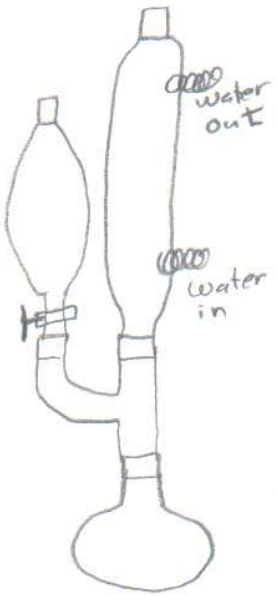
Background

In this project, we will perform a Grignard reaction using a pre-made Grignard reagent. Grignard reagents can easily be made from haloalkanes and haloaromatics, but the process is laborious and highly sensitive to atmospheric moisture. Today, pre-made Grignard reagents dissolved in inert solvents, like ethyl ether or tetrahydrofuran, can be purchased from chemical supply companies. These Grignard reagents can be used directly and quickly in reactions.[3]

Surprisingly, the Grignard reaction has been preformed in pretty much the same way for over a century. We will compare the yields of Grignard additions done in three different ether solvents: diethyl ether, tetrahydrofuran, and tert-butyl methyl ether.

Procedure

1. Set up equipment as shown in the picture below using a dry 100mL round bottom flask, condenser, additional funnel, and a stirring plate. At least two clamps please. Place a stirring magnet in the flask.



2. Measure 1.82g of benzophenone, and add to 30mL of your assigned ether in a beaker. Add the resulting solution to the closed separatory funnel. ***Ether: hazard class 3, extremely flammable and should be kept away from heat sources, extremely volatile and should be used in a well ventilated area.***

3. Bring your 100 mL round bottom with a stopper to the dispensing hood. Use a syringe to draw out 4.5mL of the Grignard reagent, 3M phenylmagnesium bromide in ethyl ether, from the stock bottle. Inject the Grignard reagent directly into the round bottom flask and place the stopper on the ground-glass opening. At your hood, refasten the flask to the set-up. ***phenylmagnesium bromide: highly flammable, reacts violently with water, causes burns***

4. Plug the top openings of the condenser and additional funnel with plugs of cottonballs.

5. **Slow step.** Slowly add the ketone solution over the course of 30 minutes into the round-bottom flask. Also at this time turn on the stirring plate to mix solution to the mixture already in the flask. Do not heat the flask please.

6. Place a stir bar in the round bottom and place on the stirplate. Acidify the product by adding a 10% solution of sulfuric acid, 1 mL at a time. Determine the pH using pH paper. ***Sulfuric Acid: corrosive! Very irritating to respiratory and digestive systems, skin, and eyes. Wear gloves and goggles.***

7. Add water to dissolve any precipitation. Pour the solution into a separatory funnel. Extract the acidic aqueous suspension using three 10 mL portions of methyl *tert*-butyl ether. a) Add 10 mL of methyl *tert*-butyl ether to the separatory funnel containing the aqueous solution. b)

Shake to extract. c) Let settle. d) Drain out the bottom (aqueous) layer into a flask. e) Drain out the ether layer into a separate beaker. f) Add the aqueous solution back into the separatory funnel. g) Repeat twice more. ***When extracting, remember to open the spout to relieve pressure. Do this away from your body and others.***

8. Use the separatory funnel to eliminate any acid remaining in the combined ether extracts. Pour 15 mL of saturated sodium bicarbonate into a separatory funnel containing combined ether extract. Place the top on the funnel. Shake contents under the hood away from self. Extract the bottom layer. You will need to keep the ether layer for the next steps.

9. Dry the ether layer using an anhydrous drying agent (Na_2CO_3 or Na_2SO_4). Decant the ether layer from the solid drying agent or filter out the drying agent with gravity filtration. Collect the ether solution in a preweighed beaker. Evaporate the ether in the hood with a stream of forced air. Do not heat please.

10. Obtain the mass of your crude product.

Analysis

1) Do a TLC of your product (dissolved in a suitable solvent such as dichloromethane). Compare your product to triphenylmethanol and benzophenone standards.

2) Perform an IR scan of your product.

Data Entry:

Enter the name of your ether and the mass of your product on a spreadsheet.

Submit sample for further (GC-FID) analysis:

Hand in a vial with your product: Include your name, date, your ether, and the name of your product on the label.

Disposal

- Dispose of pH paper, TLC slides, capillary tubes, filter paper, gloves, and drying agent: in “hazardous solids” container under hood
- Dispose of leftover liquid from extractions, TLC solvents, filtrate: in “hazardous liquids” container under hood
- Dispose of Paper towels: in general waste basket unless soaked in chemicals, then in “hazardous solids” container under hood

Physical Constants. Complete table of physical constants and safety data:

Name	Formula	M.W. g/mole	m.p. ºC	b.p. ºC	Density g/mL
ethyl ether	$C_4H_{10}O$	74.1224	-116.3	34.6	0.7134
methyl t-butyl ether	$C_5H_{12}O$	88.15	-109	55.2	0.7404
tetrahydrofuran	C_4H_8O	72.11	−108.4	66	0.8892
benzophenone	$C_{13}H_{10}O$	182.2214	48.5	305.4	1.11
phenyl magnesium bromide	C_6H_5BrMg	181.3145			1.14
10% H_2SO_4	H_2SO_4	98.0734	~ 0	~ 100	~ 1
saturated sodium bicarbonate	$CHNaO_3$	84.00687	270	851	2.159
hexane	C_6H_{14}	86.1766	-95	69	0.6548
dichloromethane	CH_2Cl_2	84.9328	-96.7	39.8	1.3255

Name	Solubility	Safety Information
ethers	Immiscible with water Miscible with alcohols and non-polar solvents	Irritation-Eyes, Nose, Throat, Skin Extremely flammable!
benzophenone	Insoluble in water Soluble in alcohol and nonpolar solvents	Is an irritant. Take precautions to not allow contact with any part of your body.
phenyl magnesium bromide	Reacts violently in water	Flammable
H_2SO_4 sulfuric acid	Fully miscible (exothermic) in water	Cause severe skin burns. Causes severe eye burns.
saturated sodium bicarbonate	Soluble in water	Eye contact may cause mild irritation, redness, and pain.
hexane	Immiscible with water Miscible with alcohols and non-polar solvents	Is an irritant. Take precautions to not allow contact with any part of your body. Flammable!
dichloromethane	Immiscible with water Miscible with alcohols and non-polar solvents	Is an irritant. Take precautions to not allow contact with any part of your body.

- **Pre-Lab**

Title & Purpose

Flowchart: (1 point) Your assigned ethers: ethyl ether (1R, 3R, 5R, 6R,7R, 8R) tetrahydrofuran: (1L, 2L, 4R, 5L,7L,8L) or methyl t-butyl ether (2R , 3L, 4L,6L, 9, 10)

Calculations: (3 points)

Write a balanced equation (with chemical structures) for the Grignard addition of phenyl magnesium bromide to benzophenone.

Write the chemical characteristics of the expected organic product: chemical formula, molecular weight, melting point, …

Calculate the theoretical yield for your expected product. Show your calculations please.

Safety Question: (1 point) Compare the three ethers:

Why are MTBE and THF considered "safer" than ethyl ether?

Name	flash point	explosion limits	autoignition temperature	vapor pressure
ethyl ether	-40º C	1.7 - 48%	170º C	400 mm Hg at 18º C
methyl t-butyl ether	-10	1.6 - 15.1%	435	245 mm Hg at 20º C
tetrahydrofuran	-14	1.5% - 12%	321	129 mm Hg at 20 C

http://www.pcl.ox.ac.uk/MSDS/DI/diethyl_ether.html
http://msds.chem.ox.ac.uk/BU/tert-butyl_methyl_ether.html
http://msds.chem.ox.ac.uk/TE/tetrahydrofuran.html

Experimental Observations and Data (4 points)

Hand in a copy of your experimental observations and data before you leave lab.

Lab Report

Results

____ (1 point) % yield of product (mass of recovered product x 100/theoretical yield). Show your calculations please.

____ (1 point) Interpret TLC (identity and purity)

____ (1 point) Interpret the IR spectrum (identity and purity)

____ (1 point) Interpret the GC-FID chromatogram of your sample. (identity and purity)

____ (1 point) Assign Carbons and Hydrogens of the expected product according to the ^{1}H NMR & ^{13}C NMR spectra given.

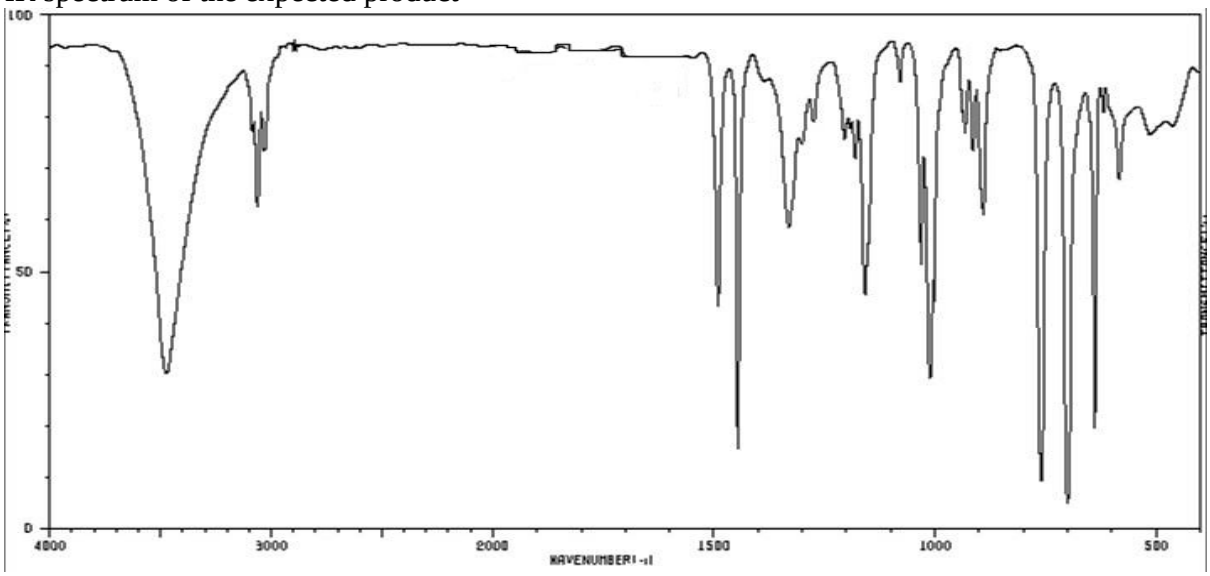
Discussion and Conclusion

_____ (1 point) What is the outcome of the class data for this experiment?

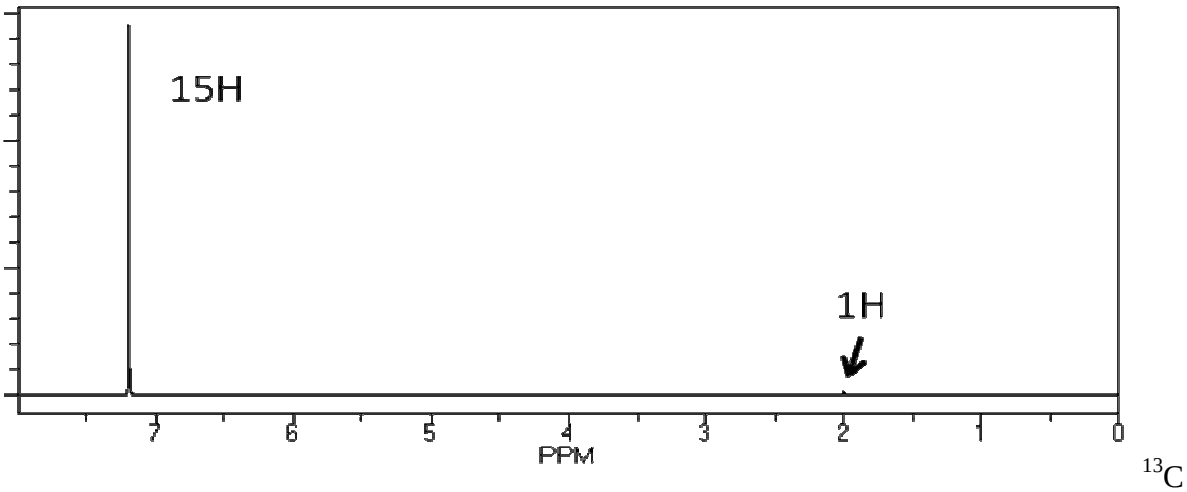
Write a Journal of Organic Chemistry style introduction of this experiment including class data. (5 points)
JOC website: http://pubs.acs.org/journal/joceah
Sample article with introduction: http://pubs.acs.org/doi/pdf/10.1021/jo101791w
Write at least three paragraphs.
Include at least one figure.
Cite at least 6 references written in JOC style.

Extra credit – help Dr. Friesen create a better diagram for page 1!

IR spectrum of the expected product



^{1}H NMR spectra of the expected product:



^{13}C NMR spectra of the expected product: