



**SIC2019  
SIC2002  
ORGANIC  
CHEMISTRY II**

LIFE IS AN EXPERIMENT  
TEST ALL YOUR HYPOTHESES

Name:

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## Safety in the Second Year Laboratory

Further information in the details of the safety and health practice in the Universiti Malaya can be found at:



Office of Safety and  
Health, Universiti Malaya



Universiti Malaya  
Safety Handbook



Manual Keselamatan dan  
Kesihatan Pekerjaan,  
Universiti Malaya

The University has a statutory obligation to comply with the safety requirements and you, as a student, have a duty to abide by the regulations. The following notes are to guide you in good laboratory practice and to familiarize yourself with the safety aspects of your laboratory work.

### **Emergency Telephone Numbers:**

- National Emergency Number 999 (Mobile phone, dial 112)
- Universiti Malaya Security Office +603 7967 7070
- Universiti Malaya Medical Centre (UMMC) +603 7949 2892  
Emergency Department
- Universiti Malaya Students' Health Clinic +603 7967 6445
- Occupational Safety & Health and Environment +603 7967 6597  
(OSHE)
- Department of Chemistry Office +603 7967 4204
- Pantai Fire Station (Jalan Pantai Baru) +603 2282 4444
- Pantai Police Station (Jalan Pantai Baru) +603 2282 2222

(The numbers given above are working telephone numbers, as of 5<sup>th</sup> October 2022)

Safety is the primary concern in any chemical laboratory. Chemicals, particularly organic chemicals, are almost all potentially hazardous. Fortunately, with sensible and correct

precautions, the risks can be minimized if basic safety practices are followed. The responsibility for laboratory safety lies with everyone working in the laboratory. Sensible laboratory conduct does not mean memorizing a list of rules! The true test is the actual conduct in the laboratory and safety rules apply to all laboratory activities. Individual safety is affected by the action of fellow workers in the laboratory. Therefore, it is in everyone's best interest to follow safety work practices.

### **General Safety Rules for the Undergraduate Laboratories**

The guidelines below are recommended for working safely in the laboratory.

- No work is to be carried out unless a member of staff is present.
- Plan your work. Follow instructions. If you do not know how to do the experiment safely, ask the lecturer or demonstrator.
- Know the location of all exits for the laboratory and the building. There are two exits in the first year organic lab.
- Know the location of the alarm and fire extinguishers and how to operate them. There are two fire extinguishers located at the two sides in the lab.
- Know the location and use of safety showers, eye-washers and safety aid boxes. The safety shower and eye washer are located right next to the exit of the Second Year Organic Lab.



The fire extinguisher, eye wash and safety shower in the Second Year Organic Laboratory

- Know the location of the nearest telephone that can be used during an emergency.





- All persons in laboratories (whether or not they are actually doing practical work) must wear safety spectacles or goggles and laboratory coats. You might find them a nuisance to wear, but your eyes are very precious. You are not allowed to wear contact lenses in the laboratory. Hair should be secured so that it does not hang below the neck. Other articles of clothing that may become entangled should also be secured. It is important to wear suitable clothing, and your footwear must incorporate flat heels, slip-resistant soles and uppers fully enclosing the foot.
- No food, drink (including drinking water!), cigarettes and cosmetics are allowed to be taken into the laboratory or storage place for chemicals.
- Do not smell or taste chemicals.
- Know the potential hazards of the materials and equipment with which you will work. The preparation for an experiment involves the study of the respective material safety data sheets for **all** chemicals used in that experiment. Refer to the chemicals' Material Safety Data Sheet (MSDS) before usage.
- Do not make skin contact with any substances. Use gloves where necessary, always remembering that they are semi-permeable. Gloves typically only provide a short time protection; when you notice the glove to get wet, remove it asap and replace with a new one. This particularly applies for the common single-use protective gloves.
- Experiments must be conducted on clean working surfaces; any spillage should be cleaned immediately. A high standard of tidiness should be maintained at all times. Contaminated surfaces and equipment must be cleaned as soon as it is practicable after use. The equipment should then be put away. Do not clutter bench space with unused equipment and bottles of chemicals.
- Waste should be disposed off in the appropriate containers. Organic chemicals should be disposed in designated waste bottles. Chemical wastes are segregated into three (3) groups and stored separately; halogenated wastes (examples are chloroform, dichloromethane), non-halogenated wastes (examples are acetone, alcohol, toluene, xylene) and other waste, such as mercury (broken thermometer).
- Bags and other personal items should be placed in the lockers provided outside the laboratory and not left along corridors or on benches.
- All accidents and dangerous occurrence must be reported immediately to the lecturer in charge or the demonstrator or the laboratory assistant. The first aid box is located

inside the preparation room of the laboratory. The accident book is also kept in the preparation room; the laboratory assistant must file out a report for all incidents.

- It is important to ensure that hands are washed, and all protective clothing removed before leaving the laboratory.
- Do not wear laboratory coats, gloves or other personal protective clothing out of the laboratory and in non-laboratory areas. These clothing may have become contaminated.

### **Additional Guidelines**

Remember that in a laboratory you have fellow students around you. They do not know what you are doing, but they hope and expect that what you are doing is sensible and safe. Always think carefully about what you are about to do.

- Know the lecturer in charge, the demonstrator and the laboratory assistants of the laboratory.
- Undergraduates are not allowed to work or even be in any of the teaching laboratories at any time outside of the specified laboratory hours, unless they have explicit permission from the lecturer in charge. This includes times before and after class, and the lunch break.
- Students should come to the laboratory on time and be prepared by studying the experiment. Therefore, plan your activities before you come to the laboratory.
- Write everything you do, and observations in your notebook so that you can trace your action and make corrections if necessary. Please designate one notebook for this purpose and use it for the whole session / cycle.
- Do not use cracked or broken glassware. Check glassware before using it.
- Never use open flames, unless instructed by the lecturer in charge. If flames are permitted, plan your experiments so that you never leave your flame unattended. There are other sources of heat such as steam baths and hot plates.
- Handle all chemicals with care and read labels before attempting to get them.
- Use a spatula to get solid chemicals. Never using your fingers.
- Be careful not to contaminate reagents with your spatulas or droppers. Do not take more than needed. If you take too much of a chemical or reagent, give it to a fellow



student – but **do not return it to the bottle.**

- Do not wander off with the only bottle of reagent that everyone needs; keep it in its assigned location.
- Do not pipette by mouth. Use only mechanical pipetting devices.
- Never look directly into the mouth of a flask containing a reaction mixture.
- Never point a test tube or reaction flask towards yourself or your neighbour.
- When using a separating funnel, vent frequently and remove the stopper immediately upon setting it upright for separation.
- Never use a thermometer as a stirrer! If a mercury thermometer breaks, immediately contact the lecturer in charge, the demonstrator or laboratory assistant.
- Turn off water, burners or electrical equipment when not in use.
- Wash your glassware at the end of the laboratory session. You will have clean and dry glassware ready to be used for the next laboratory class.
- Make sure glassware or equipment is put away in the correct locker – your personal locker or the common locker.
- Clean your work area and equipment used before leaving the laboratory.

## Chemistry Laboratory Safety Agreement

In the interest of safety and accident-prevention, there are regulations to be followed by all credit students in designated Chemistry Laboratory at Department of Chemistry, Faculty of Science, University of Malaya. Faculty and staff members are authorized to deny the use of any laboratory to students who do not adhere to the regulations mentioned below or in instances when the safety of any of the student, staff or faculty member in the laboratory might be jeopardized.

Regulations for all Chemistry Laboratories are as follows:

1. Proper attire must be worn at all times in all laboratories, including shoes that completely cover the foot (no high-heeled shoes), and a shirt that covers the entire upper torso, including the stomach and the back. Lab coats must be worn in the laboratory at all time. Long hair must be tied back. No loose or baggy clothes and dangling jewelry is allowed.
2. Safety eyewear must be worn at all times during laboratory sessions.
3. Food, drinks, chewing gum, tobacco products, and applying cosmetics are prohibited in the laboratories. Hands, pencils, pens, etc. must be kept away from the eyes, nose, and mouth in order to avoid contamination.
4. Fume hood sashes are not to be opened beyond the 18'' mark when in use. (Never put your head into the hood.)
5. Be organized. Maintain a clean, open work area free of anything except materials directly required for the exercise. Keep laboratory material/equipment away from edges of work surfaces and electrical cords from hanging below the surface of tables.
6. Equipment and/or chemicals should never be taken out of the lab unless authorized by Instructor or laboratory staff.
7. Many of the lab activities have students moving around the lab or involve moving objects. Be alert and aware of what's going on around you.
8. Be familiar with the location and the use of the following in your laboratory: e.g. broken glass receptacle, first-aid kit, emergency gas shut-off valves, closest fire alarm, fire extinguisher, eye wash, safety shower, and emergency exits and routes.
9. It is of utmost importance to know the rooms that are off-limits to the students. The students should not enter those prohibited areas.
10. Be prepared. Study the assigned experiment before you come to lab. Being familiar with the lab exercise to prevent confusion and accidents. No unauthorized experiments are to be performed. Students must follow the procedural instructions in the lab handout/manual unless modifications to the procedures have been announced by the laboratory professor, in which case the student must follow the professor's procedural instructions.
11. NEVER TOUCH ANY FORM OF BROKEN GLASS. Broken glass should be disposed of only by laboratory staff.
12. Unused reagents should not be returned to the reagent stock bottle. One should make sure to take only what is actually needed out of the reagent bottle. Reagents must not be contaminated.





13. CONTACT LENSES should not be worn in the lab as chemicals can get between the eye and the lens.
14. Lab experiments have been designed to minimize unnecessary exposure to any hazardous substances; however, it is not advisable for pregnant women or those with certain medical conditions to be exposed to any chemicals. We cannot insure that a pregnant student will not be exposed to chemicals that might be unhealthy for her or her fetus. In addition, we cannot know the level of exposure, the length of exposure or the number of encounters that might occur with any chemical during a semester. By maintaining the safety rules, we expect that all students, including a pregnant student, should be able to carry out lab procedures safely. However, it is the Department's professional advice that pregnant students should be advised NOT to take a lab course unless she is willing to understand and assume the risks. She should certainly be seeking and following proper medical advice from her physician.
15. If you are pregnant, or you suspect, should become, or plan to become pregnant during the semester, or have any medical condition or concern, including but not limited to the following, immunocompromised system, seizures, epilepsy, severe allergies, it is your, the student's, responsibility to consult with your medical care provider regarding any medical issue associated with taking this lab. Students are encouraged to provide their physician with a list of the chemicals that they might be exposed to while in lab. They should also check the MSDS sheets to be aware of the hazards of the chemicals.

**SAFETY INFORMATION ACKNOWLEDGEMENT  
INFORMED CONSENT****(Sign and keep for your records)**

I acknowledge receipt and that I have read and understand the lab safety regulations and that I received a briefing on these regulations from my laboratory Instructor/Lecturer. I also acknowledge that I was given the opportunity to ask any relevant questions during the safety briefing. I understand that there may be inherent risks and possible hazardous exposure with laboratory experiments depending on one's medical condition. If pregnant, or you suspect, should become, or plan to become pregnant during the semester, or have a medical condition that may be affected by my participation in this laboratory session, I understand that it is my responsibility to discuss any and all issues with my medical care provider.

Further, I accept any and all risk associated with the use of the Chemistry laboratory(s) and the equipment contained therein. I also understand that I am responsible for my personal property at all times. By signing this agreement I fully understand and consider it my responsibility to comply with the safety regulations outlined above. I hereby agree for myself, my family, successors, and assigns to hold harmless the University of Malaya (UM), Department of Chemistry of the University of Malaya, Faculty of Science of the University of Malaya, Lecturers, Laboratory Staff and assigns from any and all claims, causes of action, suits, liabilities, damages, losses, demands, costs, expenses or judgments for damages or injuries to myself or others arising from my participation in the lab, whether or not I consulted a medical provider as delineated above.

Signature of the student: \_\_\_\_\_ Course: \_\_\_\_\_

Name: \_\_\_\_\_ Lecturer: \_\_\_\_\_

Matric Number: \_\_\_\_\_ Session: \_\_\_\_\_

IC number: \_\_\_\_\_ Semester: \_\_\_\_\_

Date: \_\_\_\_\_

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Provide the name and telephone number of two "Emergency Contacts" that can be reached during lab class times. Please note that your medical or physical condition may be released to the contact person at the time of the emergency call.

Indicate the relationship to the person and also the telephone location (office, home or cellular). Please print clearly.

\_\_\_\_\_  
Emergency Contact (Name)\_\_\_\_\_  
Relationship\_\_\_\_\_  
Phone\_\_\_\_\_  
Emergency Contact (Name)\_\_\_\_\_  
Relationship\_\_\_\_\_  
Phone

**SAFETY INFORMATION ACKNOWLEDGEMENT  
INFORMED CONSENT**

**(Return this signed page to your lecturer)**

I acknowledge receipt and that I have read and understand the lab safety regulations and that I received a briefing on these regulations from my laboratory Instructor/Lecturer. I also acknowledge that I was given the opportunity to ask any relevant questions during the safety briefing. I understand that there may be inherent risks and possible hazardous exposure with laboratory experiments depending on one's medical condition. If pregnant, or you suspect, should become, or plan to become pregnant during the semester, or have a medical condition that may be affected by my participation in this laboratory session, I understand that it is my responsibility to discuss any and all issues with my medical care provider.

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Signature of the student: \_\_\_\_\_ Course: \_\_\_\_\_

Name: \_\_\_\_\_ Lecturer: \_\_\_\_\_

Matric Number: \_\_\_\_\_ Session: \_\_\_\_\_

IC number: \_\_\_\_\_ Semester: \_\_\_\_\_

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Relationship

\_\_\_\_\_  
Phone

\_\_\_\_\_  
Emergency Contact (Name)

\_\_\_\_\_  
Relationship

\_\_\_\_\_  
Phone

### Experiments' Planning

The laboratory component is an essential part of SIC2002 course. Attendance at all laboratory classes is compulsory. Students are also expected to be prepared. Students may be prohibited from doing an experiment if we believe that they are unprepared.

The laboratory component of the course is composed of seven (7) experiments. Below is the planning of the experiments sequence to be filled in after discussion with the lecturer in charge.

Laboratory Class	Date	Experiment	Remarks
1			
2			
3			
4			
5			
6			
7			

## **The Laboratory Notebook**

A lab notebook is used to record all the work carried out in the laboratory and the experimental data. In industry or in academic research, it is an important legal document that can be used to provide evidence regarding the discoverer and date of discovery of new chemicals or processes.

In the undergraduate laboratory course, it is important to develop the skill of recording a good lab notebook. The records will be needed to generate lab reports at some point in the course, and the keeping of the lab notebook will be assessed regularly by your lecturer.

Marks will be awarded for continued good use and practices of the notebook throughout the laboratory classes.

All relevant aspects of an experiment should be recorded, together with the order in which steps were carried out. All observations should be noted, in principle even those that at first sight appear unimportant.

### **General Guidelines**

1. Use ballpoint pen and press hard if you are using duplicate pages.
2. Write on one side only.
3. Do not erase or use whiteout. If you make a mistake, draw a single line through the error (strikethrough) and write the correct entry on the top or side of it.
4. Do not remove an original page. If the entire page is incorrect, draw a single diagonal line through the page and state the reason for this line.
5. Record all data and results (with units) directly into your notebook.  
DO NOT record data on scrap paper, your hand etc. to be transferred later. A laboratory notebook does not need to look nice, but must be logically ordered and reasonable readable.
6. Start a new page for each new experiment.
7. Write the title of the experiment, date and your name at the top of each page.
8. NEVER skip a space for later additions.
9. Be neat and thorough! Someone should be able to pick up your notebook twenty years from now and be able to repeat your experiments.



At the beginning of each experiment, record:

- The date
- Structural formula (abbreviated, if necessary) and all reagents in order of addition
- Molecular formula and molecular weights, preferably under the relevant structural formula
- Literature references for the procedure (or for analogous preparations)
- Mass (and number of moles) of each compound used
- List of apparatus (with sketches in unusual cases)
- The purity of all compounds and solvents
- Simplified procedures from your reading of lab manual, it can be a flow chart or schematic diagram, to your preference, which transforms the lengthy and wordy procedures into simple yet informative procedures at a glance.

**Components:** (this is to be discussed with the lecturer in charge)

A. Pre-Lab – a detailed plan of the work that you will be doing

1. Brief statement of purpose.
2. A paragraph discussion of the safety and environmental issues (e.g., waste generation, impact on earth, etc.)
3. Step-by-step procedure in your own words. Be **concise** and **complete**, but DO NOT copy the lab manual. Use diagrams and sketches when necessary. Reference all sources of information. Do NOT mix your preparation instructions with the records that you record during the operation of the experiment.

B. Factual Record – what to record

1. Keep a running account of all procedures carried out and observations made during experimental work.
2. Record observations such as physical appearance, color, (odor), and physical properties.

3. Sketch apparatuses and label parts.
4. Use a table to record all information about reactants.
5. Record all data and results, including the crude yield of products and mixtures. Use tables when possible.
6. For calculations, show the formula and a sample calculation. Examples are yields and percentage yield. If the calculation is repeated, use a table to report your results.
7. Attach all spectra to your notebook, label the axes, and reference the spectra in the procedure section.
8. Do NOT place TLCs into your lab notebook. The chemicals can contaminate your lab notes and even damage your lab notes over time. If you want to keep record of TLC, sketch it instead.

C. Data Analysis/Conclusions:

1. Examine and discuss your experimental results.
2. Summarize the key results and provide a conclusion. Describe any difficulties you came across. Discuss which results are poor and provide explanations. Provide suggestions for improvement.
3. Include literature references, preferably, a variety and not limited to online resources.

### **A Good Lab Notebook Organization**

The first page of the lab notebook should be used as a cover page and should include name, course and email address (in case of loss). The second page should be left blank to be used as a content's page. This page should be completed as the lab course progresses. Begin to write experimental data into the lab notebook from the third page onwards. A ball point pen is better than a fountain pen as it is less likely to smudge if water is splashed on it.

Lab notebooks need to be looked after carefully. Do not soil them with chemicals as they may transfer hazardous substances out of the laboratory.

### **What to Include**

The lab notebook is not a copy of the contents of your lab manual. It should expand upon the

instructions given in the lab manual. It is important to include the name(s) of any lab partners or group members and the date so that work can be monitored.

The aim of the experiment should concisely explain the task for that lab session. E.g.: “To synthesize xxxx.” If it is a synthesis experiment, a correct chemical equation for the reaction should be provided.

The experimental plan explains precisely what is to be done in that session. In cases that detailed experimental plans are provided in the lab manual and the lab notebook can state that these were followed directly. If the lab manual provides only an outline method, a more detailed method should be prepared in the lab notebook before entry to the lab session so that work can begin immediately. For experiments that require the development of a method before the lab session begins, editing may be needed during the session if changes are made. These changes should be clearly noted. When writing a method, use clear language and simple direct statements in a numbered list so that instructions can be followed easily in the laboratory. Do not use personal pronouns (such as “I” or “we”). The experimental plan section should also be used to note any special safety instruction, or to write a risk assessment for the chemical used. A diagram should be used to illustrate novel or unfamiliar apparatus and should show the cross-section of the equipment. Keep it simple. Label where appropriate. Do not use diagrams for common apparatus or procedures.

Observations, measurements and data should be recorded immediately in full (with units, where relevant). Take the lab notebook to the balances to record masses. Do not use scraps of paper and then transfer the data to the lab notebook later. Record all observations, measurements and data honestly. The lab notebook is a record of exactly what was observed and measured, not what is predicted to happen or be observed. Do not copy data from someone else after the experiment. If data are to be shared with a partner or group, clearly flag the observations and data as belonging to someone else. Data should be recorded in a table, where possible, and the table should be written in vertical columns using headers and units at the top of each column. Individual cells in the table should only contain a number; units only appear in headers.

The discussion session needs to include clear presentation of any observation or calculations

during the experiment. Comments should be made about how the results relate to any hypotheses or how they answer a question posed in the experimental aims.

The conclusion should state the experimental findings and should include any error analysis and any notes about unusual findings or improvements that could be made if the experiment were to be performed again.

### **Lab Notebook Checklist**

The list is not intended to be complete, but it is a very good place to start.

- Experiment title and number
  - The date
  - The name(s) of any laboratory partner(s)
  - Aim of the experiment
  - Chemical equations, where required
  - Experimental plan and explanation of any experimental decisions
  - Diagram or equipment (if required)
  - Observations and comments on the chemistry
  - Tables of raw and processed data (where required)
  - Conclusion
-

**WRITING A REPORT**

A good clear report is easy to produce if one has a comprehensive description of the work including all relevant data on the starting materials and products as well as all the experimental details in one's laboratory notebook.

The experimental procedure should be described concisely with neat formula and relevant references.

A report on a preparative experiment should have suitable title. This should include the name of the product, the names of the experiments, and, where relevant, the date. Examples are: "Isolation of cyclopenten-3-one from ....." and "Synthesis of cyclopenten-3-one from ....."

The report may be arranged in the following sections:

- (a) Method: Here the overall transformation carried out in each step of a multi-stage synthesis is described.

e.g. "Pinacol is prepared by the reductive dimerization of acetone"

"Endo-bicyclo[2,2,1]hept-2-ene-5-carboxylic acid is formed by the cycloaddition (Diels-Alder Reaction) of cyclopentadiene and acrylic acid".

- (b) Reaction scheme: This shows the transformation of starting materials to products by means of formulae (configuration or conformation if necessary). Reaction conditions (reagents, solvents, catalysts, temperature, etc.) are indicated in abbreviated form above and below the arrows in the usual way. The molecular formulae and molecular weights can be appended to the relevant structures. All structures should be numbered. In general, diagrams showing mechanisms are presented separately.

- (c) Experimental section: The description of the experiments (past tense, third person, passive voice) should be sufficiently detailed to permit the repetition of the reaction without further consultation of the literature. The report should be sufficiently complete for it to be used in preparing a paper for publication. The weights of all compounds (and the number of moles), the purity of starting materials and solvents (these data on substances used repeatedly in a series of experiments can be collected and placed at the beginning of



the experimental section, if desired), and all relevant reaction conditions (temperature, time, pressure, etc.) should be quoted, as well as the work-up and purification procedures. One should also provide information about the apparatus used, any peculiarities observed, and simple procedures for the following the course of the reaction.

In the text, names of all chemicals should be written out in full: formulae are used only in reaction schemes. On the other hand, abbreviated or trivial names (with the structure numbers used in the reaction schemes) make it easier to follow descriptions when long and complex names are involved.

The yield is quoted (not the average yield over several preparations) with an indication of purity ("crude", "after recrystallisation", etc.), as well as the literature yield with reference (where relevant).

Finally, the physical data used to characterize the compound should be reported (again with literature references): mp, bp, n<sub>D</sub> (with temperature superscript), R<sub>f</sub> (with details of TLC system, IR, UV, NMR, MS, etc.

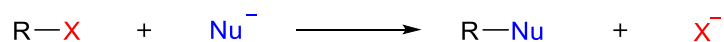
Some typical expressions and abbreviations

- bright yellow crystals (11 mg, 78%)
- tetramethylsuccinic anhydride (33.8 g, 0.217 mol)
- nitrile (1.15 g, 8.5 mmol)
- a solid residue (68.9 g) remained, and was recrystallized from ... (ca. 250 mL) with charcoal decolorization
- absolute ethanol (2 mL)
- poured onto ice (1.5 kg)
- in sodium hydroxide solution (1 N)
- with methyllithium in ether (1.49 M, 16 mL)

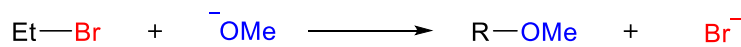
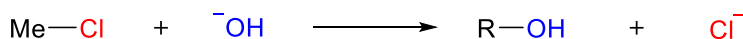
## EXPERIMENT 1 – S<sub>N</sub>2 REACTION

### PREPARATION OF *n*-BUTYL PHENYL ETHER

Alkyl halides can undergo a general reaction as indicated in the following:



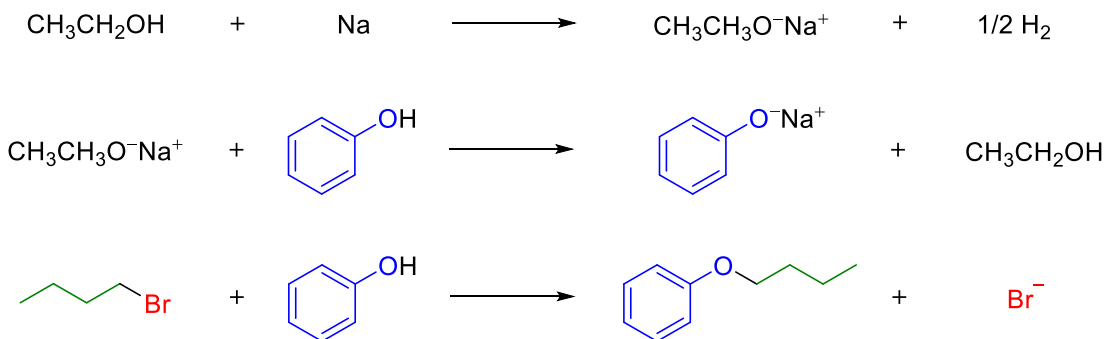
Two examples are shown as follows:



In this reaction, a species having an unshared pair of electrons (nucleophile), reacts with an alkyl halide to replace the substituent, a halogen. Substitution reaction has occurred and the halogen leaves as a halide ion. This reaction is called a nucleophilic substitution reaction.

The carbon-halogen bond may be cleaved before or during the formation of a new bond between the carbon and the nucleophile. This depends on the structure of the alkyl halide involved in the reaction

Primary alkyl halides undergo bimolecular nucleophilic substitution reaction, S<sub>N</sub>2. In this experiment, *n*-butyl phenyl ether is prepared *via* S<sub>N</sub>2 reaction, from a reaction between *n*-butyl bromide with a phenoxide ion. As phenol is more acidic than ethanol (or water), it is added to sodium ethoxide in absolute ethanol, and the resulting phenoxide ion formed reacts with the alkyl halide.



The most important points about  $S_N2$  reactions:

- A bond forms at carbon and a bond breaks on the same carbon.
- It proceeds *via* a backside attack of the nucleophile on the alkyl halide, the “big barrier” is “steric hindrance”. The rate decreases as the alkyl halide goes from methyl to primary to secondary to tertiary
- $S_N2$  reactions do not proceed at all with tertiary alkyl halides OR with alkenyl or alkynyl halides (i.e. where the halogen is attached directly to a C-C double or triple bond).

### APPARATUS

Two-neck round bottom flask, 250 mL (B14/B19 and B19/B24)

Reduction adapters B19/B24

Water-condenser

Drying tube (cotton and  $\text{CaCl}_2$ )

Separating funnel

### CHEMICALS

1.9 g sodium

Absolute ethanol

7.8 g phenol

*n*-butyl bromide (13 mL, ~17 g)

### PROCEDURE

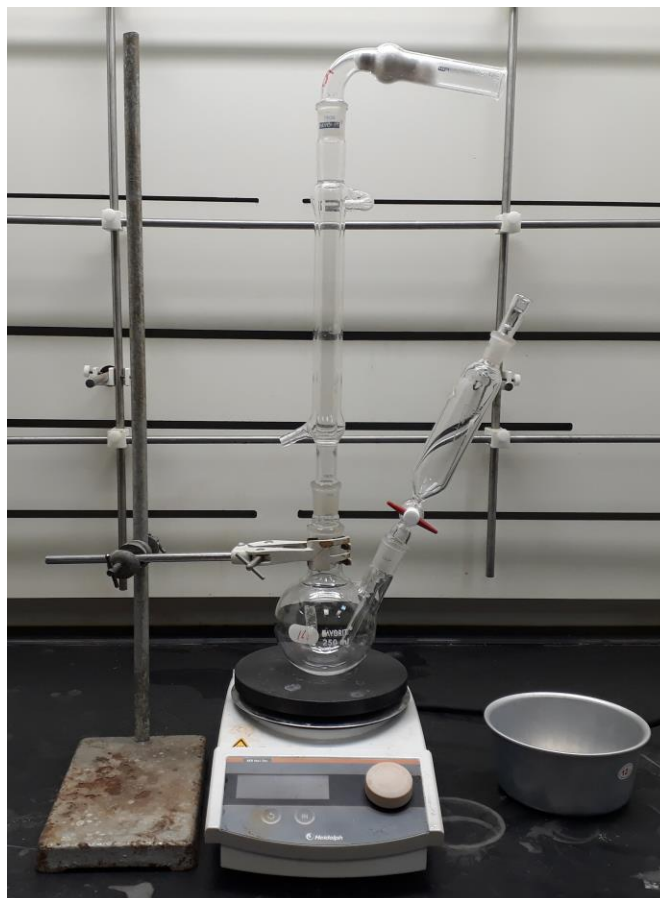
All apparatus must be **dried**. Prepare the apparatus as depicted in **Figure 1**, and add 44 mL of absolute ethanol. Cut 1.9 g sodium (Note 1) into 3 or 4 pieces, and add all the pieces into the reaction flask. Cool the flask in water bath to make sure the ethanol is refluxed slowly (if required). After all the sodium has dissolved, add 7.8 g phenol (Note 2) in absolute ethanol (10 mL) into the reaction flask and then mix the mixture thoroughly. Add *n*-butyl bromide *via* a dropper funnel within 1 minute and reflux the mixture in a water bath for 15 minutes. After the reflux, a distillation apparatus is set up to distill excess EtOH in the mixture (*ca.* 50 mL). After the distillation, cool the reaction mixture and add ~20 mL  $\text{H}_2\text{O}$  into the mixture (Note 3). Transfer the mixture into a separating funnel. Wash the organic layer with 10% NaOH solution (2 x 5 mL, do not shake too strongly as emulsion may be formed), followed by 10%  $\text{H}_2\text{SO}_4$  solution (2 x 5 mL), and finally  $\text{H}_2\text{O}$ . Transfer the organic layer into a dry conical flask (50 mL). Add anhydrous  $\text{MgSO}_4$  to dry the organic layer (Note 3). Filter the organic layer directly into a pear-shaped flask. Finally, distill the organic layer *via* air-bath method. State the boiling point and weight of the *n*-butyl phenyl ether obtained.

**NOTE**

1. Precautions must be taken when handling sodium. Contact with sodium metal might cause burn on the human skin. When handling sodium metal, avoid all contact with water. Note that sodium can be replaced by KOH pellets (4.9 g). Weigh the hygroscopic KOH pellets quickly.
2. Phenol is a highly corrosive compound. Beware of accidental exposure on your skin.
3. If time does not permit you to continue with the experiment, you may stop at this step.

**POST-LAB QUESTIONS**

1. Provide the reason for distilling excess EtOH (*ca.* 50 mL) from the reaction mixture after the reflux process.
2. Provide the expected product when (*R*)-2-bromobutane reacts with the phenoxide ion *via* S<sub>N</sub>2 reaction. Show the stereochemistry clearly by drawing the structure of the starting material and product.

**Figure 1**

**EXPERIMENT 1****Title:****Objective:****Experimental:**

i) Reaction scheme:

ii) Calculation of limiting reagent:

Calculation of the number of mole of reactants:

$$\text{Number of mole of reactant} = \frac{\text{Mass of reactant}}{\text{Molar mass of reactant}}$$



Reactant	Mass (g)	Molecular weight (g/mole)	Mole
<i>n</i> -butyl bromide			
Phenol			
Sodium			
<i>n</i> -butyl phenyl ether			

Theoretical yield of *n*-butyl phenyl ether:

**Results:**i) Mass of *n*-butyl phenyl ether (crude product) before air-bath distillation

Parameter	Unit (g)
Mass of pear-shaped flask	
Mass of pear-shaped flask + <i>n</i> -butyl phenyl ether (crude product)	
Mass of <i>n</i> -butyl phenyl ether (crude product)	

ii) Mass of *n*-butyl phenyl ether after air-bath distillation:

Parameter	Unit (g)
Mass of pear-shaped flask	
Mass of pear-shaped flask + <i>n</i> -butyl phenyl ether	
Mass of <i>n</i> -butyl phenyl ether	

Boiling point of *n*-butyl phenyl ether: \_\_\_\_\_Volume of *n*-butyl phenyl ether: \_\_\_\_\_Density of *n*-butyl phenyl ether = 
$$\frac{\text{Mass of } n\text{-butyl phenyl ether}}{\text{Volume of } n\text{-butyl phenyl ether}}$$

Percentage yield of n-butyl phenyl ether =  $\frac{\text{Experimental yield of } n\text{-butyl phenyl ether}}{\text{Theoretical yield of } n\text{-butyl phenyl ether}} \times 100$

**Discussion:**

Reaction mechanism:

**Suggestion for improvement:**

**Precaution step:**

**Conclusion:**

**References:**

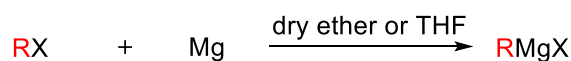




## EXPERIMENT 2 – GRIGNARD REACTION

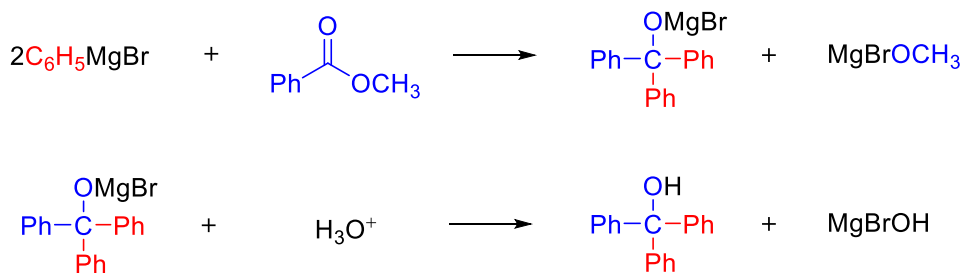
### PREPARATION OF TRIPHENYLCARBINOL

An example of a class of reaction that involves a formation of a new carbon-carbon bond in the carbon skeleton of a molecule is the Grignard reaction. In 1912, François Auguste Victor Grignard (University of Lyon, France) was awarded the Nobel Prize in Chemistry for the discovery of the Grignard reaction. The Grignard reaction is typical class of organometallic chemical reaction, in which, a Grignard reagent acts as a source of nucleophilic carbon, reacting with a relatively electron deficient or electropositive carbon, typically an aldehyde, ketone, or organic ester. In general, Grignard reagent is prepared by reacting an organic halide with magnesium metal in dry ether or tetrahydrofuran (THF).



A Grignard reagent has a formula  $\text{RMgX}$  where X is a halogen, and R is an alkyl or aryl group. Since the Grignard reagent is very reactive, it will also attack any of a large variety of acidic or electropositive reagents. The Grignard reaction involves a nucleophilic attack of a carbanion (the Grignard reagent) on a carbonyl carbon. The  $\text{C}=\text{O}$   $\pi$ -bond is broken and a new  $\text{C}-\text{C}$  bond is formed between the Grignard reagent and the carbonyl carbon. Upon hydrolysis, an alcohol is isolated as the product.

This experiment aims to prepare triphenylcarbinol *via* a Grignard reaction by reacting methylbenzoate with phenylmagnesium bromide as shown in the scheme below



**PROCEDURE****Part A: Preparation of Grignard Reagent**

Placed about 1.4 g of Mg turnings and sodium-dried ether (enough to cover the Mg turnings, ~10 mL) in a dry 250 mL two-neck flask fitted with a 50 mL dropping funnel and a reflux condenser (all apparatus must be completely dry). Place a drying tube filled with  $\text{CaCl}_2$  at the top of the condenser. This is to prevent the entrance of moisture from the condenser and the dropping funnel during the addition.

Into the dropping funnel, place a mixture of bromobenzene (6.2 mL, 9.2 g) in dry ether (30 mL). Run in a small amount of the mixture of bromobenzene in ether (about 5 mL) slowly into the reaction flask and shake the flask gently. Add one or two iodine crystal as catalyst to initiate the reaction. If the reaction does not start after 2-3 minute (iodine color disappears, cloudy solution is formed, and ether solution start to boil) warm the reaction flask gently (use water bath) until the reaction start on its own, then remove the water bath (if the reaction still does not start, use ultrasonic or add 1 mL of Grignard reagent prepared by lab assistant). When the reaction has started (**not before**), add the rest of the mixture of bromobenzene in dry ether into the reaction vessel at such a rate as to cause refluxing (cool in ice-bath if the reflux becomes too vigorous). When the addition is completed, continue refluxing the solution on water bath for another 15 minute to ensure that the reaction is complete. At this point, there should not be any Mg left. Cool the reaction mixture to room temperature.

**Part B: Grignard Reaction**

To the Grignard solution, 3.5 g (3.2 mL) of methyl benzoate in 10 mL dry ether is added (via the 50 mL dropping funnel) at such a rate that the mixture refluxes gently (within 20 minute). From time to time shake the flask gently to ensure the reaction mixture mix thoroughly. After the addition is completed, the mixture is refluxed for about 10-15 min on a water bath. The reaction mixture is cooled in an ice bath and then poured slowly, with constant stirring, into a 600 mL beaker contains mixture of 75 g of cracked ice and 30 mL 10% aqueous sulfuric acid. The mixture is stirred until all the solid has dissolved. If necessary, additional ether may be added if the amount present is insufficient to dissolve all the product. When the solids have completely dissolved, the ether layer is transferred into separating funnel. Remove the aqueous layer and

wash the organic layer successively with 15 mL 10% aqueous  $\text{H}_2\text{SO}_4$ , 12 mL water, and finally with 1 g sodium bisulfite in 12 mL water. Transfer the organic layer into a dry conical flask and add anhydrous  $\text{Na}_2\text{SO}_4$  to dry the organic layer. Filter the dried organic layer into a dry conical flask and add 15 mL petroleum ether (60-80 °C) to the solution. Concentrate the solution gently on steam bath until triphenylcarbinol precipitate out. Leave the mixture to cool to room temperature and then place the flask into an ice-bath to maximize the precipitation of the triphenylcarbinol solid. Recrystallize the crude triphenylcarbinol solid with methylated spirits (4 mL of solvent per gram of solid) and collect the recrystallized triphenylcarbinol with suction filtration (wash with cold methylated spirits). Weight the dried crystals, take the melting point, and calculate the total yield of triphenylcarbinol obtained.

### POST-LAB QUESTIONS:

1. Why must all the apparatus used in the reaction be completely dry?
2. Compare the molar quantities of magnesium, bromobenzene, and methyl benzoate used and explain the sense to the specified reactant ratios.
3. How does using ether solvent help decrease the formation of the by-products resulting from reaction with oxygen and carbon dioxide of the atmosphere?
4.  $\text{NaHSO}_3$  solution is used in the work-up step to remove iodine used as catalyst early in the reaction? Provide the equation for the reaction between iodine and  $\text{NaHSO}_3$ .

### REFERENCES

1. *Techniques & Experiments for Organic Chemistry*, Ault, Addison, 6th Edition, University Science Books, 1997
2. W. E. Bachmann and H. P. Hetzner, *Organic Syntheses, CV 3*, 839
3. Org. Syn. Coll. Vol. 3, 841
4. Operational Organic Chemistry: A Problem-Solving Approach to the Laboratory Course, John W. Lehman, Prentice Hall; 3<sup>rd</sup> edition, 1998

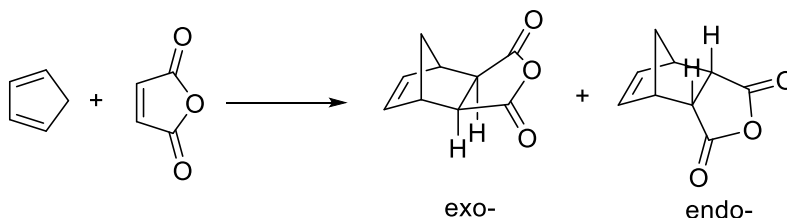
## EXPERIMENT 3-DIELS-ALDER REACTION

### BACKGROUND

The formation of new carbon-carbon bonds is one of the most important aspects of synthetic organic chemistry. Many reactions, such as the Grignard reaction and the use of acetylide ions in  $S_N2$  reactions, have been developed with this one goal in mind. One problem associated with most of these C—C bond-forming reactions is the necessity for exotic conditions — the Grignard reaction requires completely water-free conditions and acetylide ions must be generated in liquid ammonia solution.

When a synthetic sequence calls for the formation of a ring of carbon atoms, this problem is compounded. Fortunately, the formation of six-membered carbon rings is much simpler than it would first appear. As described in Organic Chemistry by Carey (Section 10.12), the Diels-Alder reaction was discovered in 1928. This reaction forms a six-membered ring from two pieces: a conjugated "diene" (which provides four of the ring atoms) and a "dienophile" (which provides two of the ring atoms). The main requirements for these species are that the *conjugated* diene must be somewhat electron rich (which is normally the case for dienes) and able to achieve the *s-cis* conformation, and that the "dienophile" have a two-atom  $\pi$  system that is relatively electron poor.

In this experiment you will react cyclopentadiene (the diene) with maleic anhydride (the dienophile) to produce the bicyclic compound, *endo*-bicyclo[2.2.1]hept-5-ene-2,3-dicarboxylic anhydride. The *endo*-adduct is formed exclusively. Why?



One important aspect of this experiment is that the cyclopentadiene must be freshly distilled within one day before the reaction is carried out. Why? Answer at end of experiment.

**EXPERIMENT 3.1****REACTION OF CYCLOPENTADIENE WITH MALEIC ANHYDRIDE****PROCEDURE****PART A: DISTILLATION OF CYCLOPENTADIENE**

Place dicyclopentadiene (10 mL) in a 25 mL round-bottomed flask (**in the fumehood**). Complete the set-up with a Vigreux column (for fractional distillation), an adapter and a condenser for distillation. Heat the dicyclopentadiene on a hot-plate until it refluxes briskly. The monomeric cyclopentadiene should start to distill within a few minutes. Continue to heat the dimer reagent to promote fairly rapid distillation and collect the cyclopentadiene into a receiver flask which is cooled to 0 °C using an ice-water bath. (Note 1). **Do not allow the distillation temperature to exceed about 45 °C, which is slightly above the boiling point of cyclopentadiene (40-43 °C).**

After all the cyclopentadiene has been collected, stop the distillation and discard the unused residue from the reaction flask, into the liquid waste container. If the cyclopentadiene is cloudy, add a few pieces of anhydrous sodium sulfate (or anhydrous magnesium sulfate). Decant the dry cyclopentadiene from the drying agent for use in the experiment below.

**PART B: DIELS-ALDER REACTION**

Grind 5 g maleic anhydride using a small mortar and pestle to break up any chunks, and dissolve it in 20 mL of ethyl acetate (you may need to heat it) in a 125 mL Erlenmeyer flask. Once the maleic anhydride is dissolved, add 20 mL of petroleum ether and place the solution in an ice bath to cool to well below room temperature. Add (*in the hood*) about 5 mL of the freshly distilled cyclopentadiene directly to the **cold** maleic anhydride solution (*if the solution contains any crystals, dissolve them before adding the cyclopentadiene*). Swirl the reaction mixture in an ice bath until the product has finished precipitating.

After crystals have formed, recrystallize your product by simply heating the product mixture on a hot plate until the solid dissolves (but do *not* boil). Allow the solution to cool at room temperature until recrystallization has finished. Collect the crystals using a Buchner funnel. (If you have crystals still present in the flask, do not use water to wash the crystals, as the acid anhydride will react; use the filtrate (mother liquor) to wash the flask. Collect as much crystals as possible.

**NOTE 1: SAFETY**

**Cyclopentadiene** (and its dimer, dicyclopentadiene) is an irritant, is flammable, has an unpleasant odor and is harmful if inhaled – avoid breathing its vapors. No flames will be allowed in the lab. Wear gloves while handling these chemicals. *Dispense and use these chemicals in the hood to minimize inhalation hazards.*

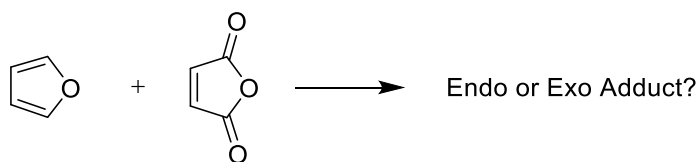
**Maleic anhydride** is corrosive and toxic-wear gloves while handling it. Be sure to wash your gloves and your hands after handling it.

**POST-LAB QUESTIONS**

1. How many new bonds, and of what type ( $\sigma$  or  $\pi$ ), are created in a Diels-Alder reaction?
2. What is the theoretical yield of product, based on the amount of cyclopentadiene used in the experiment?
3. What is the structure of the dicyclopentadiene?

**EXPERIMENT 3.2****REACTION OF FURAN WITH MALEIC ANHYDRIDE**

The objective of this experiment is to perform a Diels-Alder reaction between the furan and maleic anhydride.

**PROCEDURE**

Prepare 10 mL of a 4 M solution of maleic anhydride in  $\text{CH}_2\text{Cl}_2$ . (Use the calculations in your lab notebook). Filter off the insoluble maleic acid using a Hirsch funnel and suction filtration. Measure 1 mL furan into a test-tube and add the appropriate equimolar amount of maleic anhydride to the reaction tubes (use calculations in prelab). Cork the test tubes, seal the corks with parafilm, and set them in your locker until the next laboratory period because the reaction takes 24 - 48 hours to reach completion.

(Progress of reaction could be monitored through TLC. The TLC plate should have three spots (or lanes) on the origin: one for the main organic starting material that is being transformed, one for a co-spot (starting material and the reaction mixture), and one for the reaction mixture).



### **ISOLATION AND PURIFICATION**

If crystals haven't formed, insert a clean stirring rod or boiling stick into the reaction tube, remove the wet rod or stick, and allow it to dry, forming seed crystals. When reinserted, crystallization should be instantaneous. Pipet off the remaining liquid, wash the crystals with ice-cold  $\text{CH}_2\text{Cl}_2$  or 1:1 (V/V)  $\text{CH}_2\text{Cl}_2$ : hexane, let the crystals dry, and determine the yield and melting point.

Take the melting point of the furan adduct before recrystallization. Use a 5:2 mixture of hexane: ethyl acetate to dissolve only part of the crude product and place the flask in hot water bath. The temperature of the water bath should be adjusted to just below the melting point obtained to dissolve the adduct. Alternatively, acetone could be used as the solvent for recrystallisation and crystallization could be induced by dripping hexane into the acetone solution. Obtain melting points of all recrystallized products.

The furan adduct requires much more "finesse" to recrystallize since it undergoes a reverse or retro Diels-Alder reaction at the melting point.

### **CAUTION**

Maleic anhydride and the Diels-Alder adducts are intense skin irritants. Furan is very low boiling.

### **POST-LAB QUESTIONS**

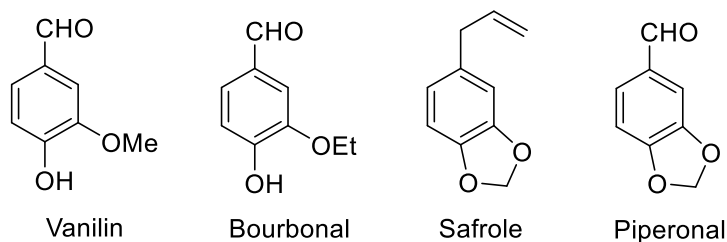
1. Determine which of the possible products were produced, *exo* or *endo*, by comparing your melting points with the literature values.
2. How would you prepare 5 mL of a 4 M solution of maleic anhydride in  $\text{CH}_2\text{Cl}_2$ ? Show calculations.
3. How many moles are in 0.5 mL furan? How many mL of the 4 M maleic anhydride in  $\text{CH}_2\text{Cl}_2$  would be an equimolar amount?
4. Explain why the 4 M solution of maleic anhydride is made in  $\text{CH}_2\text{Cl}_2$  and not in water. Show the reaction between maleic anhydride and water.
5. Give structures for the major Diels-Alder product of the following reactions:  
  
1,3-cyclohexadiene and tetrachloroethene 1,3-cyclohexadiene and fumaric acid, the trans isomer of maleic acid.

**REFERENCES**

1. *Techniques & Experiments for Organic Chemistry*, Ault, Addison, 6th Edition, University Science Books, 1997.
2. *Operational Organic Chemistry: A Problem-Solving Approach to the Laboratory Course*, John W. Lehman, Prentice Hall; 3<sup>rd</sup> edition, 1998.

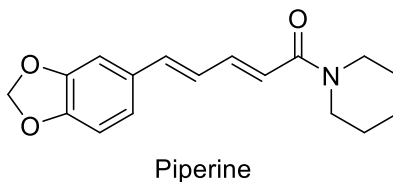
## EXPERIMENT 4 – SEPARATION OF PIPERINE FROM BLACK PEPPER

Some of the organic compounds found in nature have specific smell or odour and they are usually known, in general, as aromatic compound. In the early days, aromatic compounds meant then that the compound had a low hydrogen/carbon ratio and that it was fragrant. The parent compound of the aromatics is benzene. Today, not all aromatic compounds are fragrant but they are called aromatic compounds because of their structure. Some examples of aromatic compounds that have specific smell are vanillin and safrol.



Vanillin is obtained from vanilla and is widely used as deodorant, food flavour and one of the ingredients in pharmaceutical products. A related compound is bourbonal or 3-ethoxy-4-hydroxybenzaldehyde while safrol can be obtained from sassafras and camphor oil. Piperonal is derived from safrol through isomerization to isosafrol followed by oxidation. Piperonal is used as flavour in soap and deodorant because of its sweet smell.

One of the spices which is widely known is pepper. Peppercorns are the fruits of the Asian vine *Piper nigrum* L. It has a rather hot and sharp taste. This is due to the presence of piperine. However, the aromatic part of the taste is not due to piperine but to a small fraction of terpenoid ethereal oils in the peppercorns. Piperine has a unit of methylenedioxy as in safrol and piperonal.



**ISOLATION OF PIPERINE**

Powdered black pepper (20 g) is placed in the thimble of a Soxhlet apparatus and extracted with 95% ethanol (150 mL) for 2 hours. The extract was concentrated *in vacuo* using a rotary evaporator to give a brown oil. Add an alcoholic potassium hydroxide solution (10%, 10 mL) to the concentrate and swirl the flask for 5 minutes. The mixture is filtered with a fluted filter paper and the filtrate is allowed to stand overnight in a refrigerator. Piperine crystals will be obtained as yellowish needles. Collect the crystals by suction filtration.

Take the melting point and calculate the percentage yield. Record the UV (in EtOH) and IR spectrum (KBr disc) of piperine.

**THIN LAYER CHROMATOGRAPHY**

Dissolve a small amount of piperine in acetone and blotch it on the thin layer chromatography plate (silica gel Merck 60, F<sub>254</sub>). Place the TLC plate in a chromatography tank and develop it using toluene-ethyl acetate solution (volume/volume 2:1). Place the plate under UV light (UV<sub>254</sub>) and take note of your observation and the R<sub>f</sub> value of the sample.

**REFERENCES**

1. Operational Organic Chemistry, A Laboratory Course, Second Edition, John W. Lehman, Allyn and Bacon, 1988.
2. Organic Chemistry, Volume 2: Stereochemistry and the Chemistry of Natural Products, Fifth Edition, I.L.Finar, Longman, 1989.
3. Natural Products, A Laboratory Course, Second Edition, Raphael Ikan, Academic Press, 1991.
4. Classics in Spectroscopy: Isolation and Structure Elucidation of Natural Products, Stefan Berger, Dieter Sicker, WILEY-VCH, 2009.

**POST-LAB QUESTIONS**

1. Why a solution of 10% KOH in EtOH was added to the concentrate?
2. What are the compounds formed when piperine undergoes basic hydrolysis?
3. Besides using UV light, what other method can be used to detect piperine in the TLC plate?
4. Predict the <sup>1</sup>H NMR spectrum for piperine.

## EXPERIMENT 4

**Title:**

**Objective:**

**Experimental:**

**Results:**

Structure of piperine:

Parameter	Unit (g)
Mass of black pepper	
Mass of empty plastic bag	
Mass of empty plastic bag + piperine	
Mass of piperine	

Percentage yield of piperine =

TLC profile:

R<sub>f</sub> value of piperine :

**Discussion:**

**Suggestion for improvement:**

**Precaution step:**

**Conclusion:**



**References:**

*e.g. John J. E., John R. M., Lu, A., McNulty, Paul M. & Anne M. W. (2009). A Simple S<sub>N</sub>2 Reaction for the Undergraduate Organic Laboratory. J. Chem. Educ., 86 (7), p 850.*

**Post-lab questions:**

## EXPERIMENT 5 – PREPARATION OF AN AZO DYE

### 1-(p -NITROPHENYLAZO)-2-NAPHTHOL

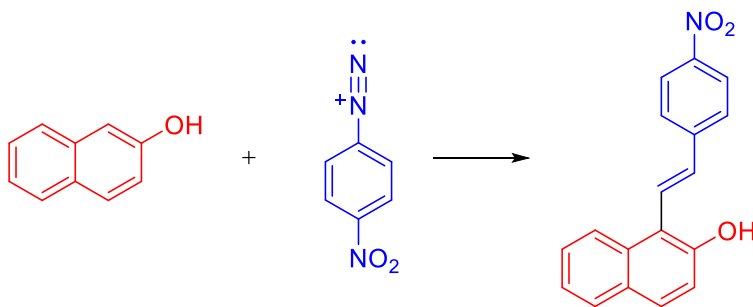
#### BACKGROUND

The azo class of compound accounts for 60-70% of all dyes. Azo dyes are dyes with -N=N- azo structure which links two  $sp^2$  hybridised carbon atoms. Usually, these carbons are part of an aromatic system, although this is not always the case. Most azo dyes contain only one azo group, but others may contain two (*disazo*), three (*trisazo*) or more.

In theory, azo dyes can supply a complete rainbow of colours. However, commercially they tend to supply more yellows, oranges and reds than any other colours though there are now some viable blue azo dyes on the market.

The general formula for making an azo dye requires two organic compounds - a coupling component and a diazo component. Since these can be altered considerably, an enormous range of possible dyes are available, especially as the starting molecules are readily available and cheap. Furthermore, the simplicity of the reactions mean that the process can be scaled up or down very easily, which is always a key factor in the cost of chemicals. Energy requirements for the reaction are low, since most of the chemistry occurs at or below room temperature. The environmental impact is reduced by the fact that all reactions are carried out in water, which is easy and cheap to obtain, clean and dispose of. As other dye classes become less viable from either an environmental or economic reasons, azo dyes become ever more attractive options.

1-(p-nitrophenylazo)-2-naphthol or Para Red is an example of an azo dye. This intense orange-red dye was discovered in 1880 by von Gallois and Ullrich, and was the first azo dye made. It dyes cellulose fabrics a brilliant red, but is not very fast.



## **PROCEDURE**

### **PART A: PREPARATION OF *p*-NITROBENZENDIAZONIUM SULFATE**

Dilute 2.0 mL (0.036 mol) concentrated H<sub>2</sub>SO<sub>4</sub> to 10 mL H<sub>2</sub>O. Add 1.4 g (~0.01 mol) *p*-nitroaniline and heat the solution slowly till all the amine has dissolved. Cool the solution to 10 °C or lower in an ice-bath. Prepare a solution of 0.7 g (0.01 mol) NaNO<sub>2</sub> in 2 mL H<sub>2</sub>O, cool it in an ice-bath, and add it slowly into the solution of *p*-nitroaniline prepared earlier (with stirring). Ensure that the temperature of the reaction does not rise to higher than 10 °C during the addition. Keep the product in ice bath while Part B is being prepared.

### **PART B: COUPLING REACTION OF THE DIAZONIUM SALT: PREPARATION OF 1-(*p*-NITROPHENYLAZO)-2-NAPHTHOL (PARA RED)**

Dissolve 1.44 g (0.01 mol) 2-naphthol in 25 mL 10% NaOH solution. Cool the mixture to 10 °C and add slowly to the diazonium salts prepared earlier (in Part A). Acidify the mixture and collect the solids *via* suction filtration. Recrystallize the product with acetic acid and take the melting point of the recrystallized product.

## **POST-LAB QUESTIONS**

1. Why do you have to keep the temperature at 10 °C when preparing the diazonium salt?
2. Provide the mechanism for the formation of the *p*-nitrobenzenediazonium sulfate.
3. What causes the color observed in Para Red?

## EXPERIMENT 6 – QUALITATIVE ANALYSIS OF UNKNOWN ORGANIC COMPOUND

The identification and characterization of an unknown organic compound normally refers to those processes or tests that need to be performed in order to answer the following important questions:

1. What kind of functional groups are in the compound?
2. Where in the molecule are these functional groups located?
3. What is the position of one functional group in relation to another?
4. Where a compound might exist as regio-, geometric or stereoisomers (diastereomers or enantiomers), can the type of isomerism be specified?

It is usually good practice before these questions can be answered, to ask some preliminary questions?

1. What kind of elements (carbon, hydrogen, nitrogen etc.) are in the compound?
2. What is the melting point or boiling point (if liquid) of the compound? This question is of particular importance since if a library of compounds or a data base of previously prepared compounds is available, agreement between the melting point or spectroscopic data for your compound and the reference compound from the published literature, can play a significant role in identifying an unknown compound, **provided it is pure**. This leads naturally to the next point.
3. Purification of your compound by recrystallisation, chromatography or (if liquid) by distillation is often essential.

Although it is possible, with modern spectroscopic equipment to completely identify a compound, thereby providing complete structural information, it is strongly recommended that you make use of other information for example, the physical state, elemental analysis (point 1a above), solubility and confirmatory tests for functional groups.

### SAFETY NOTES

**Before we survey briefly the kind of tests you will need to perform, three important points need to be emphasized:**

- **Laboratories can be dangerous places for the careless worker, therefore, make sure you protect your eyes by wearing safety spectacles. This will be particularly important when you have to heat reaction mixtures either to perform certain tests or during distillation. Wear a lab coat and shoes that cover the feet.**

- **Be observant! Notice what is going on around you in the laboratory for reasons of safety. Careful observation is also essential if you are to obtain the maximum possible information from the chemical and physical changes your compounds will undergo during the chemical tests.**
- **Assume that all unknowns are flammable and harmful by inhalation, ingestion and skin absorption. Do not inhale their vapors and avoid contact with eyes, skin and clothing.**

## PROCEDURES

### PRELIMINARY OBSERVATIONS

1. Check the purity of the sample. Impurities in the compound will make it extremely difficult to identify. Consider each of the following purification techniques:
  - Recrystallisation: Works well for solid compounds. The choice of recrystallization solvent is critical. One essential characteristic of an appropriate solvent is that the desired compound must be considerably more soluble in the solvent when it is hot than when it is cold.
  - Distillation: Works well for liquids that have boiling point of  $<250\text{ }^{\circ}\text{C}$ .
  - Column chromatography: Works well for UV active compounds. This can be done by TLC (thin layer chromatography) to identify a solvent system that will separate unknown from any impurities.
2. Note the color. Colors may suggest to the experimenter the likely classification of the compound. But this is not final proof, which, can only be obtained by performing chemical tests and spectroscopic investigations. Common colored compounds could include  $\alpha$ -diketones (yellow), quinones (yellow to red), azo compounds (yellow to red), and polyconjugated olefins and ketones (yellow to red). It is not unusual to find that phenols and amines with colors ranging from brown to dark purple because of traces of air oxidation products.
3. Note the odor:
  - A fishy odor could suggest solid or liquid amines.
  - The fragrance of esters can be extremely pleasant.
  - Alcohols, ketones, aromatic hydrocarbons, and aliphatic olefins have characteristic odors.

- Thiols, isonitriles, and low molecular weight carboxylic acids often have a rather unpleasant odor.

**Caution: extreme care must be taken when the sense of smell is being used in the laboratory, inhalation of unpleasant and perhaps toxic chemicals can be dangerous.**

4. For some investigations, you may be given a mixture of two compounds. In this case you will need to perform tests for the presence of acidic or basic groups followed by the appropriate extraction, where the compound is partitioned between two solvents of different polarities in a separating funnel. The laboratory assistant will teach you how to do this. Once this has been achieved, purification (distillation or chromatography) can proceed.

### IGNITION TEST

Heating a small sample in a spatula in a Bunsen flame can be suggestive. If the compound burns with a smoky flame, it is probably an aromatic compound. If a large ashy residue is left after is left after ignition, the unknown is probably a metal salt.

### ELEMENTAL ANALYSIS, THE SODIUM FUSION EXPERIMENT

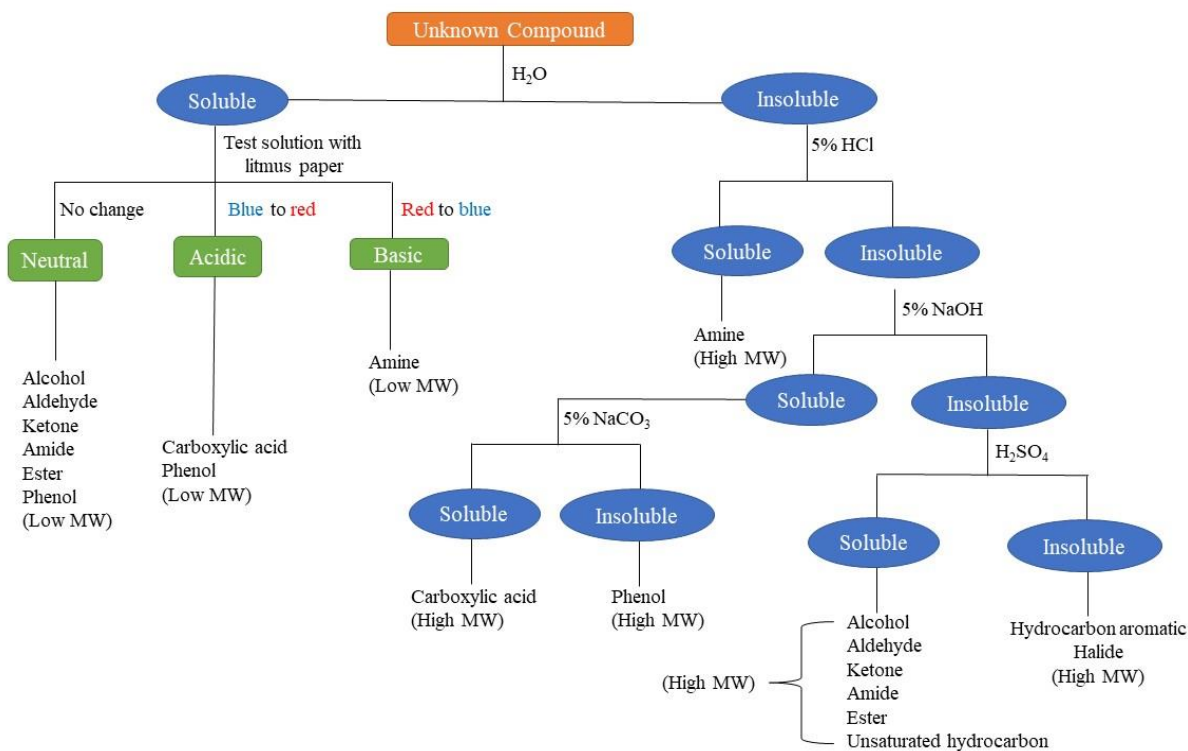
In this test, the sample is added to hot sodium in a pyrex test tube. **It is important that you follow instructions, including the advice of your instructor, faithfully and as always make sure you are wearing your safety glasses.**

If nitrogen, sulphur or halogen are present in the unknown compound, these will be converted to NaCN, Na<sub>2</sub>S and sodium halide (Cl, Br or I) respectively. These products can in turn be readily identified. Of course, caution is advisable when drawing inferences from these observations. The presence of sulphur can interfere with the nitrogen test. In addition, the sodium fusion test does not work well with nitro compounds.

### SOLUBILITY TESTS

To determine the functional group, it is recommended to start with solubility test and then conduct functional group classification tests. The solubility measurements are done at room temperature with 1-2 drops of liquid or 5 mg of a solid (finely crushed), and 1 mL of solvent. Place the appropriate amount of either solid or liquid unknown in a small test tube. Shake the tube and/or stir with a glass stirring rod. A soluble unknown will form a homogeneous solution with water, while an insoluble liquid will remain as a separate phase. The results from the solubility tests can significantly help in determining which classification tests should then be performed, or at least narrow down the list. The solubility tests are summarized in the flow charts

below.



**Flow Chart of Solubility Tests**

## FUNCTIONAL GROUP TESTS

Your reference book will provide you with information on a whole series of functional group tests. For example, for aldehydes and ketones (addition of 2,4-dinitrophenyl hydrazine resulting in the formation of a bright orange precipitate), for esters (addition of KOH, HCl, FeCl<sub>3</sub> resulting in the formation of the hydroxamic acid salt), for halogens (the silver nitrate test), for the nitro group (the purple colour produced by the titanous chloride test). Tests for phenols, alcohols, primary and secondary amines, alkyl halides can be obtained from the laboratory manuals. Further experiments for the formation and purification of suitable derivatives for melting point determinations are also available.

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