ORGANIC SYNTHESIS: BENZOIC ACID VIA A GRIGNARD REACTION

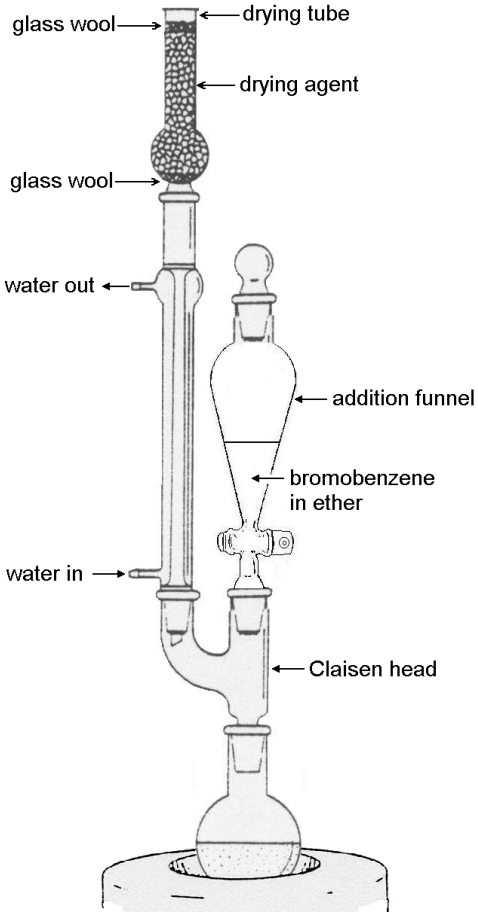
EXPERIMENTAL PROCEDURE **Work in pairs but hand in separate, individual reports.**

- **Diethyl ether is volatile AND highly flammable**
- **MAKE SURE there are NO FLAMES ANYWHERE nearby when using it.**
- **Dry ice is a cryogen. Avoid skin contact as it will cause cold burns.**
- **Pay attention to the position of power cords near hot plates.**
- **Hot stirrers / metal blocks and hot glassware ! Avoid burns!**
- **This reaction should be performed in a fumehood.**

Preparation of Benzoic acid from Bromobenzene via a Grignard Reaction

1) Preparation of Phenylmagnesium Bromide

*In order for this experiment to work, your glassware must be clean and **dry**. If needed wash the* glassware and then **ask your TA** to show you how to ensure it's dry enough to use.



In a fumehood, set-up a dry 100 mL round-bottomed flask in a heating block on a hotplate stirrer **- make sure the heating is turned off** and that the hotplate can be quickly removed if needed by carefully clamping the neck of the flask (so it can be rasied if needed). Add a stirrer bar to the flask.

Weigh out 1.74 g (0.072 g atom) of magnesium. Crush the magnesium in a mortar and pestle to "activate it" (this process provides the clean metallic surfaces necessary to initiate the reaction). Transfer the activated magnesium to the reaction flask and add a **single crystal** of iodine. Assemble the reflux with addition apparatus. Equip the 100mL round bottomed flask with a dry reflux condenser and a dry addition funnel using a Claisen head (see the diagram to the left).

(**If required** (unlikely in the dry air of Calgary), the $CaCl_2$ drying-tube can be fitted onto the top of the condenser. Do not pack the $CaCl_2$ too tightly or you will close off the system and not allow air to escape when the system is heated (a drying tube is required on humid days (or in humid climates) to ensure that water vapour does not interfere with the reaction)).

Make sure to start the gentle flow of cooling water in the condenser and that all the glass joints are well sealed. Introduce a solution of 7.0 mL of bromobenzene (10.4g; 0.066 mole) in 10 mL of anhydrous ether into the addition funnel. The funnel should be kept stoppered when the contents are not being added

to the reaction flask but the stopper must be removed to allow addition of the bromobenzene solution to be made.

While stirring gently, carefully add about 5.0 mL (approx. 1/3) of the bromobenzene / ether solution to the round bottom flask making sure it mixes and warm the flask gently **with your hands (cup the bottom of the round bottom flask in the palm of your hand**. The appearance of cloudiness, with spontaneous bubbling and heat generated by the reaction will indicate the start of the reaction and the formation of the phenylmagnesium bromide. *If the reaction proceeds too vigorously* it should be moderated by momentarily cooling the flask using an ice-bath. However, once the reaction has started *make sure you keep it going*. **DO NOT TURN ON THE HEAT UNTIL ALL THE ETHER SOLUTION HAS BEEN ADDED**.

If you encounter difficulty in initiating the reaction, talk to your TA. They may suggest one of the following measures :

a) Warm the reaction flask using the heating block and then see if boiling continues when the flask (condenser attached) is removed from the heat.

b) Add another iodine crystal (or a few drops of methyl iodide (this forms a Grignard reagent very readily and will expose fresh magnesium)).

c) Start again! Take greater care with respect to the dryness of the apparatus and the seals at the ground glass joints.

Once the reaction is initiated, add a further 20 mL of anhydrous ether to the remaining bromobenzene solution in the **dropping funnel**. Add the rest of this solution to the reaction vessel gradually over 5-10 mins, at a rate sufficient to maintain boiling of the reaction mixture and making sure it mixes but without the reaction getting too vigourous. Once the addition is almost complete or if the reaction seems to be slowing down, starting gentle heating to continue the gentle reflux of solution for 30 minutes until the magnesium has nearly all disintegrated and the solution has acquired a cloudy or brownish appearance.

2) Preparation of Benzoic Acid

- **CAUTION: Exercise caution in handling dry ice.**
- **Contact with the skin can cause severe frostbite or cold burns.**
- **Always use cotton gloves or tongs to handle dry ice.**

Moisture from the atmosphere will condense on dry ice to form a coating of water ice over its surface so it is important to try to keep the dry ice protected from the moisture in the air to avoid side reactions caused by this condensed water. Therefore, collect your 10g of dry ice *just* before you need to use it. If it looks “frosted”, wipe the surface of the dry ice pellets with a clean, dry paper towel to remove any surface frost and then place it in a beaker covered with a watch glass until you are ready to use it.

When the phenylmagnesium bromide has been prepared and the mixture has stopped refluxing, remove the condenser from the flask and then pour the liquid contents of the flask slowly but steadily over approximately 10g of **dry ice** contained in a 200 mL beaker - try to leave as much of the unreacted

magnesium metal behind in the round bottomed flask. Rinse the flask with a small amount of anhydrous ether if needed and add that to the reaction mixture (again without transferring the unreacted magnesium). Cover the reaction mixture with a watch glass and allow it to stand until the excess dry ice has completely sublimed. The Grignard addition compound will appear as a viscous glassy mass. If the mass is too viscous to stir, add an additional 5-10 mL of ether (or more) as needed.

Before starting the work-up, while the reaction mixture is sitting, draw a flow chart that summarises what is happening at each stage of the work-up process and that allows you to track the location of the product and shows how it is purified at each step. Show this to your TA before you start the work-up process.

The following steps are the *work-up*. First, hydrolyse the Grignard addition product by carefully adding the mixture of about 25g of crushed ice (ordinary water ice), stir the mixture. If there is any magnesium in the bottom of the beaker then pour (*i.e.* "decant") the liquid off the solid into another beaker leaving the unreacted magnesium behind. Now **very carefully** add concentrated hydrochloric acid DROPWISE while stirring. Check the pH with blue litmus paper (it will turn red in acid) after you have added 8mL of conc. HCl, if it is not acidic then continue to add more conc. HCl until the solution is acidic to blue litmus paper. At this point any remaining solid material should have dissolved completely, if not, then you may have to add some extra hydrochloric acid (and maybe diethyl ether) to get any remaining solid material to dissolve completely. Stir the mixture until two clear layers appear (add more diethyl ether and acid if needed). Transfer the mixture to a separatory funnel. Remove the lower aqueous layer and discard it. Wash the upper ether layer by adding a mixture of 12.5mL of water and 2.5 mL of a saturated solution of sodium thiosulfate solution, stoppering the funnel and shaking as before. Allow the layers to separate and remove the water layer. If the ether layer still appears dark yellow or brown because iodine is still present repeat the thiosulfate wash process. Extract the ether layer three times with successive 12.5 mL portions of 10% sodium hydroxide solution to remove the benzoic acid. Combine the basic extracts. Once you are sure you have the right layer, discard the ether layer, which contains the by-product biphenyl, into the organic waste container in the fume hood.

Transfer the combined basic extracts into a clean round bottom flask - do not overfill the flask, it should not be more than about half full. Use a rotary evaporator remove the dissolved ether (ether is soluble in water to the extent of 7%) - your TA's will demonstrate the correct use of this invaluable (but expensive) equipment. Unless the ether is removed before the benzoic acid is precipitated, the product may appear as a waxy solid instead of crystals. IF YOU HAVE ANY PROBLEMS WITH THE ROTARY EVAPORATOR AT ANYTIME **ASK YOUR TA.** Carefully remove the flask from the rotary evaporator and precipitate the benzoic acid by carefully adding ~8 mL of concentrated hydrochloric acid (test with litmus paper that the solution is acidic). Collect the precipitated benzoic acid on a Büchner funnel by vacuum filtration. Wash the collected crystals with several portions of *cold* water and allow the crystals to dry thoroughly at room temperature or in a cool oven. When the crystals are dry, weigh the product and calculate the percentage yield.

Determine the melting point of the product and compare to the literature value. Show your TA your product.

CLEAN UP

- Aqueous solutions should be poured into the large white container for aqueous waste.
- Organic waste should be poured into the red container for organic waste in the fume-hood.
- Used pipettes should be rinsed with acetone then put into the special container provided.

REPORT

The report for this experiment is a formal report (*i.e.* no template). **More details on writing formal reports can be found in the introduction to this manual**. Remember that more it not necessarily better. It is important to be accurate and concise rather than verbose and vague. There is a "hard" **5 page maximum** (Arial font 12, 1.5 line spacing as stated in the Chem 353 student laboratory manual) including the answers to the questions. Proper English should be used and it should be written in your own words. A **guide** to the sections you should include is shown below.

1. Title and Date, laboratory partner
2. Introduction: Describe the purpose of the experiment, include balanced equations for the reactions.
3. Procedure
4. Results – g yield, % yield, melting points *etc.*
5. Analysis of product spectra
6. Discussion - (*e.g*. yield, purity, success, sources of error *etc.*)
7. Conclusions - summarise your results and discussion
8. References
9. Questions:

(a) In order to help rationalise the reactivity of compounds containing metals, it can often be useful to visualise those compounds as ionic. Draw an ionic representation of PhMgBr showing all the appropriate formal charges of phenyl magnesium bromide.

(b) Draw a flow chart that represents each the steps in the work up to show how the product is separated from any unwanted materials from the reaction.

(c) Draw the mechanism for the reactions involved in the synthesis **starting from** the reaction of the Grignard reagent, PhMgBr, with carbon dioxide through the work-up to give the desired product, benzoic acid.