturated NaCl. An additional 50 mL of water was added to dissolve excess solid that had accumulated on the sides of the funnel.

The MTBE layers were transferred to a large 500 mL beaker and Na_2SO_4 was used to dry the solution. A 500 mL RB flask was weighed and the MTBE was transferred to it. The empty 500 mL RB weighed 133.617 g. Drying agent was rinsed twice with 10 mL portions of MTBE. The MTBE was removed via rotovac with temperature at 57°C and pressure at -24.4 in Hg. The 500 mL RB was weighed with the acetylation product to determine yield. Their combined mass was 139.794 g. Product was stored in a glass, screw-cap vial.

Step 4: Characterization

The esterification product and the acetylation product were characterized after all reactions had been completed. Products were characterized using FTIR and HNMR.

Equipment used for this step: a Nicolet Nexus 470 FTIR ESP and sodium chloride crystal plates, a desktop Magritek Spinsolve Carbon NMR (30 MHz), and a Brüker HNMR (400 MHz).

The esterification product and the acetylation product were verified by FTIR using a Nicolet Nexus 470 FTIR ESP machine and sodium chloride crystal plates (appendix B, figure 2 and figure 4).

The HNMR of the compounds were run at 30 MHz on a desktop Magritek Spinsolve Carbon NMR (figure 6 and figure 9 in appendix B) and at 400 MHz on a Brüker HNMR (figure 7 and figure 10 in appendix B). Readings were taken after diluting the compounds in d-chloroform. The measurements from the 400-MHz machine were used in analysis.

Results

Fluorescent, silica gel, TLC plates and 4:1 hexane:acetone solvent were used for all TLC development. Calculations for Rf and yield can be found in appendix A.

TLC Analysis: Distillation

The TLC plate of the distillate indicated the stock caprolactone had been purified through distillation (figure 1 in appendix B). The stock solution showed two spots, indicating impurities. The distilled caprolactone showed only one spot. Expected Rf value was taken from Bone and Bolon, "Vacuum Distillation of Caprolactone." Results are summarized in table 1.

Table 1: Distillation TLC results

Compound	Spots	Distance (cm)	Expected Rf	Experimental Rf	Rf % Error
Stock	1	1.51	-	0.1867	-
	2	0.23	-	0.0284	-
Caprolactone	1	1.64	0.17	0.2027	19.24%
Still Pot Residue	1	0.45	-	0.0556	-

TLC Analysis: Esterification

The TLC plate of the esterification reaction indicated that the reaction went to completion and that all caprolactone had been converted to 6-hydroxy ethylhexanoate (figure 1 in appendix B). Expected Rf values were taken from Bone and Bolon, "Esterification of Caprolactone." Results are summarized in table 2.

Table 2: Esterification TLC results

Compound	Spots	Distance (cm)	Expected Rf	Experimental Rf	Rf % Error
Caprolactone	1	1.18	0.17	0.1674	1.53%
Esterification	1	0.47	0.07	0.0667	4.71%

TLC Analysis: Acetylation

The TLC plate of the acetylation reaction indicated that the reaction went to completion and that all 6-hydroxy ethylhexanoate had been converted to 6-acetoxy ethylhexanoate (figure 1 in appendix B). Expected Rf values were taken from Bone and Bolon, "Acetylation to Berryflor." Results are summarized in table 3.

Table 3: Acetylation TLC results

Compound	Spots	Distance (cm)	Expected Rf	Experimental Rf	Rf % Error
Esterification	1	0.48	0.07	0.0962	37.42%
Acetylation	1	1.73	0.29	0.3467	19.55%

FTIR Analysis

A Nicolet Nexus 470 FTIR ESP machine and sodium chloride crystal plates were used to generate FTIR chromatograms (figure 2 and figure 4 in appendix B). FTIR literature values were from Dr. John Hanson of the University of Puget Sound. The 6-hydroxy ethylhexanoate FTIR and the 6-acetoxy ethylhexanoate FTIR both had peaks corresponding to all of the peak values

when compared to the spectra from the article by McCullagh and Hirakis (appendix B, figure 3 and figure 5). The loss of the OH peak between the esterification product and the acetylation product indicated that the reaction was successful. Important peaks are summarized in table 4.

Table 4: FTIR major peaks

Compound	Significant Peaks	Measured Value	Literature Value
6-hydroxy ethylhexanoate	-OH	3386, broad strong	3600-3200, broad strong
	C-H	2938	3000-2850, strong
	C=O	1733, sharp strong	1750-1735, strong
	C-O	1373 and 1184	1300-1000, two
6-acetoxy ethylhexanoate	C-H	2942	3000-2850, strong
	C=O	1737	1750-1735, strong
	C-O	1239 and 1163	1300-1000, two

HNMR Analysis

A desktop Magritek Spinsolve Carbon NMR was used to generate an HNMR spectra at 30MHz (appendix B, figures 6 and 9) and a Brüker HNMR was used at 400 MHz (appendix B, figure 7 and 10). Compounds were dissolved in d-chloroform. HNMR values were compared to spectra from the article by McCullagh and Hirakis (table 5). Only the 400-MHz spectra were compared. The hydrogens listed in table 5 correspond to the hydrogens labeled in figure 8. The 6-hydroxy ethylhexanoate HNMR and the 6-acetoxy ethylhexanoate HNMR both had peaks corresponding to all of the values from the article by McCullagh and Hirakis (appendix B, figure 8 and figure 11). Both experimental 400-MHz HNMR had an extra peak around 7.4 ppm and around 3.2 ppm. These peaks was attributed to contamination.

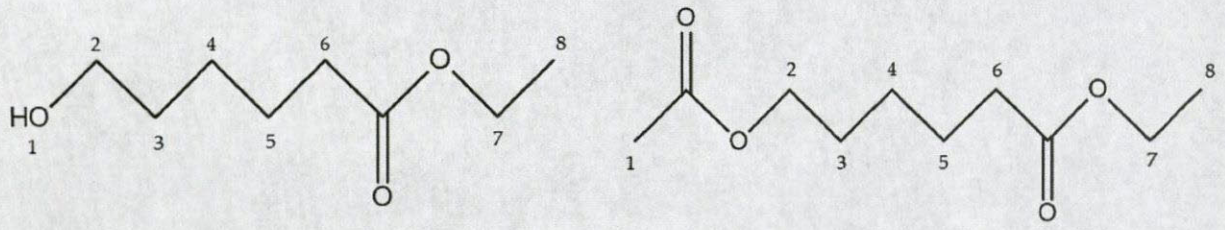


Figure 8: Labeled H's (left: 6-hydroxy ethylhexanoate, right: 6-acetoxy ethylhexanoate)

Table 5: Hydrogen splitting in HNMR

Compound	H	Measured Value (ppm)	Splitting (s, d, t, q, m)	Literature Value (ppm)	Interference
6-hydroxy ethylhexanoate	1	1.5666	s	1.6104	none
	2	3.6567	t	3.6510	-CH2
	3	1.6479	m	1.6626	-CH2 and -CH2
	4	1.3884	m	1.4044	-CH2 and -CH2
	5	1.5514	m	1.5730	-CH2 and -CH2
	6	2.3133	t	2.3162	-CH2
	7	4.1133	q	4.1373	-CH3
	8	1.2569	t	1.2570	-CH2 adjacent to O
6-acetoxy ethylhexanoate	1	2.0371	s	2.0460	none
	2	4.0573	t	4.0597	-CH2 adjacent to O
	3	1.6410	m	1.6296	-CH2 and -CH2
	4	1.4185	m	1.3919	-CH2 and -CH2
	5	1.6709	m	1.6802	-CH2 and -CH2
	6	2.3137	t	2.3102	-CH2
	7	4.1312	q	4.1386	-CH3
	8	1.2543	t	1.2575	-CH2 adjacent to O

Yield

The percent yield was determined after esterification and acetylation. The overall yield was calculated at the end of the experiment. Calculations for all values can be found in appendix A. The yield for esterification was very high. This was attributed to the solvent not being completely evaporated. The yield for acetylation was high, but not unreasonably so. Yields are summarized in tables 6 and 7.

Table 6: Esterification yield

Reactant	Amount used	Product	Theoretical yield	Actual Yield	Percent Yield
Caprolactone	5.058 g (0.04431 mol)	6-hydroxy ethylhexanoate	7.0996 g	7.229 g	101.82%
Ethanol	250 mL (excess)				

Table 7: Acetylation yield

Reactant	Amount used	Product	Theoretical yield	Actual Yield	Percent Yield
6-hydroxy ethylhexanoate	6.727 g (0.04199 mol)	6-acetoxy ethylhexanoate	8.494 g	6.177 g	72.72%
Acetic anhydride	27 mL (excess)				

The overall yield of the synthesis was calculated to be 72.72%. For this calculation, the percent yield for esterification was considered 100%. Overall, the synthesis had a very good yield.

Conclusion and Discussion of Overall Results

This synthesis allowed for several techniques to be learned and practiced, including distillation, esterification, acetylation, and verification of product. The process increased

understanding of high pressure creating a lower boiling point and the precautions to take when working with glassware under vacuum. Hands-on practice of an HNMR machine and a FTIR machine allowed for comprehension of their uses and of their basic operation.

Analysis of spectra and TLC plates indicated the synthesis was successful. Practice of these verification techniques allowed their applications to be understood. The experiment could have been improved if it had been conducted all at once. This would have resulted in less loss of yield from transferring to and from storage containers. It may have also aided the process to verify the products after each step, to ensure the correct compounds were being used in following steps.

The spectra generated during this procedure could be used as reference for other experimenters. The procedure resulted in a high yield and would be useful for anyone looking to make berryflor quickly and efficiently.

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Appendix A: Calculations

Distillation Calculations

Rf = (distance traveled by compound) / (distance traveled by solvent)

Stock spot 1 = 1.51 cm / 8.09 cm = 0.1867
Stock spot 2 = 0.23 cm / 8.09 cm = 0.0284
Caprolactone = 1.64 cm / 8.09 cm = 0.2027
Still pot residue = 0.45 cm / 8.09 cm = 0.0556

% Error = [(experimental - theoretical) / theoretical] x 100

Rf % Error for caprolactone = [(0.2027 - 0.17) / 0.17] x 100 = 19.24%

Esterification of Caprolactone

Rf = (distance traveled by compound) / (distance traveled by solvent)

Caprolactone = 1.18 cm / 7.05 cm = 0.1674
Esterification Product = 0.47 cm / 7.05 cm = 0.0667

% Error = [(experimental - theoretical) / theoretical] x 100

Caprolactone Rf % Error = [(0.1674 - 0.17) / 0.17] x 100 = 1.53%
Product Rf % Error = [(0.0667 - 0.07) / 0.07] x 100 = 4.71%

Theoretical yield = (moles reactant) x (MW product) x mol/mol ratio

Caprolactone mol = 5.058 g ÷ 114.14 g/mol = 0.044314 mol caprolactone
0.044314 mol caprolactone x 160.21 g/mol 6-hydroxy ethylhexanoate x 1 mol/1 mol
= 7.0995 g 6-hydroxy ethylhexanoate theoretically

Yield = (combined mass of RB and product) - (mass of RB)
= 140.827 g - 133.598 g = 7.229 g of 6-hydroxy ethylhexanoate

% yield = [(actual yield) / (theoretical yield)] x 100

6-hydroxy ethylhexanoate % yield = (7.229 g / 7.0995 g) x 100 = 101.82%

Acetylation of 6-hydroxy Ethylhexanoate

R_f = (distance traveled by compound) / (distance traveled by solvent)

Esterification product = 0.48 cm / 4.99 cm = 0.09619

Acetylation product = 1.73 cm / 4.99 cm = 0.3467

% Error = [(experimental - theoretical) / theoretical] x 100

Esterification R_f % Error = [(0.09619 - 0.07) / 0.07] x 100 = 37.42 %

Acetylation R_f % Error = [(0.3467 - 0.29) / 0.29] x 100 = 19.55 %

Theoretical yield = (moles reactant) x (MW product) x mol/mol ratio

6-hydroxy ethylhexanoate mol = 6.727 g ÷ 160.21 g/mol = 0.04198 mol

0.04198 mol 6-hydroxy ethylhexanoate x 202.3 g/mol 6-acetoxy ethylhexanoate x 1 mol/1 mol = 8.494 g of 6-acetoxy ethylhexanoate theoretically

Yield = (combined mass of RB and product) - (mass of RB)

= 139.794 g - 133.617 g = 6.177 g of 6-acetoxy ethylhexanoate

% yield = [(actual yield) / (theoretical yield)] x 100

6-acetoxy ethylhexanoate % yield = (6.177 g / 8.494 g) x 100 = 72.72 %

Overall Yield

% yield of esterification = 101.82%

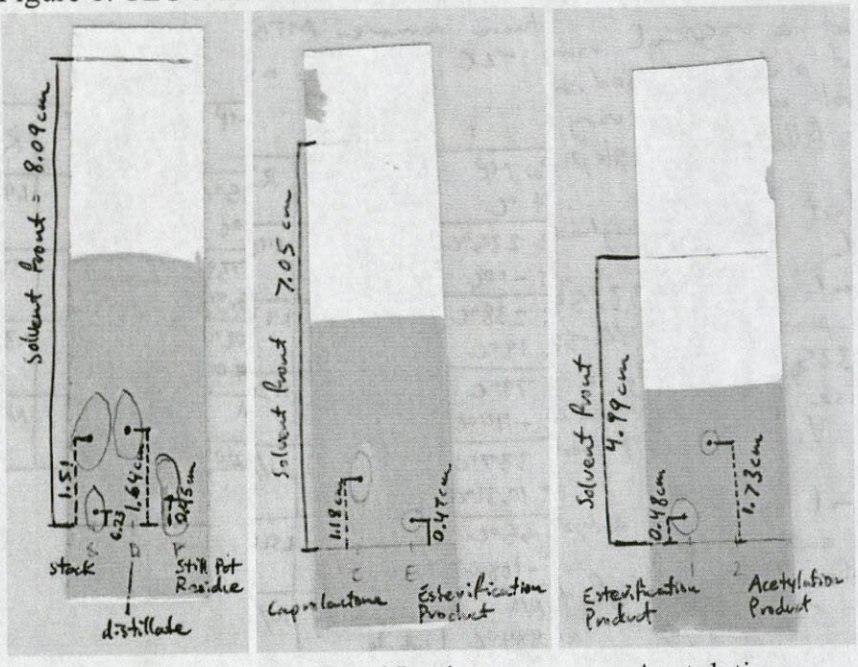
considered 100% for calculation

% yield of acetylation = 72.72 %

Overall yield = 100% x 72.72 % = 72.72 %

Appendix B: TLC plates, FTIR, HNMR

Figure 1: TLC Plates



Distillation Esterification Acetylation

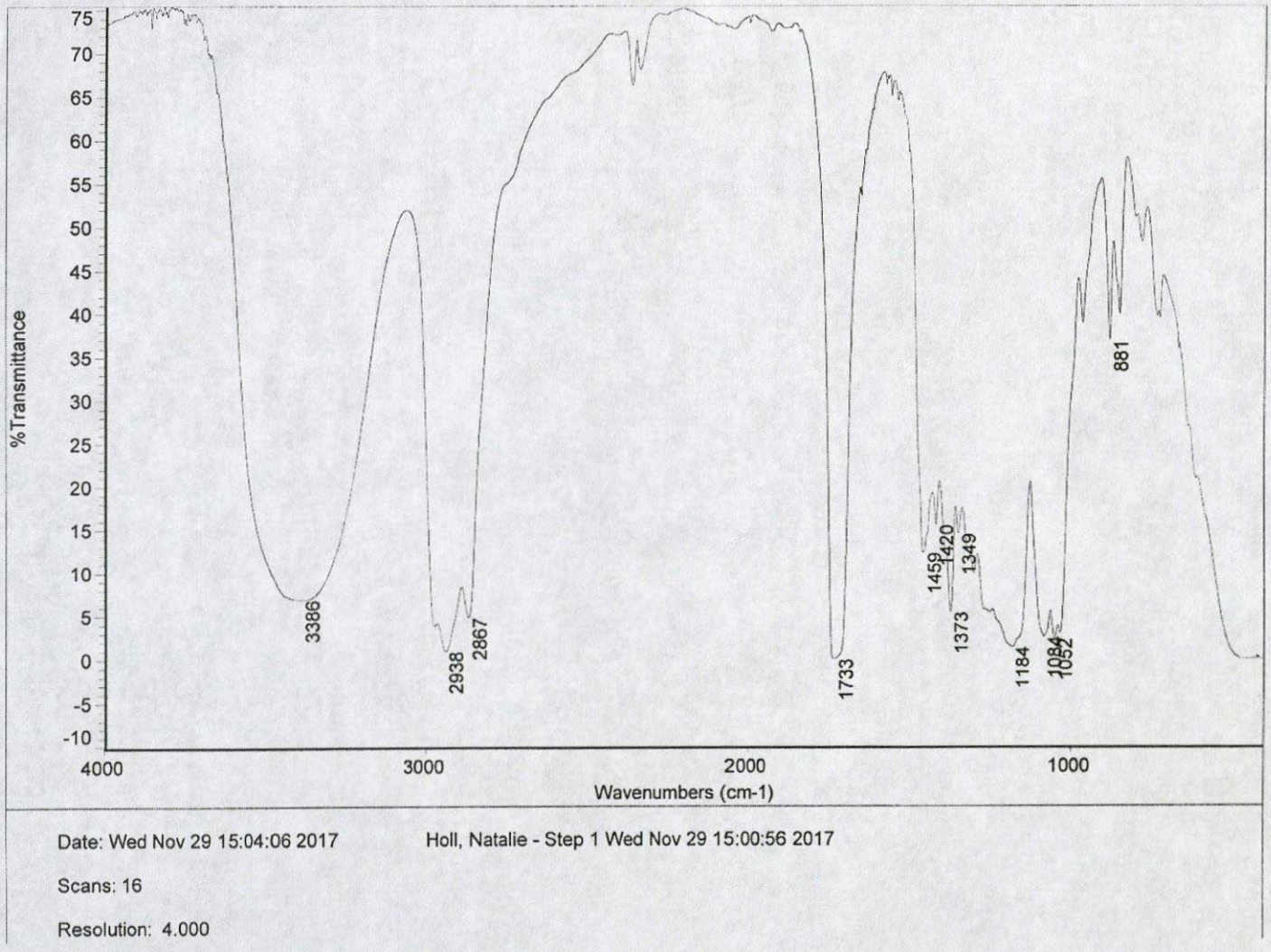


Figure 2: Esterification product IR.

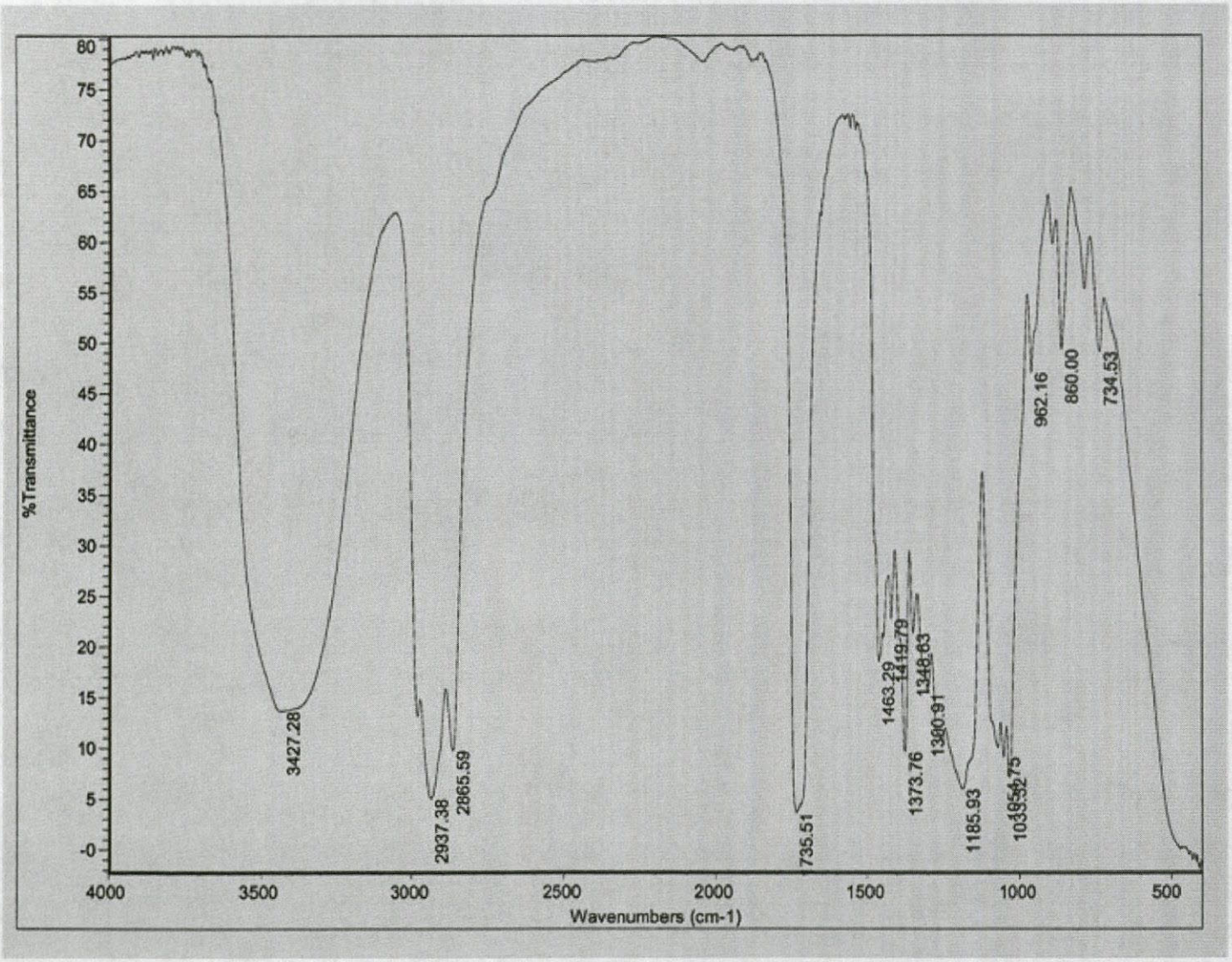


Figure 3: Esterification product IR from McCullagh and Hirakis FRIT of a commercial sample of 6-hydroxy ethylhexanoate.

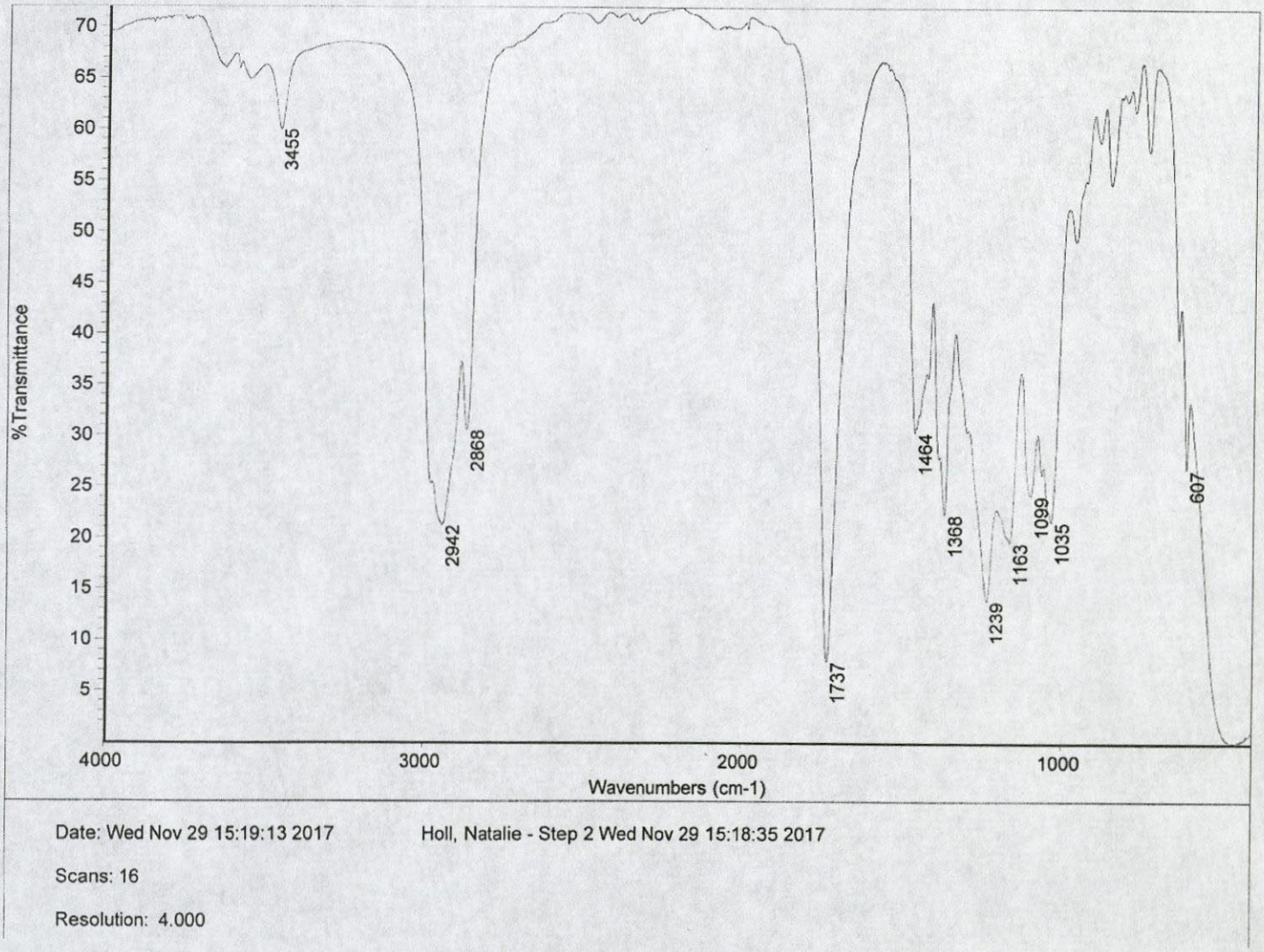


Figure 4: Acetylation product IR.

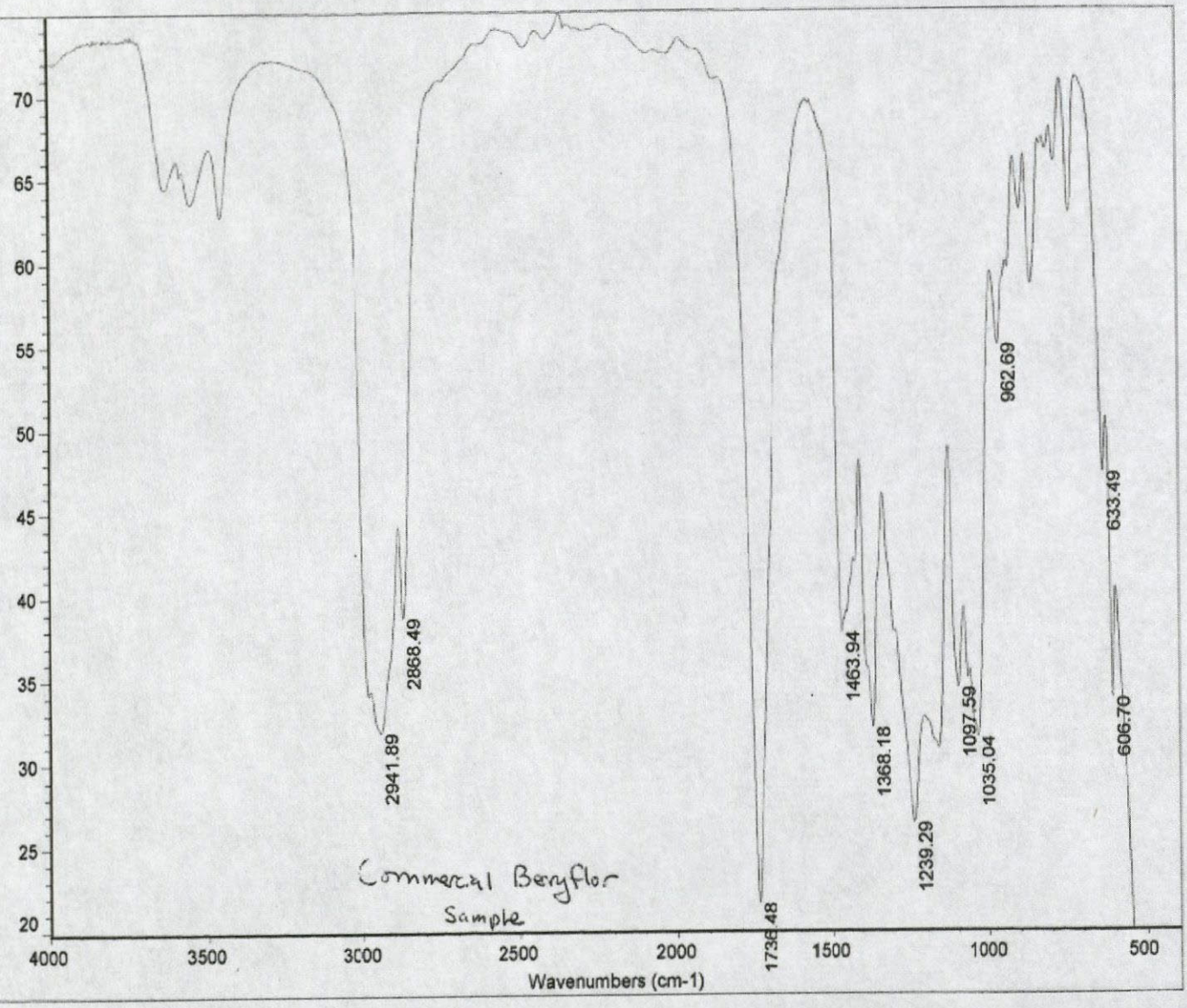


Figure 5: Acetylation product IR from McCullagh and Hirakis FRIT of a commercial sample of 6-acetoxy ethylhexanoate.

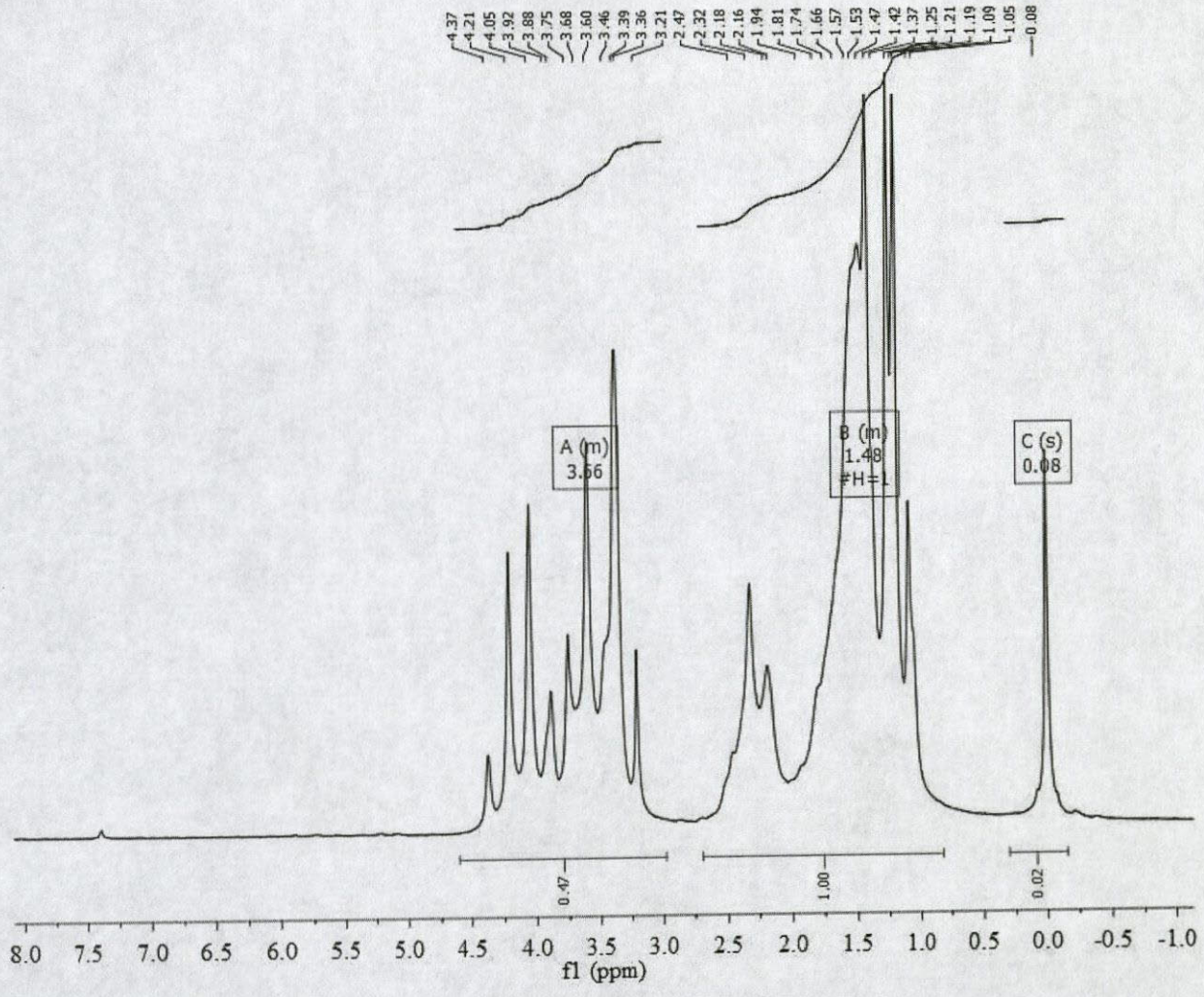


Figure 6: Esterification product HNMR at 30 MHz.

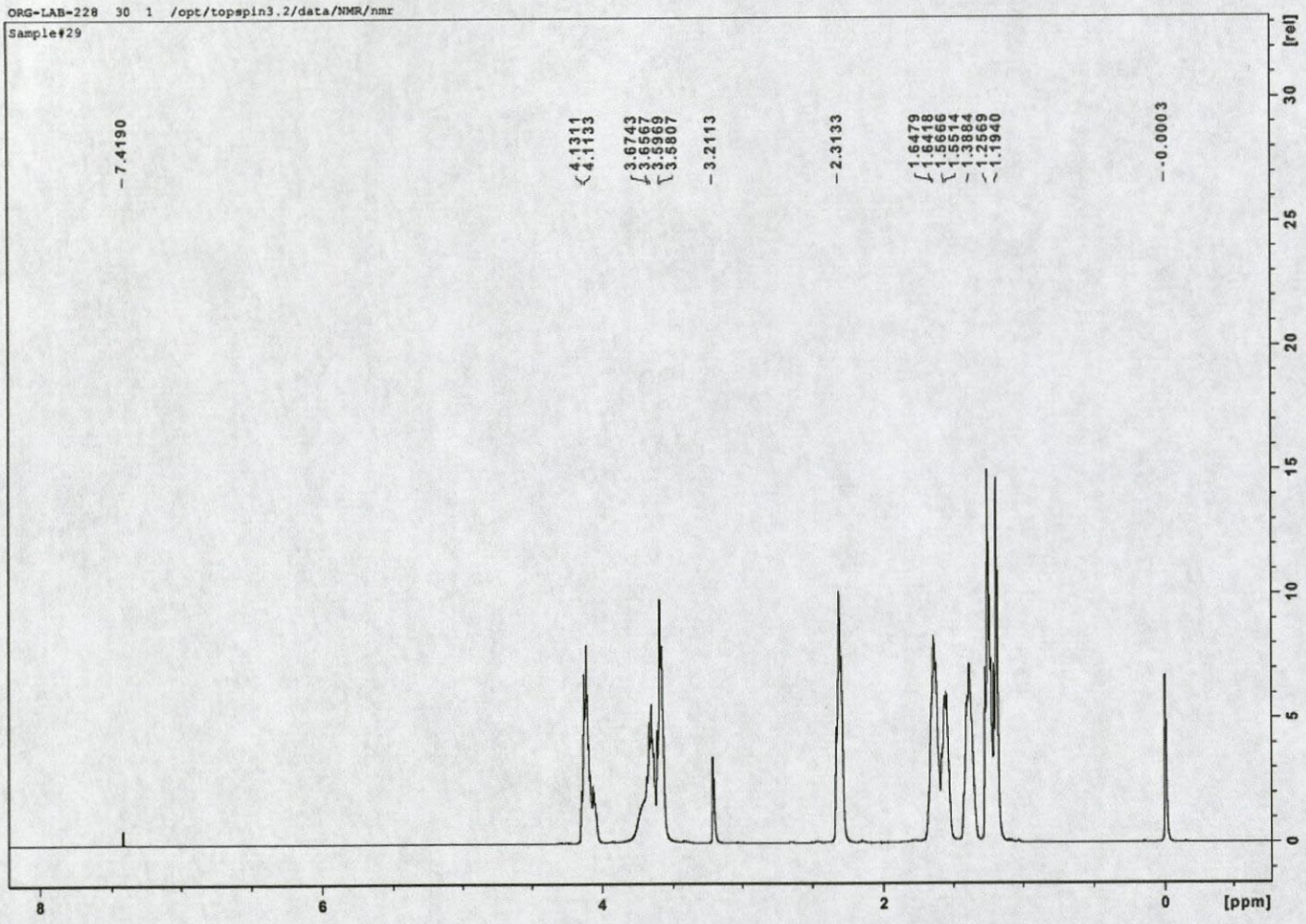


Figure 7: Esterification product HNMR at 400 MHz.

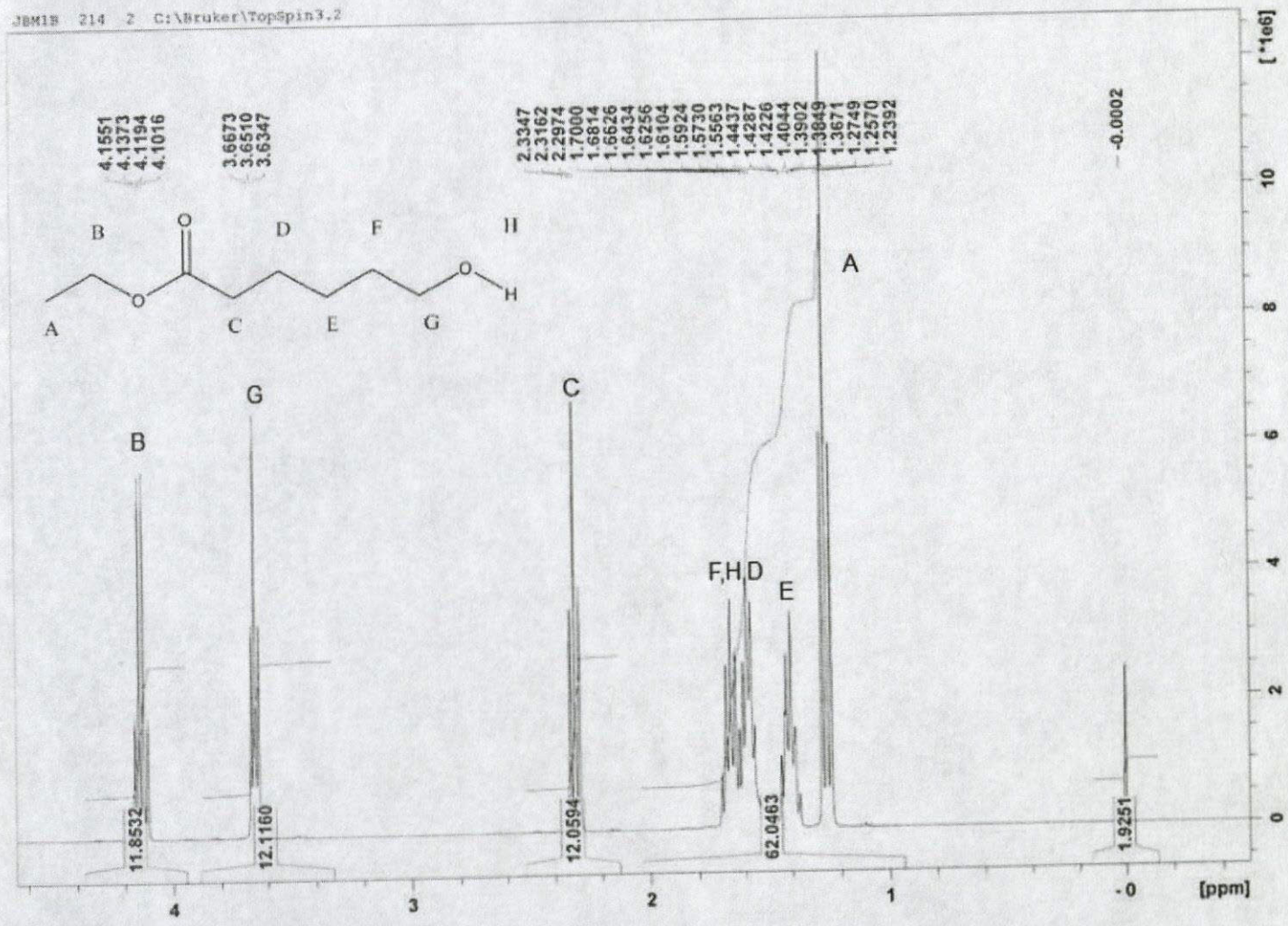


Figure 8: Esterification product HNMR at 400 MHz from McCullagh and Hirakis HNMR of a commercial sample of 6-hydroxy ethylhexanoate.

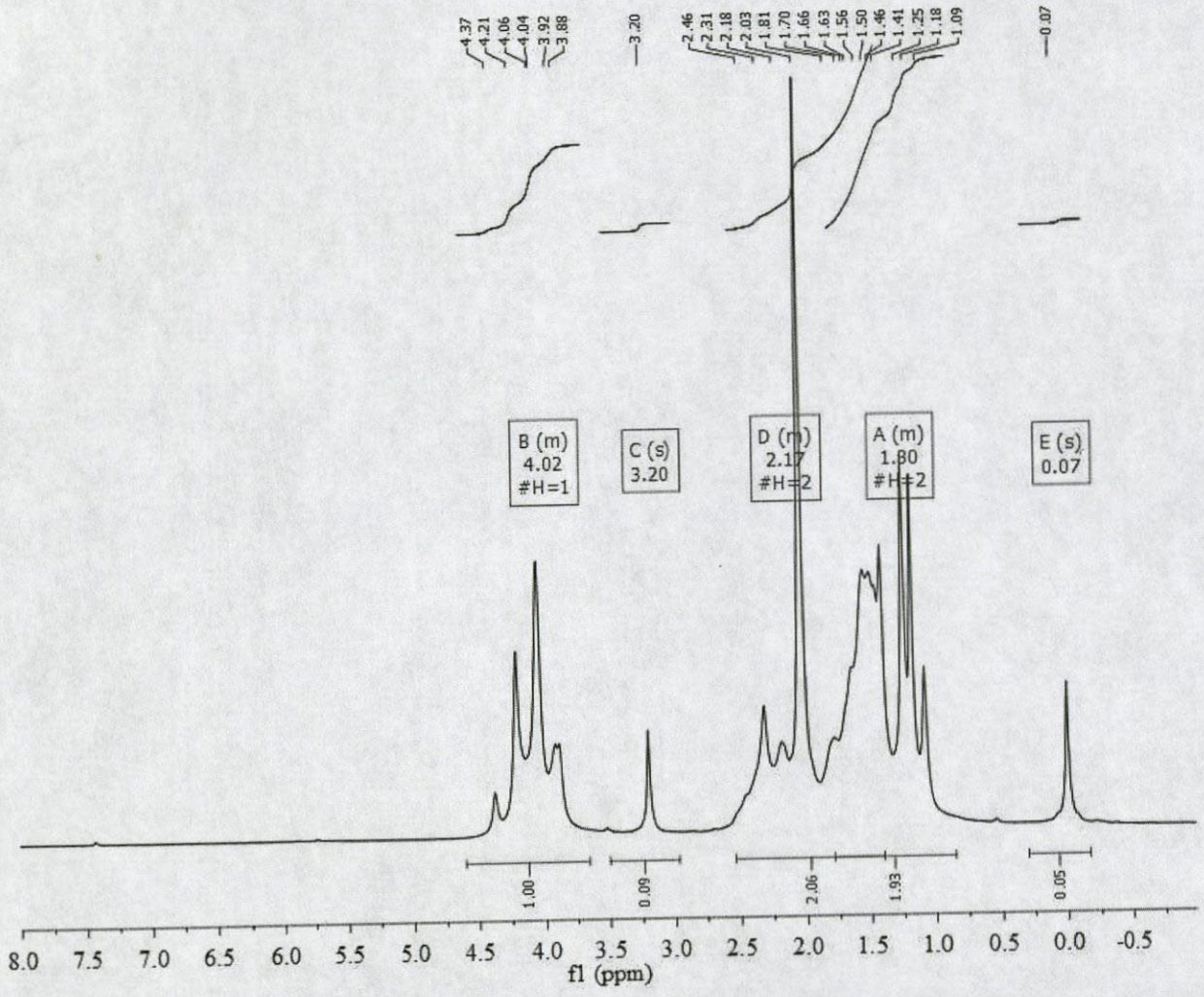


Figure 9: Acetylation product HNMR at 30 MHz.

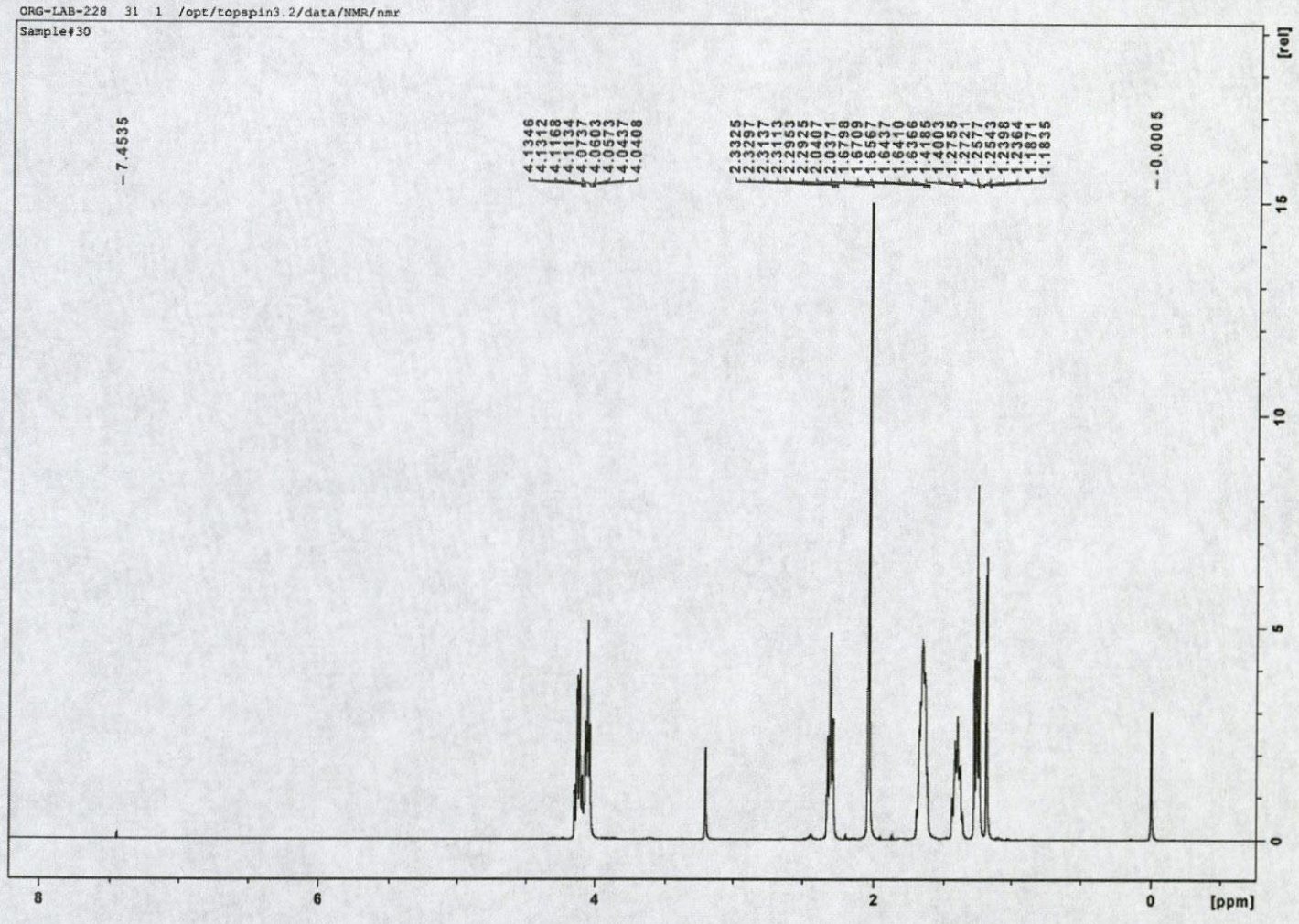


Figure 10: Acetylation product HNMR at 400 MHz.

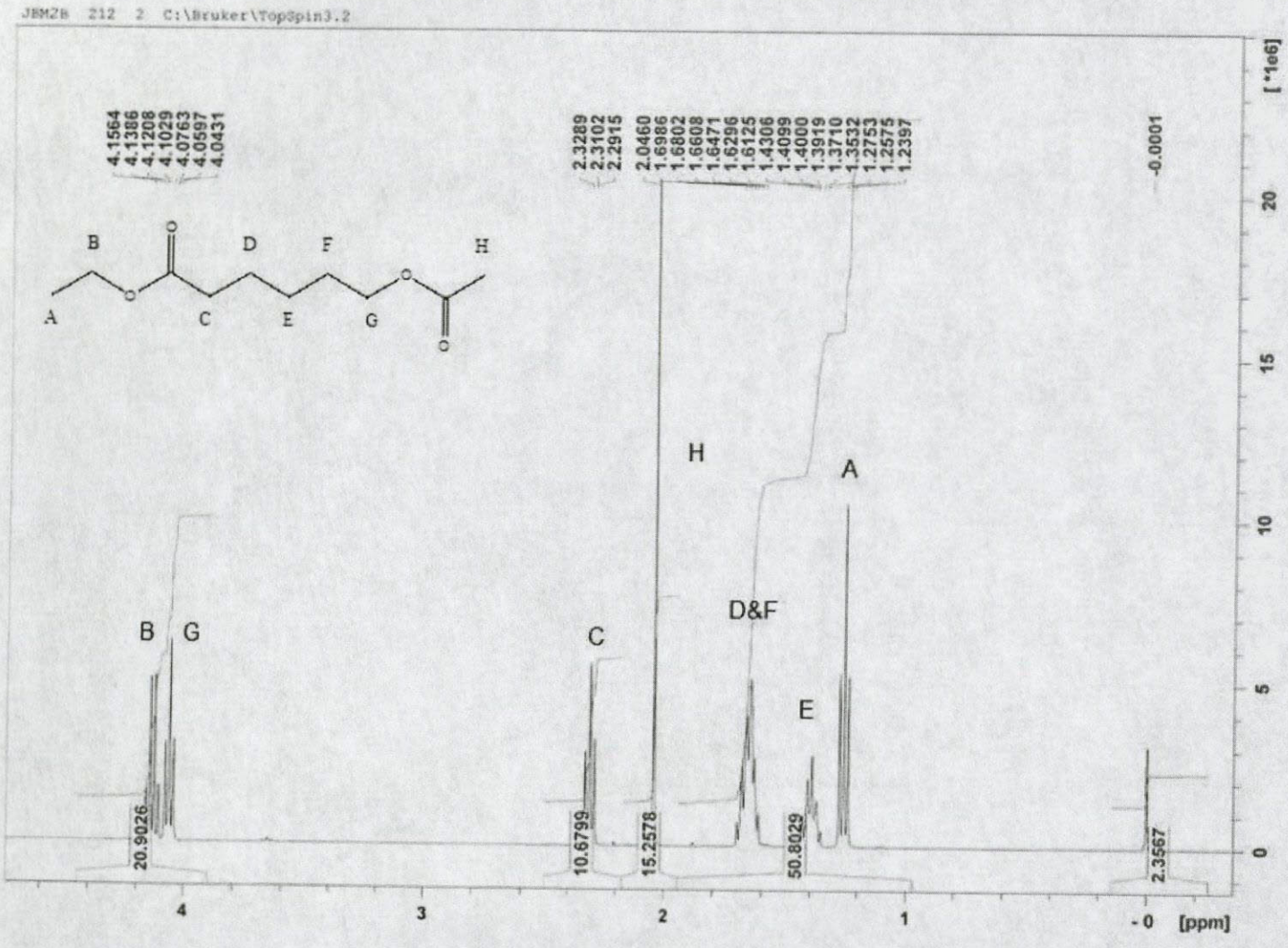
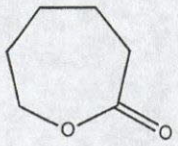
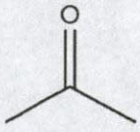
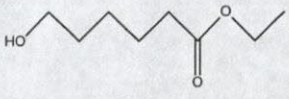
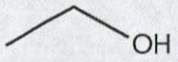
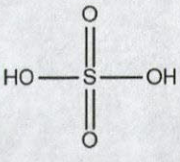
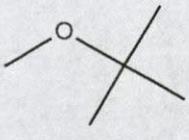
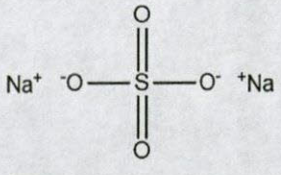
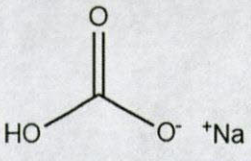
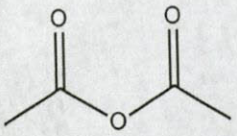
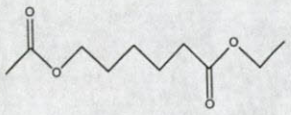
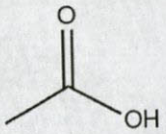
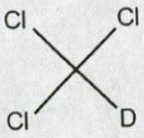


Figure 11: Acetylation product HNMR at 400 MHz from McCullagh and Hirakis HNMR of a commercial sample of 6-acetoxy ethylhexanoate.

Appendix C: Table of Physical Properties

Compound Name	Structure	CAS#	MWt	BP and MP Lit oC	State (s, l) Color	RI	Hazards
Caprolactone		502-44-3	114.14	BP: 235 MP: -1	Liquid Clear	1.463	Irrritant
Hexane		110-54-3	86.18	BP: 68.73 MP: -95.35	Liquid Clear	1.3727	Irritant, flammable, acute and aquatic toxicity
Acetone		67-64-1	58.08	BP: 56.08 MP: -94.9	Liquid Clear	1.3588	Irritant, flammable, organ toxicity
Rhodamine B	Complex	81-88-9	479.01	Decomposes at 210	Solid Red-violet	N/A	Irritant, oral and aquatic toxicity
6-hydroxy ethylhexanoate		5299-60-5	160.21	BP: 238 128 MP: 19	Liquid Clear	1.437	Irritant, flammable
Ethanol		64-17-5	46.07	BP: 79 MP: -114	Liquid Clear	1.3611	Irritant, flammable, reproductive and organ toxicity
Sulfuric acid		7664-93-9	98.07	BP: 337 MP: 10.31	Oily liquid Clear	N/A	Irritant, corrosive, target organ and aquatic toxicity
MTBE		1634-04-4	88.15	BP: 55 MP: -108.6	Liquid Clear	1.3664	Irritant, flammable, acute toxicity, carcinogen
Sodium Sulfate (Na_2SO_4)		7757-82-6	142.04	BP: N/A MP: 884	Solid White	N/A	Irritant
Sodium bicarbonate ($NaHCO_3$)		144-55-8	84	Decomposes at 50	Solid White	N/A	Irritant

NaCl	$Na^+ \ ^-Cl$	7647-14-5	58.44	BP: 1465 MP: 800	Solid White	N/A	Irritant
Acetic Anhydride		108-24-7	102.1	BP: 139 MP: -73	Liquid Clear	1.3901	Irritant, flammable, corrosive, toxic
6-acetoxy ethylhexanoate		104986-28-9	202.3	BP: 252 MP: N/A	Liquid Clear to yellow	1.426	Irritant
Acetic Acid		64-19-7	60.05	BP: 117.9 MP: 16.6	Liquid Clear	1.372	Irritant, flammable, corrosive
D-chloroform		865-49-6	120.38	BP: 61 MP: -64	Liquid Clear	1.445	Irritant, acute toxicity, carcinogen

Information compiled from: PubChem, ChemSpider, Sigma-Aldrich, Inc., and The Good Scents Company

20/20

Experiment title and number

Synthesis 1 : Vacuum distillation of Caprolactone

Date 10/18/17

Name [redacted]

Course CHEM 2229

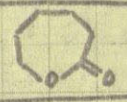
Section 3A

Lab partner

Objective: Purify caprolactone using vacuum distillation. Confirm purification by running a TLC of the distilled caprolactone vs. stock caprolactone and still pot residue. Visualize TLC plate with Rhodamine B.

~~Physical~~ NH

Physical Properties

Compound Name	Structure	CAS#	MWt	BP & MP Lit °C	State (s, l) Color	RI	Hazards
Caprolactone (E)		502-44-3	114.14	BP: 235°C MP: -1°C	Liquid clear	1.463	Irritant
Hexane		110-54-3	86.18	BP: 68.73°C MP: -95.35°C	Liquid clear	1.3727	Irritant, flammable toxic and aquatic toxicity
Acetone		67-64-1	58.08	BP: 56.08°C MP: -94.9°C	Liquid clear	1.3588	Irritant, flammable target organ toxicity
Rhodamine B	complex	81-88-9	479.01	BP: N/A MP: decomposes at 210°C	Solid Red-violet	N/A	Irritant, oral and aquatic toxicity

References

1. https://pubchem.ncbi.nlm.nih.gov
2. www.chemspider.com

Void NH
10/18/17

Caution: Place fold-in flap under yellow sheet before writing, to protect the pages that follow.

Experiment title and number: Synthesis 1: Vacuum distillation of Caprolactone

Date: 10/18/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

Procedure

1. Glassware was checked for star cracks and assembled into a distillation apparatus. Aspirator was tested to be pulling appropriate vacuum after changing the filter trap plug.
2. About 10mL of caprolactone was added to the 50mL round bottomed flask with an egg-shaped stir bar. A 25mL flask was used as a receiving flask.
3. A stirring hotplate set to zero degrees °C was used to stir the caprolactone during distillation. 3 blue Keck clips, and large clamps were used to hold the apparatus for Al foil and cotton batting was used for insulation
4. A heating mantle was used to heat the 50mL flask ~~with~~ NH containing the stock caprolactone voltage/meter setup was used to power the A small observation area was left in the ~~A~~ NH air ~~compress NH condenser~~ NH was used condenser. A thermometer was used to mo
5. Vairable voltage source was set to 100 V observed. After boiling, voltage was rec
6. Temperature was taken after first distil
   Temperature: 128.5 °C
   Vacuum was also recorded
   Vacuum: 27.0 in Hg
7. Caprolactone was distilled until about ha was filled, ~ 10 mL. Pot was not dis The mantle was removed after ~~turning~~ turned off. Apparatus was allowed to c atmospheric pressure.
8. Distillate was stored in a labelled, glass, scr
9. A TLC chamber was prepared using 4:1 A fluorescent silica gel TLC plate was stock caprolactone, still pot residue, c caprolactone. Plate was allowed to c spots were visualized by dipping the Rhodamine B in water. Spots were c disappeared.

Caution: Place fold-in flap under yellow sheet before writing, to protec

Experiment title and number: Synthesis 1: Vacuum distillation of caprolactone

Date: 10/18/17

Name: [redacted]

Course: CHEM 2224

Section: 3A

Lab partner:

Observations

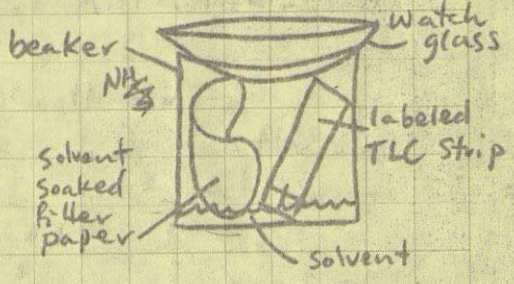
1. No glassware had starcracks.
2. A little over 10 mL of stock caprolactone was used and about 10 mL was distilled.
3. Temperature at first distillation was 128.5°C and the vacuum pressure was -27.0 in Hg
4. TLC strip was visualized with Rhodamine B in water. Spots of compound were darker pink but then faded to the same pink as the NH strip background. Distillate showed no contaminations.

Results

Compound	Spot	Rf	Distance
Stock	Spot 1	0.1867	1.51 cm
	Spot 2	0.0284	0.23 cm
Caprolactone	Spot 1	0.2027	1.64 cm
Still Pot Residue	Spot 1	0.0556	0.45 cm

→ Caprolactone Rf % Error = 19.24%

● TLC Chamber



Calculations

Rf = (distance traveled by compound)/(distance traveled by solvent)

Solvent front = 8.09 cm

Stock Spot 1 = 1.51 cm / 8.09 cm = 0.1867

Stock Spot 2 = 0.23 cm / 8.09 cm = 0.0284

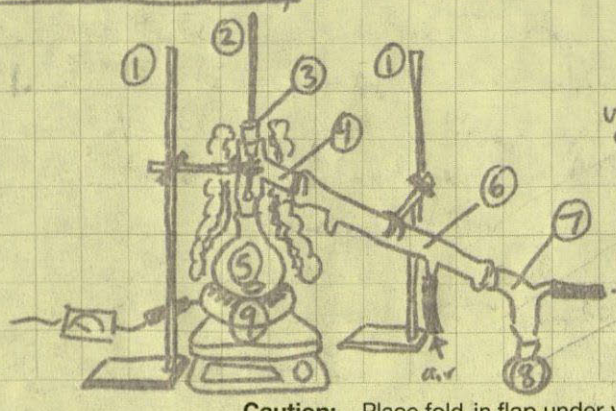
Caprolactone Spot 1 = 1.64 cm / 8.09 cm = ~~0.0~~ NH 0.2027

Still pot residue spot 1 = 0.45 cm / 8.09 cm = 0.0556

Caprolactone Rf Error = [(experimental − theoretical)/theoretical] × 100

= [(0.2027 − 0.17) / 0.17] × 100 = 19.24%

Glassware Set-up



with egg stir bar

1. Ring stand with clamp
2. Thermometer
3. Thermometer adapter
4. Distillation adapter } insulated with
5. 50 mL round bottom flask } AL foil + cotton
6. Jacketed air condenser w/ air for cooling
7. Vacuum adapter connected to vacuum
8. 25 mL round bottom collection flask
9. heating mantle on stirring plate with variable voltage

Caution: Place fold-in flap under yellow sheet before writing, to protect the pages that follow.

Experiment title and number

Synthesis 2: caprolactone reflux

Date 10/25/17

Name [redacted]

Course CHEM 2229

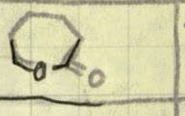
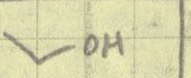
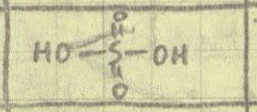
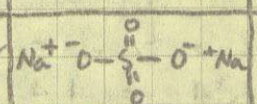
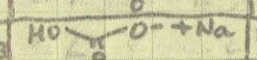
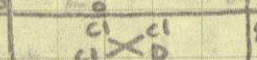
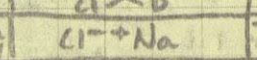
Section 3H

Lab partner

esterification of caprolactone

Objective: Produce 6-hydroxy ethylhexanoate by refluxing distilled caprolactone in ethanol and sulfuric acid catalyst. Remove excess ethanol by rotovac-evaporation (Flash evaporation). Extract product with MTBE and then remove MTBE with rotovac. Dry product and characterize by TLC, HNMR, and FTIR.

Physical Properties:

Compound Name	Structure	CAS#	MWt	BP or MP Lit °C	State (s, l) Color	RI	Hazards
Caprolactone		502-44-3	114.14	BP: 235°C MP: -1°C	Liquid Clear	1.463	Irritant
6-hydroxy ethylhexanoate		5299-60-5	160.21	BP: 238°C MP: 19°C	Liquid Clear	1.437	Irritant, flammable
Ethanol (EtOH)		64-17-5	46.07	BP: 79°C MP: -114°C	Liquid Clear	1.3611	Irritant, flammable, reproductive and target organ toxicity
Sulfuric acid (H_2SO_4)		7664-93-9	98.07	BP: 337°C MP: 10.31°C	Liquid (oily) Clear	N/A	Irritant, corrosive, target organ and aquatic toxicity
MTBE (methyl t-butyl ether)		1634-04-4	88.15	BP: 55°C MP: -108.6°C	Liquid Clear	1.3664	Flammable, irritant, acute toxicity, potential carcinogen
Sodium Sulfate (Na_2SO_4)		7757-82-6	142.04	BP: N/A MP: 884°C	Solid White	N/A	Irritant
~~NMR~~ $NaHCO_3$		144-55-8	84.00	decomposes at 50°C	Solid, White	N/A	Irritant
deuterated chloroform		865-49-6	120.38	BP: 61°C MP: -64°C	Liquid, Clear	1.445	Irritant, acute toxicity carcinogen
References		7647-14-5	58.44	BP: 1465°C MP: 800°C	Solid, White	N/A	Irritant

1. https://pubchem.ncbi.nlm.nih.gov
2. www.chemspider.com
3. www.sigmaaldrich.com

Void NH 10/25/17

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Experiment title and number: Synthesis 2: Esterification of Caprolactone

Date: 10/25/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

Procedure:

1. All glassware was checked for starcracks and washed with acetone. A hot plate and water bath were preheated at 250°C.
2. A 500 mL round bottom flask was weighed
   Flask weight: 133.598 g
   Caprolactone was added to the flask along with a stir bar (egg-shaped)
   Caprolactone weight: 5.058 g
   ~250 mL of ethanol (absolute) was added to the flask. The flask was clamped in place and a jacketed water condenser was added to the flask. The mixture was stirred while ~3mL of H_2SO_4 was added. Once water started boiling, hot plate temp was reduced to 100°C.
3. Solution was refluxed for 30 minutes. Time was started when the first condensation was observed. After 30 min, flask was raised out of water and allowed to cool briefly. A sample was removed for TLC by dipping a pipet in the mixture. Flask was returned to reflux while TLC was developed.
   A TLC chamber was prepared with 4:1 hexane : acetone and sample, diluted in acetone, was spotted on a fluorescent silica gel TLC plate along with distilled caprolactone.
   TLC strip was ~~developed~~ visualized by dipping in 0.25% aqueous Rhodamine B and spots circled immediately.
   TLC showed reaction was complete and all caprolactone was gone.
4. Water bath was removed and solution was cooled. Contents of the flask were transfered to a large beaker. Flask was rinsed twice with ~5mL of Ethanol. 8.324 g of $NaHCO_3$ was added to the beaker. Solution was stirred on the stirring hotplate with no heat. Solution was stirred until bubbling ~~stopped~~ stopped.
5. Solution was chilled in an ice bath to help precipitate solids out of solution. Solution was vacuum filtered to remove all solids. A 500mL vacuum ~~funnel~~ flask and a 3cm Hirsch funnel. Beaker was rinsed twice with ~5mL of ethanol.
6. Filtrate was poured into a dry, tared 500mL round bottomed flask.

Caution: Place fold-in flap under yellow sheet before writing, to protect the pages that follow.

Experiment title and number: Synthesis 2: Esterification of Caprolactone

Date: 10/25/17

60

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

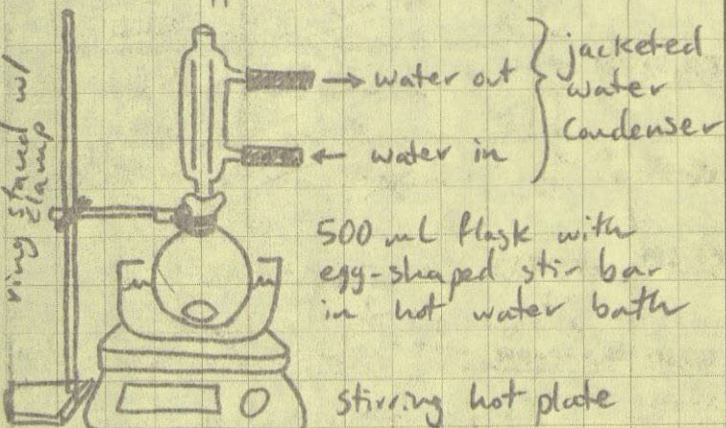
7. PH of filtrate was determined with pH paper
   pH of filtrate = 5
8. Solvent + product was not weighed because it exceeded the mass limit of the scales. Solution was capped and stirred in the 500mL round bottomed flask until next step.

10/25/17 [signature]

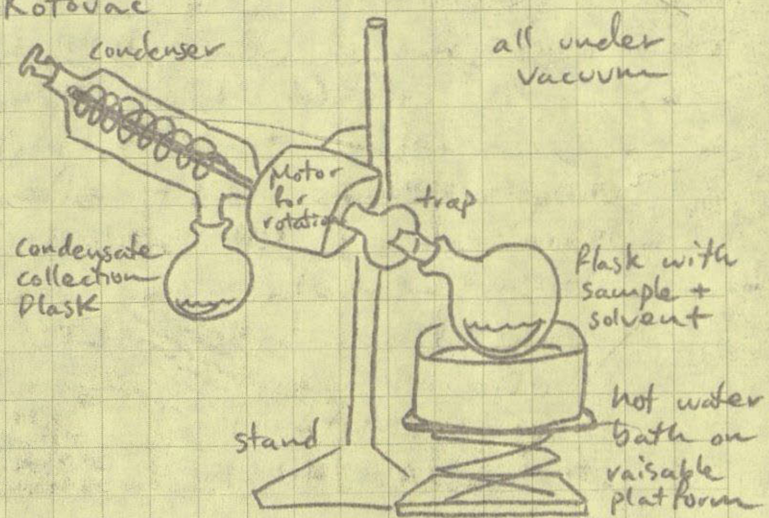
9. Ethanol was removed via rotovac after the set lab period. Bath temperature and gage pressure were recorded. Round bottom flask was weighed to determine product amount.
   Bath temperature: 63°C
   Pressure: −26.7 in Hg
   Weight: 156.460 g

Glassware

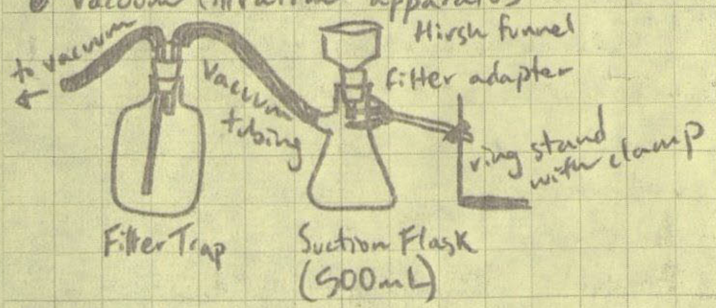
● Reflux apparatus



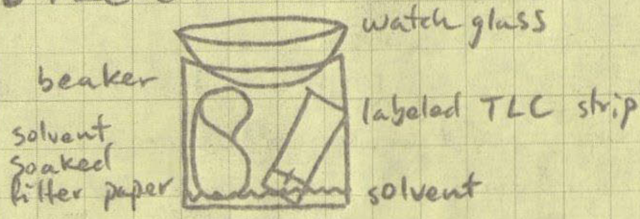
● Rotovac



● Vacuum filtration apparatus



● TLC Chamber



Rf Results:

Compound	Expected	Distance	Calculated Rf
Caprolactone	~0.17	1.18 cm	0.1674
Product	~0.07	0.47 cm	0.0667

Calculation (Rf)

Rf = (distance by compound)/(solvent front)

Caprolactone: 1.18 cm / 7.05 cm = 0.1674

Product: 0.47 cm / 7.05 cm = 0.06667

Weight of product after rotovac = 156.460 g − 133.598 g = 22.862 g

Caution: Place fold-in flap under yellow sheet before writing, to protect the pages that follow.

Caprolactone Rf % Error = [0.1674 − 0.17] / 0.17 × 100 = 1.53 %

Product Rf % Error = [0.0667 − 0.07] / 0.07 × 100 = 4.71 %

Experiment title and number: Synthesis 3: Esterification of caprolactone

Date: 10/31/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

Continued Procedure

10. 50 mL of water and 50 mL of MTBE were added to the round bottomed flask containing the esterification product. Layers were transfered to a 250 mL separatory funnel after swirling the flask. Flask was rinsed twice with 10 mL portions of MTBE which were added to the funnel.
11. Lower water layer was drained into a labeled beaker. Top layer was drained into another beaker.
12. Water layer was returned to the separatory funnel and product was re-extracted with 50 mL of MTBE. Water layer was drained into the water beaker and MTBE was drained into MTBE beaker. This was done twice.
13. Combined MTBE extracts were poured back into the sep funnel and washed with 50 mL of saturated NaCl. Lower NaCl layer was drained and discarded. MTBE layer was drained into a large 400 mL beaker and dried with Na_2SO_4.
14. Dried MTBE extract was transferred to a dry, tared 500 mL round bottomed flask. Mass was not recorded because ~~flask~~ NH liquid exceeded the ~~transfer~~ of NH limits of the scale used. Drying agent was rinsed twice with 10 mL portions of MTBE.
15. Majority of MTBE was evaporated using a hot water bath and a stirring hot plate. Round bottomed flask was heated in water bath and stirred using an egg shaped stir bar over a stirring hot plate set to 250°C. After liquid level dropped to about 1/4 an inch, remaining solvent was removed via rotovac.
16. Flask was weighed to determine product yield
    Weight: 140.827
17. Product was stored in round bottom flask until future steps.

11/1/17 CBG

Void 1/1/17 NH

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Experiment title and number: Synthesis 3: Esterification of Caprolactone

Date: 10/31/17

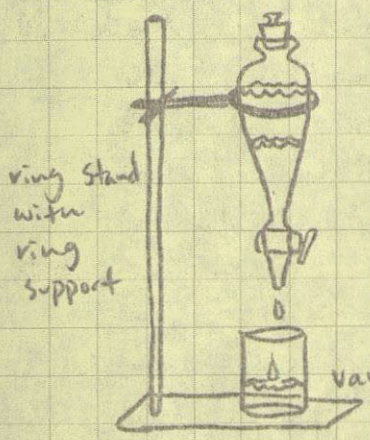
Name: [redacted]

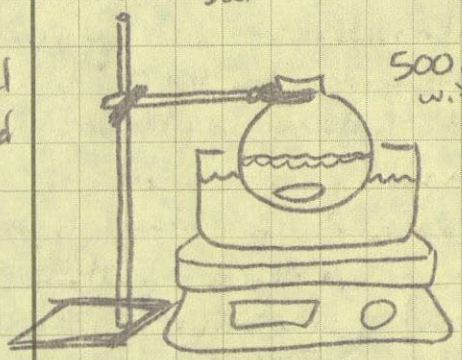
Course: CHEM 2229

Section: 3A

Lab partner:

Glassware





Observations

1. Round bottom flask weight = 133.598 g
2. Caprolactone used = 5.058 g
3. Flask weight after rotovac = 156.460 g (removed ethanol)
4. Flask weight after second rotovac = 140.827 (MTBE removed)

Results:

6-hydroxy ethylhexanoate % yield = 101.82%

Calculation:

Theoretical yield = (moles reactant) × (MW product) × mol/mol ratio

Caprolactone moles = 5.058 g ÷ 114.14 g/mol = 0.044314 moles caprolactone

0.044314 mol cap × 160.21 g/mol 6-hydroxy ethylhexanoate × 1 mol / 1 mol

= 7.0995 grams 6-hydroxy ethyl hexanoate theoretically

Yield = 140.827 g − 133.598 g = 7.229

% Yield = [7.229 / 7.0995] × 100 = 101.82%

Based on the % yield, it was assumed that not all MTBE was evaporated before the weight of the product was recorded.

Void 11/1/17 NH

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Experiment title and number

Synthesis 4: Fragrance Synthesis from Caprolactone

Date 11/7/17

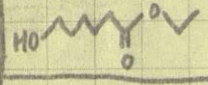
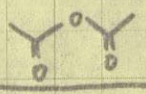
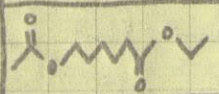
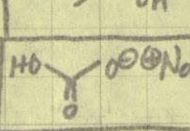
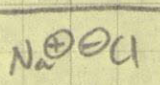
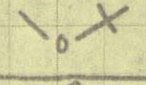
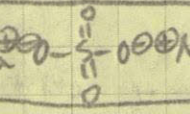
63

Name [redacted]

Course CHEM 2229 Section 3A Lab partner

Objective Reflux 6-hydroxyl ~~ethynol~~ NH ethyl hexanoate with acetic anhydride to produce fragrance (6-acetoxy ethyl hexanoate). Monitor reaction progress with TLC. Remove excess acetic anhydride with water and separate product with a separatory funnel and MTBE. Remove MTBE via rotovac. Characterize product with TLC, FTIR, and HNMR

Physical Properties

Compound Name	Structure	CAS#	MWt	BP or MP Lit °C	State (s, l) Color	RI	Hazards
6-hydroxyl ethylhexanoate		5299-60-5	160.21	BP: 238°C MP: 19°C	liquid clear	1.437	Irritant, flammable
Acetic anhydride		108-24-7	102.1	BP: 139°C MP: -73°C	liquid clear	1.3901	Irritant, flammable, corrosive, acute toxicity
6-acetoxy ethylhexanoate		104986-28-9	202.3	BP: 252°C MP: N/A	liquid clear to yellow	1.426	Irritant
Acetic acid		64-19-7	60.05	BP: 117.9°C MP: 16.6°C	liquid clear	1.372	Irritant, flammable, corrosive
$NaHCO_3$		144-55-8	84.00	~~BP: 1465°C~~ NA ~~MP: 800°C~~ decomposes at 50°C	Solid, white	N/A	Irritant
NaCl		7647-14-5	58.44	BP: 1465°C MP: 800°C	Solid white	N/A	Irritant
MTBE		1634-04-4	88.15	BP: 55°C MP: -108.6°C	Liquid clear	1.3664	Irritant, flammable acute toxicity, potential carcinogen
Na_2SO_4		7757-82-6	142.14	BP: N/A MP: 884°C	Solid white	N/A	Irritant
Hexane		110-54-3	86.18	BP: 68.73°C MP: -95.35°C	liquid clear	1.3727	Irritant, flammable toxic and aquatic toxicity
Acetone		67-64-1	58.08	BP: 56.08°C MP: -94.9°C	liquid clear	1.3588	Irritant, flammable target organ toxicity
RhodamineB	complex	81-88-9	479.01	BP: N/A MP: decomposes at 210°C	Solid Red-violet	N/A	Irritant, oral and aquatic toxicity

References

1. https://pubchem.ncbi.nlm.nih.gov
2. www.chemspider.com
3. www.thegoodscentscompany.com/data/rw1061362.html

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Experiment title and number: Synthesis 4: Fragrance Synthesis from Caprolactone

Date: 11/8/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

Procedure

1. A heating mantle was used to heat a 250mL round bottom flask during the reaction. A stirring hot plate was used only for stirring. Mantle was connected to a volt meter to vary the voltage.
2. ~1/4 of a snap cap vial was filled with step 1 product for later characterization.
3. 500mL RB flask + step one product was reweighed to determine starting amount of material.
   Mass of empty, dry 500mL RB = 133.598 g
   Mass of RB + step one product = 140.325 g
   Starting material = 140.325 g − 133.598 g = 6.727 g
4. Amount of acetic anhydride to use was determined by multi the starting material mass by 4. (1 g step 1 product to 4 m acetic anhydride)
   6.727 g starting × 4 mL ≠NH acetic anhydride
   = 26.908 mL acetic anhydride
   ~27 mL of acetic anhydride was added to RB flask, swirled to dissolve step 1 product to the 250mL RB flask. An egg-shaped added, along with a jacketed water cond reflux setup.
5. Mantle was turned to 100 V for 2 mini 50 V. ≠NH after boiling was observed. reflixed for 40 minutes, starting at
6. After 40 minutes, RB was raised and cooled used to remover a small amount of th Sample was dissolved in a small amount run along side the step 1 product on gel TLC strip. Reaction mixture was refluxing while the strip was developed in using 4:1 hexane : acetone. TLC strip wa by dipping in 0.25% aqueous Rhodamine circled immediately. Step 2 product theo Rf = 6
6. Reaction mix was allowed to continue refluxing After development, TLC plate showed that 1 complete

Experiment title and number: Synthesis 4: Fragrance Synthesis from Caprolactone

Date: 11/8/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

7. Heating mantle was removed and the reaction mix was allowed to cool to ~70°C
8. ~10 mL of water was slowly added to destroy excess acetic anhydride. After addition, flask was heated via mantle for an additional 5 minutes. Flask was cooled to room temperature by immersing in an ~~ice~~ water bath.
9. After cooling, contents were translered to a large beaker. Flask was rinsed with 2 5mL portions of MTBE. 50mL of water was used to rinse the flask and rinsing was added to the beaker
10. ~24g of $NaHCO_3$ was slowly added to the beaker. Beaker and $NaHCO_3$ was stirred until all bubbling stopped
11. pH of the solution was taken. pH was too low for storage so more $NaHCO_3$ was added to raise the pH to around 8.
12. Solution was stored in a 500mL RB flask 11/8/17 JPB
13. Stored solution was translered to a 500 mL separatory funnel. Excess $NaHCO_3$ was left in the RB. The RB and $NaHCO_3$ were rinsed twice with 50mL of MBTE. Rinsings were added to sep funnel. Sep funnel was shaken for ~1 minutes to extract Excess $NaHCO_3$ was dissolved in the sep funnel with 200mL of dH_2O.
14. Water layer was drained into a beaker. MBTE layer was drained into a different beaker. Water layer was poured back into the funnel and reextracted with 50mL of MTBE. Water layer was drained and MTBE was added to the MTBE beaker. ~~this was repeated once more.~~ NH Rextraction was repeated once
15. The combined MTBE extracts were poured back into the sep funnel. Extracts were washed twice with 50mL of saturated $NaHCO_3$. Lower $NaHCO_3$ layer was discarded both times
16. MTBE was washed once with 75 mL of saturated NaCl. An additional 50mL of water was added to dissolve excess solid
17. ~~Na_2SO_4 was a~~ NH MTBE layers were translered to a large beaker and Na_2SO_4 was used to dry ~~it.~~ NH the solution

Caution: Place fold-in flap under yellow sheet before writing, to protect the pages that follow.

Experiment title and number: Synthesis 4: Fragrance Synthesis from Caprolactone

Date: 11/8/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

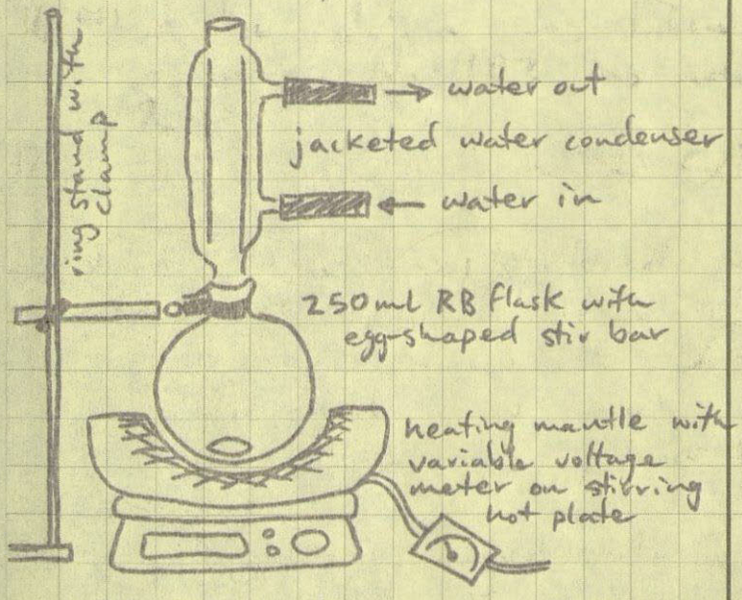
Lab partner:

18. A 500 mL RB flask was weighed and MTBE was transfered to it. Drying agent was rinsed twice w/ 10 mL MTBE.
RB weight: 133.617 g

19. MTBE was removed via rotovac. After rotovac, RB was weighed to determine mass of product.
RB + product weight: 139.794 g
Vacuum pressure and water bath temp of rotovac were recorded
Pressure: -24.4 in Hg.
Water bath temperature: 57°C

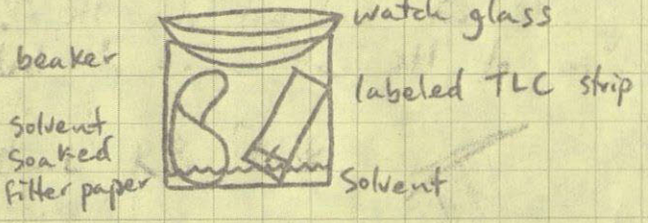
11/15/17 CBob

Glassware Setup

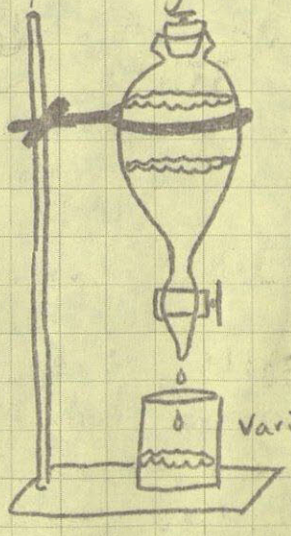


Reflux Apparatus

TLC Chamber



Separatory Funnel



500 mL separatory funnel with water and MTBE

various collection beakers

Observations

1. Starting material was a clear liquid. Final product was pale yellow liquid.
2. Mass of starting material = 6.727 g. Acetic anhydride used = 27 mL
3. Mass of 500 mL RB flask = 133.617 g.
4. Mass of RB flask + product = 139.794 g.
5. Rotovac settings: -24.4 in Hg, 57°C

Void NH

Caution: Place fold-in flap under yellow sheet before writing, to protect the pages that follow.

Experiment title and number: Synthesis 4: Fragrance Synthesis From Caprolactone

Date: 11/8/17

Name: [redacted]

Course: CHEM 2229

Section: 3A

Lab partner:

Results:

Rf Results

Compound	Expected	Experimental	% Error
Step 1	0.07	0.09619	37.42%
Step 2	0.29	0.3467	19.55%

Step 2 yield = 6.177g

Step 2 % Yield from Step 1 = 72.72 %

Overall % Yield = 72.72%

~~Step~~ NH

Calculations:

Rf = (distance by compound) / (solvent front)

Step 1 : 0.48 cm / 4.99 cm = 0.09619

Step 2 : 1.73 cm / 4.99 cm = 0.3467

% Error = [(experimental - theoretical) / theoretical] × 100

Step 1 : ([0.09619 - 0.07] / 0.07) × 100 = 37.42%

Step 2 : ([0.3467 - 0.29) / 0.29] × 100 = 19.55 %

Yield

Theoretical yield = (moles reactant) × MW product × mol/mol ratio

6-hydroxy ethylhexanoate moles = 6.727 g of NH ÷ 160.21 g/mol = 0.04198 moles

0.04198 mol 6-hydroxy × 202.3 g/mol 6-acetoxy × 1 mol / 1 mol =

8.494 g of 6-~~acetyl~~ NH acetoxy ethylhexanoate theoretically.

Yield = 139.794 g of RB+product − 133.617 g of RB = 6.177 g

% Yield = (actual / theoretical) × 100 = [6.177g / 8.494g] × 100 = 72.72 %

Overall yield = % yield of step 1 × % yield of step 2

% yield of step 1 = 101.82%

Step 1 % yield was considered 100% for calculation

% yield of step 2 = 72.72 %

Overall yield = 100% × 72.72 % = 72.72%

Void NH 11/8/17

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Experiment title and number

Product Verification

Date 11/29/17

Name [redacted]

Course CHEM 2229

Section 3A

Lab partner

Procedure

1. Step 1 product and step 2 product were verified by FTIR using a Nicolet Nexus 470 FTIR ESP machine and sodium chloride crystal plates.
2. Step 1 product and step 2 product were verified by HNMR. using a 30 MHz desktop Magritek Spinsolve Carbon ~~Nicolet Nexus 470 FTIR ENH~~ HNMR.
3. Step 1 and step 2 products were also run on a Brüker H-NMR at 400 MHz.

11-29-17

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