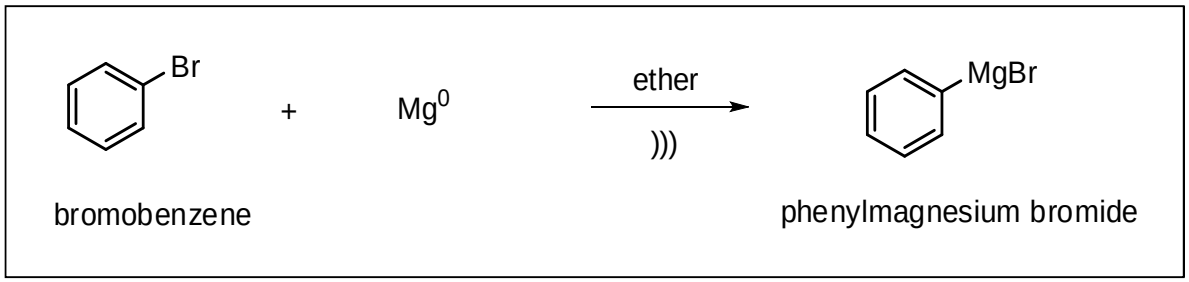
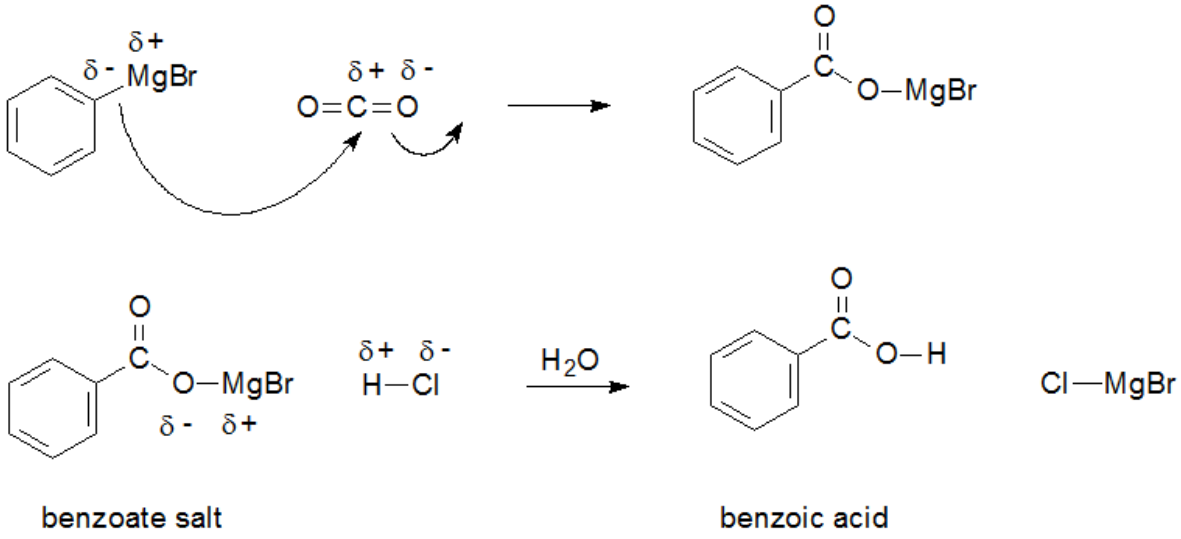
GRIGNARD REACTION – Synthesis of Benzoic Acid

In the 1920's, the first survey of the acceleration of chemical transformations by ultrasound was published. Since then, many more applications of ultrasound have been described; sonication of reactions involving metals are particularly useful. Very simply described, ultrasonic waves passed through a liquid cause the formation of bubbles that subsequently collapse with the production of powerful high-energy shock waves. The shock waves, among other effects, can "clean" and disperse metal. Sonication is thought to clean the oxide coating from the magnesium metal during preparation of a Grignard reagent so that a fresh metallic surface is present for the reaction between magnesium and the organohalide.



This ultrasound modification to the usual experimental procedure for preparing a Grignard reagent will allow the reaction to be performed with ether solvent that has absorbed atmospheric moisture, and with simple glassware that does not need to be oven-dried and cooled under N_2 atmosphere immediately before use. (Remember, Grignard reagents are destroyed by water, and even traces of water will normally prevent their formation.)

In today's experiment, the phenylmagnesium bromide will be reacted with CO_2 to form a benzoate salt, which is then hydrolyzed to form benzoic acid.



Read your lecture textbook for detailed information about the requirements and mechanism for Grignard reagent formation and reactions.

Safety Precautions

Diethyl ether is *extremely* volatile and flammable. There must be no flames or sparking sources present in the laboratory during this experiment.

Avoid breathing bromobenzene or ether fumes.

Bromobenzene is a skin irritant. Wear gloves, goggles, and a lab coat to avoid skin and eye contact with all chemicals.

Procedure

First Week

I. Formation of the Grignard reagent

Note: Use the same balance for all mass measurements in the experiment (± 0.001 g).

1. Measure about 10 mL of diethyl ether in a small graduated cylinder and pour it into a large vial.

2. Bromobenzene will be supplied in another vial. Weigh the vial+cap and contents. Add the bromobenzene to the large vial containing the ether.

   Gently swirl the large vial to mix the contents.

   Weigh the empty vial+cap to obtain the mass of bromobenzene used in the reaction.

3. Add 0.5 g of magnesium filings to a large test tube.

   Add the bromobenzene/ether solution to the test tube containing the magnesium. Loosely place a cotton ball in the open end of the tube. Do not stuff the cotton down the test tube. The purpose of the cotton ball is to minimize exposure to atmospheric water and oxygen and to help absorb any ether that might evaporate during the reaction.

4. To initiate the reaction, place the test tube in a ultrasonic water bath. When the solution begins to turn cloudy gray, white, or brownish the reaction has begun. The ether should begin to boil spontaneously due to the exothermicity of the reaction.

   If the reaction becomes too vigorous, remove it from the bath for a short period.

   If the reaction fails to start, add a crystal of I_2, which can initiate a sluggish reaction.

You should continuously monitor the reaction in your test tube. Even though the entire class is conducting the experiment in a small sonicator, it is still each student's responsibility to monitor his or her own reaction, observe any changes taking place, and record the observations in the notebook.

II. Reaction of the Grignard reagent with CO_2

1. When the Grignard reaction begins to slow down, place ~10 g of crushed Dry Ice in a 150-mL beaker labeled with your name,. Do not take time to weigh the Dry Ice. Use approximately the amount in the beaker indicated by your instructor during recitation. The CO_2 is in large excess and will not affect your calculation of percent yield of benzoic acid product. Cover the beaker with a watch glass.

2. When most of the magnesium has reacted and the ether boiling subsides, quickly pour the contents of the tube into the beaker containing Dry Ice. Add a few milliliters of ether to the test tube and swirl to rinse. Add the rinse liquid to the beaker.

3. Cover the beaker with the watch glass and allow it to stand until the next lab period. During the interim, the excess Dry Ice will have sublimed.

Second Week

III. Hydrolysis

1. Hydrolyze the Grignard addition product by slowing adding ~ 30 mL of 6M HCl to the beaker. Stir the mixture with a glass stirring rod. If there is excess magnesium present, it will react with the HCl to evolve hydrogen gas – *add HCl slowly*!

2. Add ~30mL of methyl-*tert*-butyl ether (MTBE) to the beaker. Stir the mixture. There should now be two distinct liquid layers.

   If there is solid other than magnesium present, add a little MTBE with a transfer pipette. If the solid is still not dissolved, add a little more HCl. Stir. Avoid adding excess HCl.

3. Pour the contents of the beaker into a 125-mL separatory funnel (use a glass funnel in the neck of the separatory funnel), leaving behind any residual magnesium in the beaker. Rinse the beaker with a few milliliters of MTBE and add it to the separatory funnel.

IV. Isolation of Benzoic Acid

As you proceed through the isolation procedure, refer to the Figure on a following page. It describes the various processes taking place and shows you in which phase (aqueous or organic) your product is. The diagram will also be helpful in constructing the Separation Scheme for this experiment.

Extraction with water

1. Stopper the separatory funnel. Carefully invert the separatory funnel and vent through the stopcock. Close the stopcock and gently shake the separatory funnel. Vent again. Repeat.

   Separate the layers by draining the aqueous layer into a labeled waste beaker. Do not discard the beaker contents until after you have isolated your product.

2. Add 5 mL of distilled water to the organic phase remaining in the separatory funnel. Perform another extraction by venting and shaking the separatory funnel. The drained aqueous layer can be added to the aqueous waste beaker.

3. Repeat the extraction in step 2.

Extraction with base

4. Add 5 mL of 5% aqueous NaOH to the organic phase in the separatory funnel. Shake the mixture gently, with venting. Drain the aqueous layer into a clean, dry 150-mL labeled beaker. Do not combine this aqueous layer with the aqueous waste in steps 1-3.

5. Repeat the extraction in step 4 two more times, draining the aqueous layers into the same beaker in step 4.

6. Place the organic layer into separate waste container to be disposed of at the end of the experiment as instructed. Do not discard the liquid until after you have isolated your product.

7. Gently heat the combined aqueous extracts (~15 mL) containing the benzoate salt on a hot plate, set to 4-5, for about 10 minutes to remove any residual MTBE, which is slightly soluble in water. Small bubbles will boil off. Do not to boil the water.

   Let the solution cool to room temperature.

8. Add 10 mL 6M HCl and stir. A precipitate will form in the beaker. Cool the mixture in a water/ice bath.

9. Assemble a vacuum filtration apparatus and vacuum filter the product using a Buchner funnel.

   Wash the crystals on the filter paper with 2 portions of 5 mL cold distilled water.

V. Recrystallization of Benzoic Acid

1. Carefully transfer the solid to a 50-mL Erlenmeyer flask. Add ~15mL distilled water.

2. Heat the solution to just below the boiling point, swirling the mixture occasionally, until all the solid is dissolved.

3. Allow solution to cool slowly to room temperature. If the cooled solution does not have sufficient water to suspend the purified crystals as a slurry, add 10 mL distilled water, redissolve the crystals by heating the mixture, and cool again slowly to room temperature.

4. Weigh a piece of vacuum filter paper and then vacuum filter the product crystals. Wash the crystals with 5 mL cold distilled water.

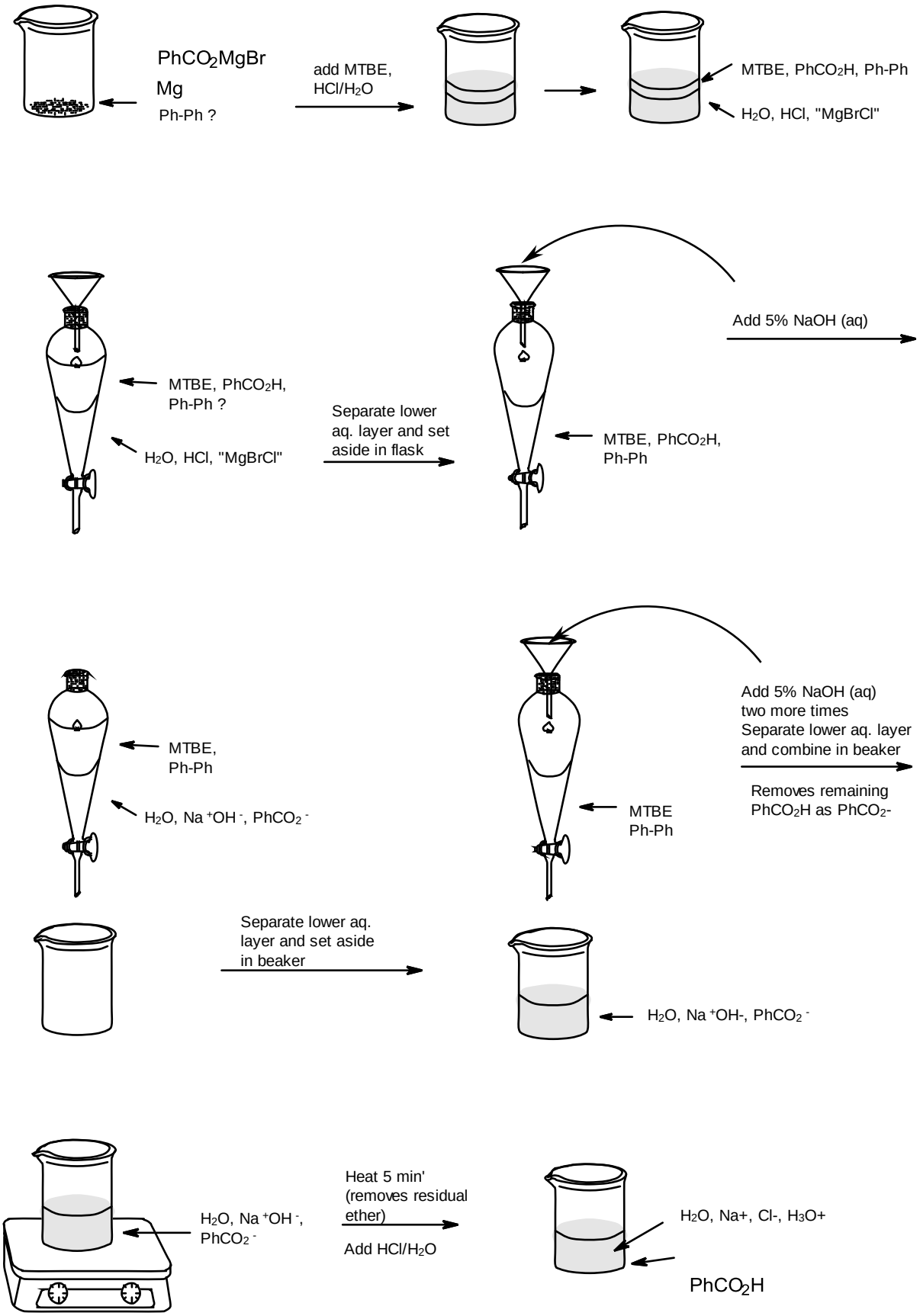
5. Remove the filter paper and crystals from the Buchner funnel. Place both in a clean, dry, labeled, pre-weighed weighing tray until the next lab period.

6. Weigh the dry benzoic acid + filter paper + weighing tray. Place the benzoic acid in a clean, labeled vial. Take a melting point.

   Take an IR of the product using a cast film technique as described in the lab textbook.

Report

See the lab manual sections **Laboratory Reports** and **Synthesis Reports** for the format for submitting your report for this experiment. Include a **Separation Scheme** and marked up literature IR and NMR spectra and your experimental IR spectrum.


PhCO2MgBr
Mg
Ph-Ph ?
add MTBE,
HCl/H2O
MTBE, PhCO2H, Ph-Ph
H2O, HCl, "MgBrCl"
MTBE, PhCO2H,
Ph-Ph ?
H2O, HCl, "MgBrCl"
Separate lower
aq. layer and set
aside in flask
Add 5% NaOH (aq)
MTBE, PhCO2H,
Ph-Ph
MTBE,
Ph-Ph
H2O, Na+OH-, PhCO2-
Separate lower aq.
layer and set aside
in beaker
Add 5% NaOH (aq)
two more times
Separate lower aq. layer
and combine in beaker
Removes remaining
PhCO2H as PhCO2-
MTBE
Ph-Ph
H2O, Na+OH-, PhCO2-
H2O, Na+OH-,
PhCO2-
Heat 5 min'
(removes residual
ether)
Add HCl/H2O
H2O, Na+, Cl-, H3O+
PhCO2H