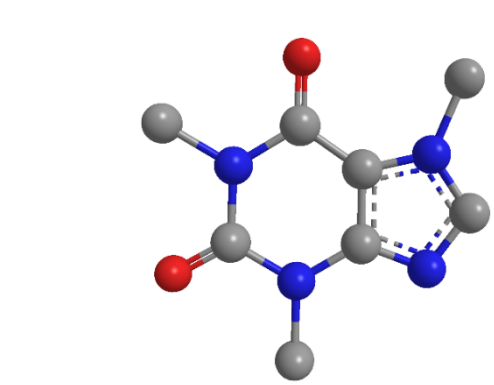
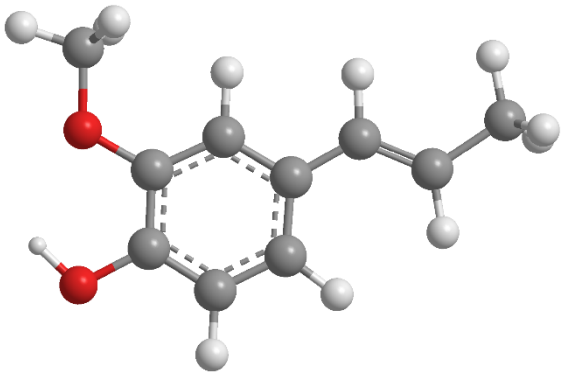
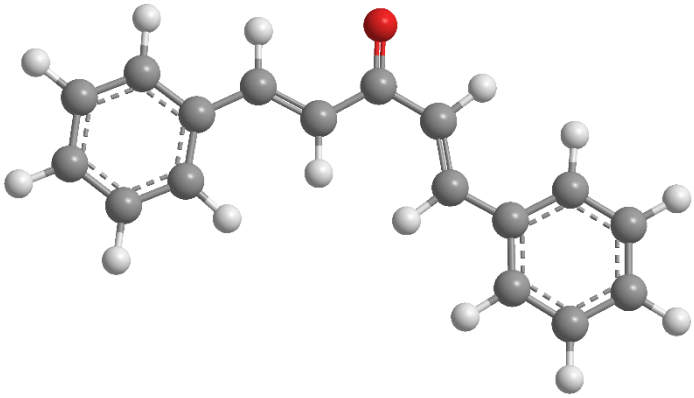
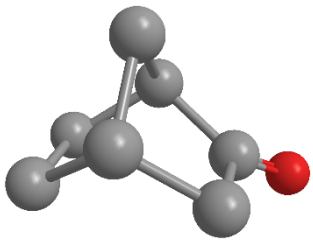
# Organic Chemistry Laboratory 1

# คม252: ปฏิบัติการเคมีอินทรีย์ 1









สาขาวิชาเคมี คณะวิทยาศาสตร์

มหาวิทยาลัยแม่โจ้

ภาคการศึกษา 1/2564

**จัดทำโดย** คณาจารย์ สาขาวิชาเคมี

# Contents

**ประมวลการสอนรายวิชา (Course Syllabus)**

**ประจำปีการศึกษาที่ 2564 ภาคเรียนที่ 1**

**ชื่อวิชา** ปฏิบัติการเคมีอินทรีย์ 1 **รหัสวิชา** คม 252

**จำนวนหน่วยกิตรวม** 3 หน่วยกิต [ปฏิบัติการ 3 ชั่วโมง/สัปดาห์]

**อาจารย์ผู้สอน** อ.ดร. ปิยธิดา กล่ำภู่

**ผู้ประสานงาน** อ.ดร. ปิยธิดา กล่ำภู่

**คำอธิบายรายวิชา (Course description)**

การศึกษาเทคนิคปฏิบัติการทางเคมีอินทรีย์ เช่น การหาจุดเดือด จุดหลอมเหลว การสกัด การตกผลึก การระเหิด การกลั่น การแยกสารด้วยโครมาโทรกราฟี และการระบุเอกลักษณ์ของสารประกอบอินทรีย์ การศึกษาสเตอริโอเคมี และกลไกของปฏิกิริยาเคมีอินทรีย์ ได้แก่ ปฏิกิริยาการแทนที่ ปฏิกิริยาการเติม ปฏิกิริยาออกซิเดชัน ปฏิกิริยารีดักชัน ของสารประกอบแอลเคน แอลคีน แอลไคน์ แอลคิลเฮไลด์ แอลกอฮอล์ แอลดีไฮด์ คีโตน

**วัตถุประสงค์รายวิชา**

1. นักศึกษามีความรู้ในหลักการ ทฤษฎี เกี่ยวกับเทคนิคปฏิบัติการทางเคมีอินทรีย์และปฏิกิริยาเคมีอินทรีย์
2. นักศึกษามีความรู้ทางทฤษฎีและปฏิบัติและสามารถทำปฏิบัติการเกี่ยวกับเทคนิคปฏิบัติการทางเคมีอินทรีย์ และปฏิกิริยาเคมีอินทรีย์
3. นักศึกษาสามารถนำความรู้ที่มีมาใช้ในการวิเคราะห์และอภิปรายผลปฏิบัติการทางเคมีอินทรีย์และปฏิกิริยาเคมีอินทรีย์
4. นักศึกษามีคุณธรรม จริยธรรม และจรรยาบรรณในการวิจารณ์ผล สรุปผลการทดลอง และการเขียนรายงานปฏิบัติการ

**เวลาเรียน** วันจันทร์ 15.00-18.00 น.

**สถานที่เรียน** วิทย์ 1214

**สอนนักศึกษา** สาขาวิชาเคมี ชั้นปีที่ 2 สาขาเคมีอุตสาหกรรมและเทคโนโลยีสิ่งทอ ชั้นปีที่ 2 และสาขาเทคโนโลยียางและพอลิเมอร์ ชั้นปีที่ 2

**แผนที่แสดงการกระจายความรับผิดชอบต่อของรายวิชา (Curriculum Mapping)**

| รายวิชา | คุณธรรมและจริยธรรม | | | | | ความรู้ | | | | ทักษะทางปัญญา | | | ทักษะระหว่างบุคคลและความรับผิดชอบ | | | ทักษะวิเคราะห์เชิงตัวเลข การสื่อการและการใช้เทคโนโลยีสารสนเทศ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 4 |
| คม252 ปฏิบัติการเคมีอินทรีย์ 1 | ● | ● | ○ | | | ● | ● | | | ● | ○ | | ● | ● | | ● | ○ | | ○ |

## ความสอดคล้องกับผลการเรียนรู้ระดับหลักสูตร (PLO)

### 1. ผลการเรียนรู้เฉพาะทาง (Specific PLO)

| PLO# | รายละเอียด PLO |
|---|---|
| PLO5 | มีความรู้ความสามารถทางเคมีทั้งในเชิงทฤษฎีและปฏิบัติ |
| PLO6 | มีคุณธรรมและจริยธรรม มีจรรยาบรรณในวิชาชีพ |

### 2. ผลการเรียนรู้ทั่วไป (Generic PLO)

| PLO# | รายละเอียด PLO |
|---|---|
| PLO1 | มีความรู้ในหลักการและทฤษฎีทางด้านวิทยาศาสตร์และหรือคณิตศาสตร์ |
| PLO2 | มีความรู้พื้นฐานทางวิทยาศาสตร์และคณิตศาสตร์ที่จะนำมาอธิบายหลักการและทฤษฎีในศาสตร์เฉพาะ |

### ความเชื่อมโยงผลการเรียนรู้ระดับหลักสูตร (PLO) สู่ระดับรายวิชา (CLO)

| PLO# | CLO# | รายละเอียด CLO | บท# |
|---|---|---|---|
| PLO1 | CLO1 | นักศึกษามีความรู้ในหลักการ ทฤษฎี เกี่ยวกับเทคนิคปฏิบัติการทางเคมีอินทรีย์และปฏิกิริยาเคมีอินทรีย์ | 1-10 |
| PLO5 | CLO2 | นักศึกษามีความรู้ทางทฤษฎี และปฏิบัติ และสามารถทำปฏิบัติการเกี่ยวกับเทคนิคปฏิบัติการทางเคมีอินทรีย์ และปฏิกิริยาเคมีอินทรีย์ | 1-10 |
| PLO2 | CLO3 | นักศึกษาสามารถนำความรู้ที่มีมาใช้ในการวิเคราะห์และอภิปรายผลปฏิบัติการทางเคมีอินทรีย์ และปฏิกิริยาเคมีอินทรีย์ | 1-10 |
| PLO6 | CLO4 | นักศึกษามีคุณธรรม จริยธรรม และจรรยาบรรณในการวิจารณ์ผล สรุปผลการทดลอง และการเขียนรายงานปฏิบัติการ | 1-10 |

### ความสอดคล้องระหว่างการประเมินผล วิธีการสอน และผลการเรียนรู้ระดับรายวิชา (CLO)

| การประเมินผล | วิธีการสอน | CLO# |
|---|---|---|
| - ประเมินจากรายงานมีการเขียนหลักการทฤษฎี และปฏิบัติ และการวิเคราะห์อภิปราย การคำนวณ ที่ถูกต้องตามหลักวิชาการ<br>- ประเมินผลจากรายงาน ในการอภิปรายที่มีการค้นคว้าเพิ่มเติม<br>-ประเมินจากการสอบข้อเขียนปลายภาค | - การทำปฏิบัติการ มีการเตรียมความพร้อมก่อนทำปฏิบัติการในการเขียนหลักการ ทฤษฎี และวิธีการปฏิบัติ ก่อนเข้าชั้นเรียน<br>- ปฏิบัติการทดลองแบบกลุ่ม ฝึกกระบวนการคิด วิเคราะห์และวิพากษ์ ทั้งในระดับบุคคลและกลุ่ม | CLO1 นักศึกษามีความรู้ในหลักการทฤษฎี เกี่ยวกับเทคนิคปฏิบัติการทางเคมีอินทรีย์ และปฏิกิริยาเคมีอินทรีย์<br>CLO2 นักศึกษามีความรู้ทางทฤษฎีและปฏิบัติ และสามารถทำปฏิบัติการเกี่ยวกับเทคนิคปฏิบัติการทางเคมีอินทรีย์ และปฏิกิริยาเคมีอินทรีย์ |
| -ประเมินจากพฤติกรรมของผู้เรียนระหว่างร่วมกิจกรรมการเรียนการสอน<br>- ประเมินจากรายงานผลการทดลอง การสรุปและอภิปรายผลการทดลอง<br>-ประเมินจากการให้คะแนนการเข้าห้องเรียนและการส่งงานตรงเวลา | - ปลูกฝังให้นักศึกษามีระเบียบวินัยโดยเน้นการเข้าชั้นเรียนให้ตรงเวลาและการส่งงานภายในเวลาที่กำหนด<br>-ปลูกฝังในทางวิชาการ ซื่อสัตย์สุจริต ในการเขียนผลการทดลอง การสรุปและอภิปรายผลการทดลอง | CLO3 นักศึกษาสามารถนำความรู้ที่มีมาใช้ในการวิเคราะห์และอภิปรายผลปฏิบัติการทางเคมีอินทรีย์ และปฏิกิริยาเคมีอินทรีย์<br>CLO4 นักศึกษามีคุณธรรม จริยธรรม และจรรยาบรรณในการวิจารณ์ผล สรุปผลการทดลอง และการเขียนรายงานปฏิบัติการ |

**รายละเอียดเนื้อหาวิชา**

| สัปดาห์ที่ | หัวข้อ/รายละเอียด | จำนวนชั่วโมง |
|---|---|---|
| **1-3**<br>(5 ก.ค.–19 ก.ค. 2564) | แนะนำห้องปฏิบัติการ ข้อควรปฏิบัติและความปลอดภัยในห้องปฏิบัติการ แนะนำและอธิบายวิธีการเขียนรายงานการทดลอง การเก็บข้อมูล การคำนวณ การสรุปผล และการอภิปรายผลการทดลองของทุกปฏิบัติการ (ออนไลน์) | 9 |
| **4**<br>(26 ก.ค. 2564) | **26 ก.ค. 64 วันหยุดชดเชยวันอาสาฬหบูชา**<br>**งดปฏิบัติการ** | |
| **5**<br>(2 ส.ค. 2564) | **ปฏิบัติการที่ 1**<br>Determination of Melting Point and Boiling Point | 3 |
| **6**<br>(9 ส.ค. 2564) | **ปฏิบัติการที่ 2**<br>TLC and Column Chromatographic Adsorption | 3 |
| **7**<br>(16 ส.ค. 2564) | **ปฏิบัติการที่** 3<br>Acid-Base Extractions, Separations and Drying Agents | 3 |
| **8**<br>(23 ส.ค. 2564) | **ปฏิบัติการที่ 4**<br>Reaction of Alkane, Alkene and Alkyne | 3 |
| **สอบกลางภาค 1/2564 (30 ส.ค. – 5 ก.ย. 2564)**<br>**งดปฏิบัติการ** | | |
| **9**<br>(6 ก.ย. 2564) | **ปฏิบัติการที่ 5**<br>Stereochemistry: Addition Reaction: Camphor Derivative | 3 |
| **10**<br>(13 ก.ย. 2564) | **ปฏิบัติการที่ 6**<br>Solid-Liquid Extraction and Crystallization: Caffeine Part 1 | 3 |
| **11**<br>(20 ก.ย. 2564) | **ปฏิบัติการที่ 7**<br>Sublimation: Caffeine Part 2<br>Simple Distillation: Mixed Compound | 3 |
| **12**<br>(27 ก.ย. 2564) | **ปฏิบัติการที่ 8**<br>Stream Distillation: Eugenol oil / Citronella oil | 3 |
| **13**<br>(4 ต.ค. 2564) | **ปฏิบัติการที่** 9<br>Williamson reaction and identification of ether synthesis: Paracetamol derivative | 3 |
| **14**<br>(11 ต.ค. 2564) | **ปฏิบัติการที่** 10<br>The Oxidation of $1^{o}$-, $2^{o}$ –Alcohol and Identification of Aldehyde and Ketone with 2,4-DNP | 3 |
| **15**<br>(18 ต.ค. 2564) | **สอบเทคนิคปฏิบัติการ (5%)**<br>เช็คและคืนอุปกรณ์ ตรวจเช็คคะแนนรายงาน | 3 |
| **สอบปลายภาค (30%) 1/2564 25 ต.ค.- 7 พ.ย. 2564** | | |

**เกณฑ์คะแนน**

| การประเมินผล | สัดส่วน |
|---|---|
| แบบทดสอบก่อนเรียน | 5% |
| แผนการทดลองและบันทึกผลการทดลอง | 5% |
| สังเกตพฤติกรรมในห้องปฏิบัติการ | 5% |
| รายงานผลการทดลอง | 50% |
| สอบเทคนิคปฏิบัติการ | 5% |
| สอบข้อเขียนปลายภาค | 30% |
| **รวมทั้งสิ้น** | **100 %** |

**เกณฑ์การประเมินผล (สามารถปรับเปลี่ยนได้ตามความเหมาะสม)**

| | | | |
|---|---|---|---|
| 45 + 3.5SD % ขึ้นไป | ระดับคะแนน A | 45 + 1.5SD % | ระดับคะแนน C |
| 45 + 3.0SD % | ระดับคะแนน B+ | 45 + 1.0SD % | ระดับคะแนน D+ |
| 45 + 2.5SD % | ระดับคะแนน B | 45+ 0.5SD % | ระดับคะแนน D |
| 45 + 2.0SD % | ระดับคะแนน C+ | ต่ำกว่า 45 % | ระดับคะแนน F |

## การเขียนรายงาน

รายงานประกอบด้วย 2 ส่วน ดังนี้

<u>ส่วนที่ 1</u> บทนำและแผนการทดลอง (ทำมาก่อนทำการทดลอง และส่งก่อนเริ่มเรียนปฏิบัติการ)

**เรื่อง.....**

**วันที่ทดลอง.....กลุ่มที่.....**

ผู้เขียนรายงาน ชื่อ) ..... รหัส.....สาขา.....

ผู้ร่วมงาน ชื่อ).....รหัส.....สาขา.....

ชื่อ).....รหัส.....สาขา.....

<u>วัตถุประสงค์</u>

ให้บอกวัตถุประสงค์ของการทดลองให้ชัดเจนว่า เพื่อต้องการหาค่าอะไร ของสารอะไร โดยวิธีไหน (ตามวิธีทำการทดลองจริง)

<u>ทฤษฎี (หลักการ)</u> ไม่เกิน 1 หน้ากระดาษ

ให้อธิบายทฤษฎีหรือหลักการโดยย่อ พร้อมทั้งสูตรและสัญลักษณ์ ในการทดลองหรือการคำนวณ เพื่อให้ได้ผลการทดลองตรงตามวัตถุประสงค์ที่ต้องการ

<u>วิธีการทดลอง</u>

- สารเคมี (ถ้ามี) จัดทำในรูปแบบตารางข้อมูล ดังตัวอย่าง

| สารเคมี | Ethanol | | | | |
|---|---|---|---|---|---|
| สูตร/โครงสร้าง | $C_2H_5OH$ | | | | |
| MW (g/mol) | 46.07 | | | | |
| ปริมาณที่ใช้ (g/mL) | 10 mL | | | | |
| Mmol | | | | | |
| Equivalent | | | | | |
| BP ($^oC$) | 78.24 | | | | |
| MP ($^oC$) | -114.14 | | | | |
| ข้อควรระวัง | Flammable | | | | |

- สมการแสดงปฏิกิริยาเคมี (ถ้ามี)
- วิธีการทดลอง อธิบายวิธีทำการทดลองโดยย่อ ตามลำดับขั้นที่ทำการทดลองในห้องปฏิบัติการ ตั้งแต่เริ่มต้นจนกระทั่งถึงขั้นสุดท้ายของการทดลอง แสดงรูปประกอบ Flow Chart

<u>ส่วนที่ 2</u> ผลการทดลอง สรุปและวิจารณ์ผลการทดลอง (เขียนจากผลการทดลองจากการเรียนปฏิบัติการ)

<u>ผลการทดลอง</u>

จากการทดลองได้สารอะไร ลักษณะทางกายภาย เช่น สี รูปร่างผลึก ปริมาณสารที่ได้ (กรัม/มิลลิลิตร) สมบัติทางกายภาพอื่น ๆ ที่ทำการวิเคราะห์ เช่น จุดเดือด จุดหลอมเหลว การละลาย เป็นต้น

<u>การคำนวณ</u>

ให้แสดงวิธีการคำนวณที่สำคัญ ให้แสดงผลลัพธ์หรือค่าเฉลี่ยของผลลัพธ์ที่ได้จากการคำนวณสาร กำหนดปริมาณ, %yield, %conversion และ %recovery

<u>สรุปและวิจารณ์ผลการทดลอง</u>

สรุปตามจุดประสงค์ ว่าได้สาร(ชื่อ) ได้สารกี่กรัม คิดเป็น ร้อยละ (%yield)

การวิจารณ์ผลการทดลอง วิจารณ์ผลว่าทำไมถึงเป็นเช่นนั้น และ ทำไมถึงไม่เป็นเช่นนั้น อาจอิงตามจุดประสงค์การทดลอง

<u>เอกสารอ้างอิง</u>

เอกสารอ้างอิง อย่างน้อย 3 เอกสาร (หนังสือหรือเว็บไซต์)

# Laboratory Safety and MSDS

## Safety!

Organic chemistry laboratory can provide social benefit, basic scientific discoveries, and intellectual satisfaction. Chemical experiments are not just fun, But can also be very hazardous, some experiments inherently so. Complacency is often observed by experience. One often forgets that chemistry is a potentially dangerous enterprise; a cavalier attitude often results in disastrous consequences. Therefore, extreme caution should be exercised at all time, especially when one handles large-scale reactions that are exothermic or when dealing with toxic chemicals.

## Personal Protection Equipment

*1. Safety Glasses*

If a chemical splashes into your eyes, it could do serious and sometimes permanent damage to your vision. The most common forms of eye protection include safety glasses (with side shields), goggles, and face shields. Prescription eye glasses are acceptable provided that the lenses are impact resistant and they are equipped with side shields.

*2. Gloves*

Laboratory gloves are an essential part of safe laboratory practice and must be worn while handling chemicals. Despite practicing good safety techniques, tragedy may still strike. The types of gloves available and their recommended use. The manufacturer's description of the gloves should be consulted.

*3. Laboratory Coats*

Laboratory coats provide an important barrier for your clothes and, more important, your skin from chemicals. The laboratory coat should fit comfortably, have long sleeves and should be clean.

*4. Material Safety Data Sheets (MSDS)*

When dealing with chemicals, caution is warranted, especially with reactive chemicals, carcinogens, and toxic reagents. A useful resource is the Material Safety Data Sheets (MSDS). There are a variety of resources that can be accessed online, including the following:

MSDS Solution [www. msds.com (accessed June. 10, 2013),

MSDS online [www.msdsonline.com (accessed June. 10, 2013),

Cornell University [www.msds.ehs.cornell.edu (accessed June. 10, 2013),

Chemical suppliers/manufactures such as Sigma-Aldrich (www.sigmaaldrich.com), (accessed June. 10, 2013),

www.msds.ped.go.th (accessed June. 10, 2013)

*5. Useful Preparations*

Setting up the reaction is probably the most import job for an organic chemist. Once a reaction is initiated, there is little left that needs to be done to change the outcome.

# Experiment 1
# Melting Point and Boiling Point Determination

The physical properties of organic compounds are those properties that are intrinsic to a given compound when it is pure. A compound may often be identified simply by determining its physical properties. The most commonly recognized physical properties of a compound include its color, melting point, boiling point, density, refractive index, molecular weight and optical rotation. In modern chemistry, organic compounds would include the various types of spectra (infrared, nuclear magnetic resonance, mass, and ultraviolet-visible) among the physical properties of a compound. A compound's spectra does not vary from one pure sample to another.

Many reference books list the physical properties of substances. The most useful works for finding list of values for the non-spectroscopic physical properties include:

*Sigma-Aldrich index*

*The Merck index*

## 1.1 Melting Point (M.P.) Determination

The M.P. of a substance is the temperature at which a material changes from a solid state to a liquid state. The pure crystalline substances have a clear, sharply defined melting point. During the melting process, all of the energy added to a substance is consumed as heat of fusion, and the temperature remains constant. A pure substance melts at a precisely defined temperature, characteristic of every crystalline substance and dependent only on pressure (though the pressure dependency is generally considered insignificant). Determining the M.P. is a simple and fast method used in many diverse areas of chemistry to obtain a first impression of the purity of a substance. This is because even small quantities of impurities change the melting point. The melting point is easy to measure and classify. Extensive collections of tables give the exact values of many pure organic compounds. The M.P. determination is a fast and cost-effective technique which remains a strong link to the vast pre-instrumental chemistry literature.

*Sample Preparation:*

Careless preparation of a sample is the leading cause of inaccurate and irreproducible results in melting point determinations. Any substance being loaded into a melting point capillary must be:

1. Fully dry (oven-dried)
2. Homogeneous
3. In powdered form

*Packing Sample tube:*

Capillary:

Place the sample in a piece of thin-walled capillary tubing (1 mm X 100 mm) that has been sealed at one end.

To pack the tube:

Fill a capillary tube with crystals about 0.5-1.0 cm high. To transfer the crystals to the closed end of the tube, drop the capillary tube, closed end first, down all length of glass tubing, which is held upright on the desk top. "When the capillary tube hits the desk top, the crystals will pack down into the bottom of the tube.

Capillary tube attached to the thermometer:

It is held by a rubber band or a thin slice of rubber tubing. It is important that this rubber band be above the level of the oil (allowing for expansion of the oil on heating) so that the oil does not soften the rubber and allow the capillary tubing to fall into the oil. If a cork or a rubber stopper is used to hold the thermometer, a triangular wedge should be sliced in it to allow pressure equalization.

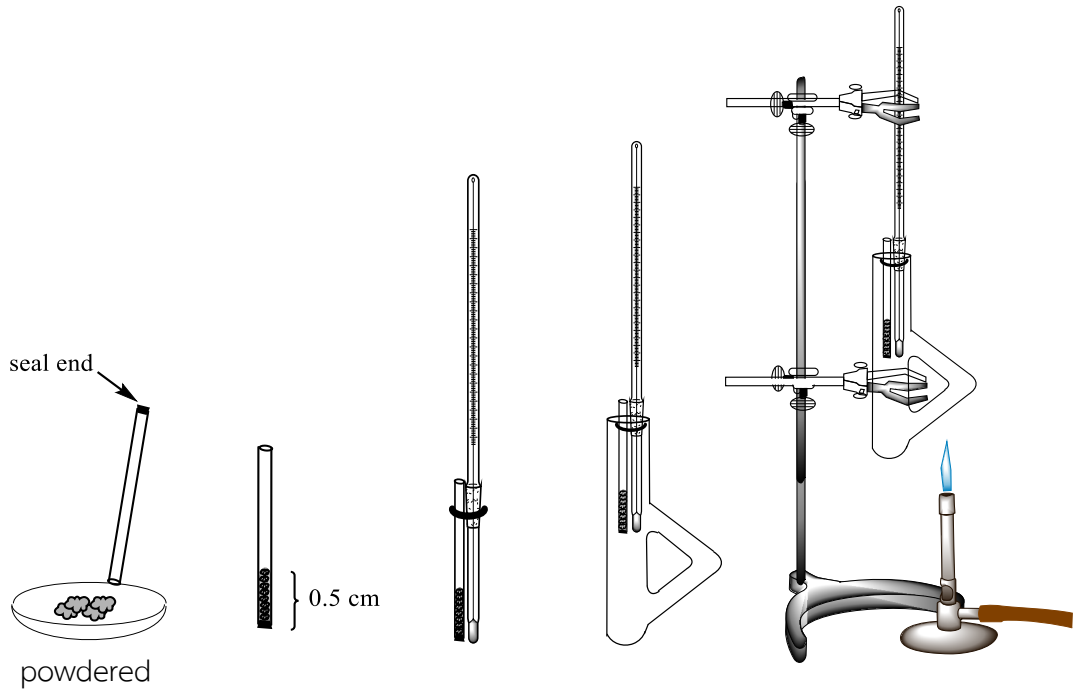



Figure 1.1: Packing sample and determination melting point with Thiele tube

*Determining with Thiele tube*

There are two principal types of melting point apparatus available: the Thiele tube and electrically heated instruments. The Thiele tube (shown in Figure 1.1) is the simple device and was once widely used. It is a glass tube designed to contain a heating oil (paraffin oil) and a thermometer to which a capillary tube containing the sample is attached.

Set melting point apparatus as Figure 1.1. Place the capillary tube in the Thiele tube that contains paraffin oil.

The Thiele tube is usually heated by a micro-burner. During the heating, the rate of temperature increase should be regulated. For melting point determination, follow these four basic steps:

1. The heating stand is rapidly preheated, to a user-specified start temperature, selected just a few degrees below the expected melting point of the samples.

2. Once the temperature is stable, the sample capillaries are inserted into the oven and after the temperature stabilizes a heating ramp is immediately launched.

3. The temperature of the samples continues to rise at the user-specified ramping rate until a user-specified stop temperature is reached. Automated and/or visual observations of the melting point, **melting range**,

Melting range = T1 – T2

T1: sample start to melt

T2: sample complete melting (transparent)

4. At the end of the heating ramp, the capillaries are discarded and the heater stand is rapidly cooled down using a low flame, move the burner slowly back and forth along the bottom of the arm of the Thiele tube.

Table 1.1: The Melting point of common organic compounds

| Compounds | M.P. (°C) |
|---|---|
| Water | 0 |
| *p*-Dichlorobenzene | 53 |
| *m*-Dinitrobenzene | 90 |
| Acetanilide | 114 |
| Benzoic acid | 122 |

| | |
|---|---|
| Benzamide | 128 |
| Urea | 133 |
| Adipic acid | 152 |
| Salicylic acid | 157 |
| Benzanilide | 161 |
| Succinic acid | 189 |
| 3,5-Dinitrobenzoic acid | 205 |
| *p*-Nitrobenzoic acid | 239 |
| Anthraquinone | 289 |
| *N,N'*-Diacetylbenzidine | 332 |

**1.2 Boiling Point (B.P.) Determination**

If a sample of a liquid is placed in an otherwise empty space, some of it will vapourise. The pressure in the space above the liquid will rise and will finally reach some constant value. The pressure under these conditions is due entirely to the vapour of the liquid, and is called the equilibrium vapour pressure. The phenomenon of vapour pressure is interpreted in terms of molecules of liquid escaping into the empty space above the liquid. In order for the molecules to escape from the liquid phase into the vapour phase, the intermolecular forces (in order of increasing strength:

1. Van der Waals,
2. Dipole-Dipole,
3. Hydrogen bonding

These forces have to be overcome which requires energy. Since the nature of the intermolecular forces is determined by the molecular structure, then the amount of energy required to vapourise the sample also depends on the molecular structure.

The vapour pressure-temperature curve for water is shown on the Figure 1.2. When the vapour pressure of a liquid is equal to the atmospheric (or applied) pressure then boiling occurs. The temperature at which this occurs, for a given pressure, is the boiling point. It should be noted, therefore, that the boiling point of a liquid decreases

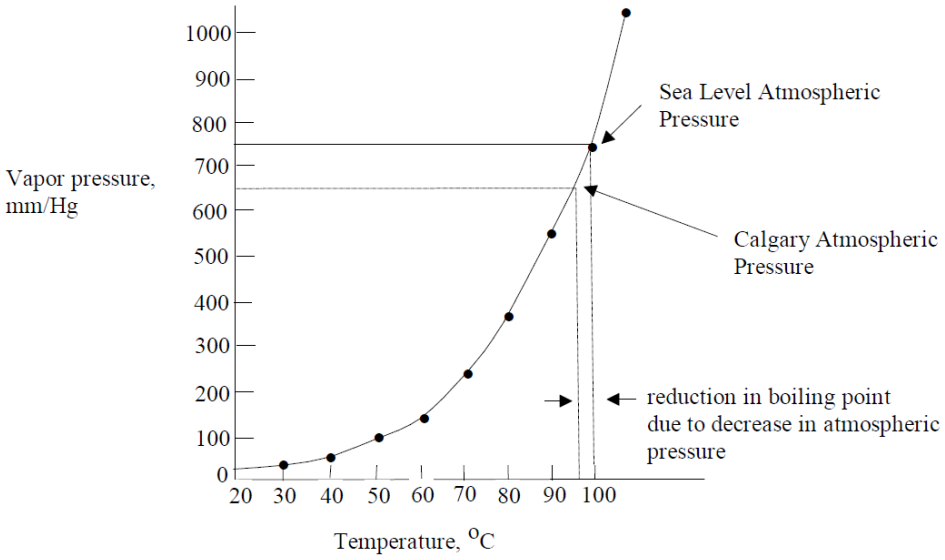



Figure 1.2: The vapor pressure-temperature curve for water

As the atmospheric (or applied) pressure decreases. This is illustrated by the Vapor Pressure-Temperature Curve above in Figure 1.2 For example,

The atmospheric pressure is 760 mm Hg and pure water boils at 100 °C. For example if we are on a mountain 3500 feet above sea level, the atmospheric pressure would be approximately 660 mm Hg, and water boils at about 96.5 °C.

As a rule of thumb, the boiling point of many liquids will drop about 0.5 °C for a 10 mm decrease in pressure in the vicinity of 760 mm Hg. At lower pressures, a 10 drop in boiling point is observed for each halving of the pressure. A rough measure that seems to work relatively well for calculating the boiling point of a liquid in on our mountain is to subtract 1 °C for every 14-16 °C of temperature above 50 °C,

So, in order to convert an experimental measurement taken at a top of a mountain (higher altitude and lower pressure) to that reported at sea level (higher pressure) one needs to ADD a correction factor since the boiling point at sea level is higher than that at higher altitudes. The correction factor can be obtained by algebraically rearranging the equation given above.

There are more accurate methods available for this calculation. At lower pressures, a boiling point monograph or temperature-pressure alignment chart (shown below) can be used.

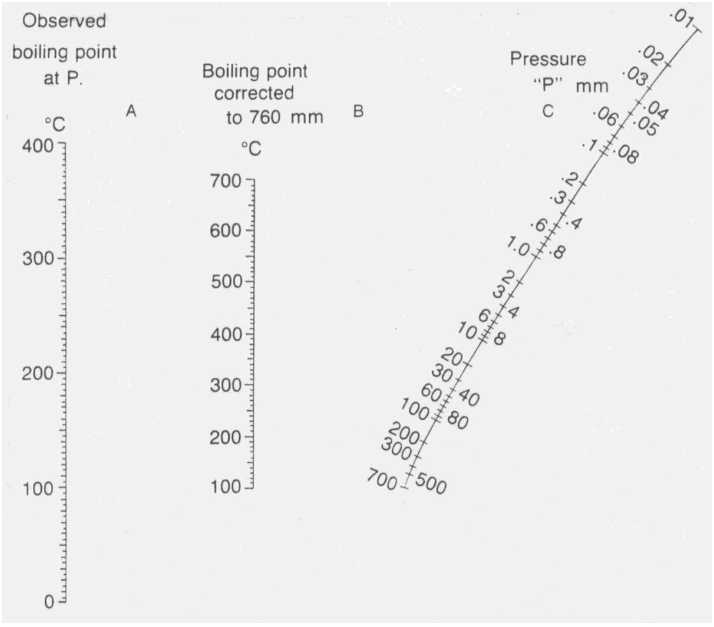



Figure 1.3: The pressure-temperature alignment monograph

The basic principle is that a line through two known points on any two different scales (A, B and C) can be used to read off the value on the third scale.

There are two ways in which a pressure monograph can be used

(1) to determine the boiling point at atmospheric pressure (760 mm Hg) given the boiling point at a lower pressure and

(2) to determine the boiling point at a lower pressure given the boiling point at atmospheric pressure.

Firstly, let's say we have a compound with a boiling point of 100 °C at 1 mm Hg pressure. What is the boiling point at 760 mm Hg

To do this we need to draw a line from 100 °C on scale A (left side, observed boiling point) to 1.0 mm Hg on scale C (right side, pressure "P" mm). We can then read off the boiling point at 760 mm on line B, it is about 280 °C.

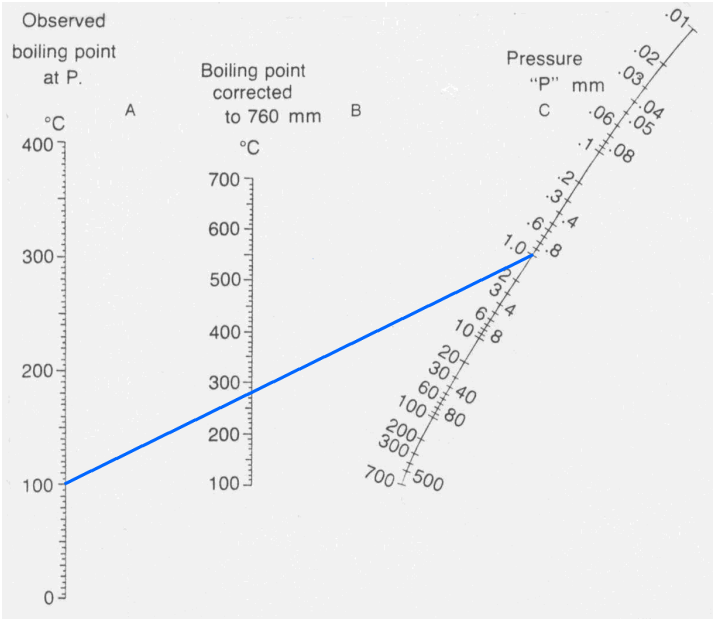



Figure 1.4: Using a pressure nomograph: Determining the boiling point at 760mm Hg (scale B) for a sample that boils at 100 °C (scale A) at 1mm Hg (scale C)

Now what temperature would that same compound boil at 10 mm Hg pressure? Now we draw a line that passes through 280 °C on scale B (middle scale, the boiling point at 760 mm Hg) and to 10mm Hg on scale C. By extending that line to scale A, we can read off the new boiling point on scale A (left side) as being about 140 °C. Of course, you don't really have to "draw" the line, it can be done using the edge of a ruler or something else straight (Figure 1.5)

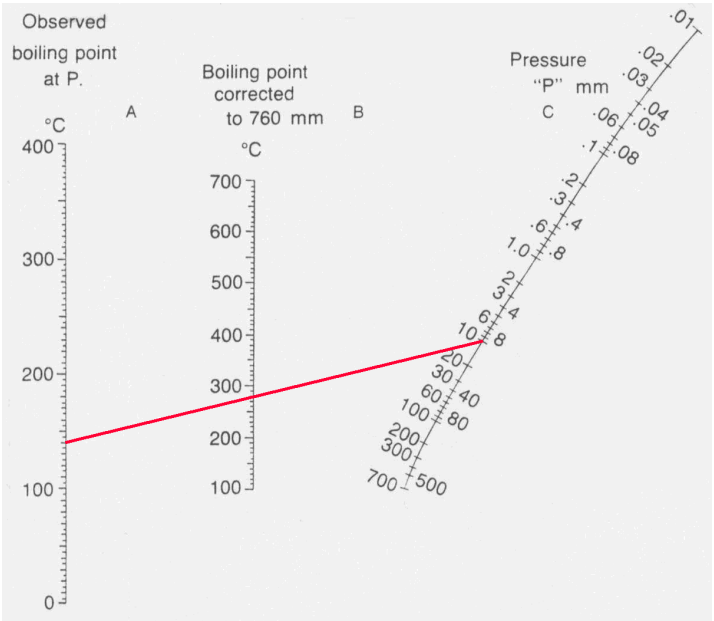



Figure 1.5: Using a pressure monograph: Determining the boiling point (scale A) at 10 mm Hg (scale C) for a sample that boils at 280 °C at 760mm Hg (scale B)

*Sample Preparation:*

Careless preparation of a sample is the leading cause of inaccurate and irreproducible results in boiling point determinations. The substance must be:

1. Fully dry (anhydrous)
2. Homogeneous
3. In liquid form

*Packing Sample tube:*

Put the sample liquid 1.0 – 2.0 mL in a small test tube and a short piece of melting point capillary tubing (sealed at one end) is dropped in with the open end down.

The small test tube assembly is attached to a thermometer with a rubber band or a thin slice of rubber tubing. (Figure 1.6).

*Sample tube attached to the thermometer:*

It is held by a rubber band or a thin slice of rubber tubing. It is important that this rubber band be above the level of the oil (allowing for expansion of the oil on heating) so that the oil does not soften the rubber and allow the capillary tubing to fall into the oil. If a cork or a rubber stopper is used to hold the thermometer, a triangular wedge should be sliced in it to allow pressure equalization.

*Determining:*

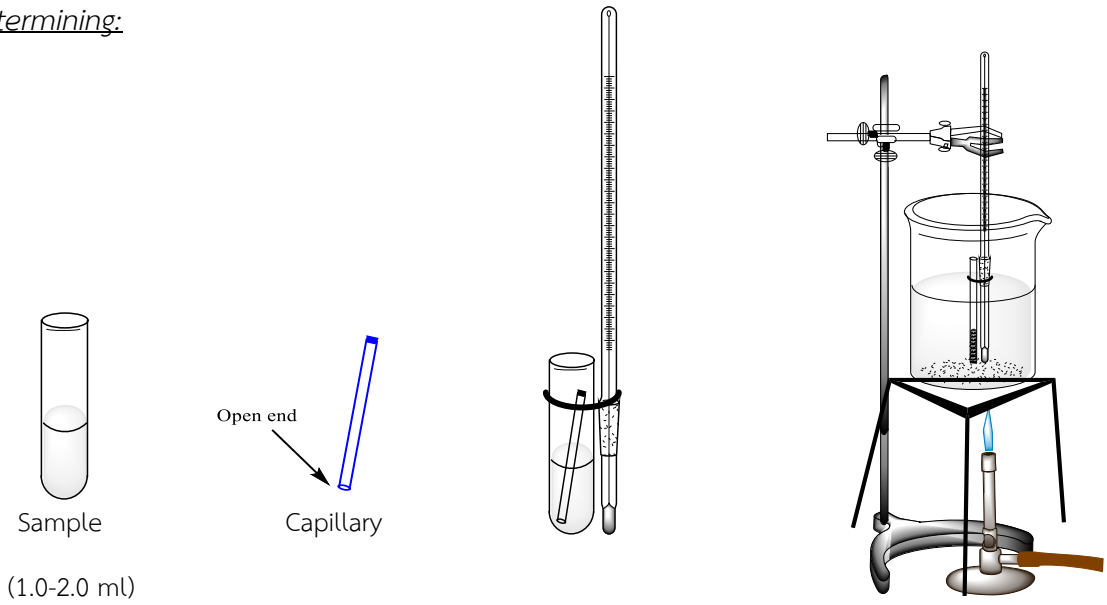



Figure 1.6: Packing sample and determination boiling point

Set boiling point apparatus as Figure 1.6.

The boiling point determination procedure, followed by virtually every modern instrument, involves three basic steps:

1. Initial stream of bubbles as dissolved air is expelled and then, a little later, a rapid and continuous stream of bubbles emerges from the inverted capillary tube.

2. At this point stop heating. Soon the stream of bubbles will slow down and stop. When they stop, the liquid will enter the capillary tube.

The moment when the liquid enters the capillary corresponds to the boiling point of the liquid, and the temperature is recorded (T1)

3. The slowly heating. The bubbles will come out the capillary tube.

The moment when the bubbles come out the capillary corresponds to the boiling point of the liquid, and the temperature is recorded (T2)

Boiling range = T1 – T2

T1: liquid enters the capillary

T2: bubbles come out the capillary

During the initial heating, the air trapped in the capillary tube expands and leaves the tube and vapour from the liquid also enters the tube. There is always vapour in equilibrium with a heated liquid. This gives rise to the initial stream of bubbles. When the temperature reaches the boiling point, the vapour pressure inside the capillary tube equals the atmospheric pressure. As the temperature rises just above the boiling point then the vapour will start to escape: the second set of bubbles.

Once the heating is stopped, the only vapour left in the capillary comes from the heated liquid which seals its open end. As the liquid cools, its vapour pressure will decrease and when the vapour pressure drops just below atmospheric pressure, the liquid will be drawn into the capillary tube (forced there by the higher atmospheric pressure. The common organic compounds are shown in Table 1.2.

Table 1.2: The Boiling point of common organic compounds

| Compounds | B.P. (°C) |
|---|---|
| Water | 100.0 |
| Methanol | 64.6 |
| Ethanol | 78.5 |
| Acetone | 56.4 |
| *n*-Butanol | 117.6 |
| *s*-Butanol | 98.0 |
| *t*-Butanol | 82.2 |

| | |
|---|---|
| Tetrahydrofuran (THF) | 66.0 |
| Hexane | 69.0 |
| Heptane | 98.0 |
| Ethyl acetate | 77.0 |
| Cyclohexane | 80.7 |
| Toluene | 110.6 |
| *o*-Xylene | 144.0 |
| *m*-Xylene | 139.1 |
| *p*-Xylene | 138.4 |

**Procedures**

*Part I: Melting point Determination of Pure Compounds A*

1) Set the apparatus in Figure 1.1
2) Determine the M.P. with the Thiele tube
3) Compare the M.P. range with standard on Table 1.1
4) Conclusion; what is Compound A

*Part II: Boiling point Determination of Pure Compounds B*

1) Set the apparatus in Figure 1.6
2) Determine the B.P.
3) Compare the B.P. range with standard on Table 1.2
4) Conclusion; what is Compound B

*Part III: Determination of Unknown..**X...** Liquid or Solid Sample*

1) Set the apparatus
2) Determine M.P. or B.P.
3) Compare the M.P. or B.P. range with standard on Tables 1.1 and 1.2.
4) Conclusion; what is the unknown liquid or solid?

**For your report**

1. Report M.P. and B.P. of pure compound then identify what are the compounds?
2. Report M.P. or B.P. of Unknown compound then identify what is the Unknown?
3. Discuss how experimental M.P. or B.P differ from the references? What can cause the errors?

# Experiment 2

# Chromatographic Adsorption

The most common method of separation mixtures available to the organic chemist all involve chromatography. Chromatography is defined as the separation of a mixture compounds or ions by distribution between two phases, one of which is *Stationary phase* and the other is *Mobile phase*. Many types of chromatography are possible, depending on the nature of the two phases involved:

**Solid-liquid** (column, thin-layer and paper)

**Liquid-liquid** (high-performance liquid)

**Gas-liquid** (vapor-phase)

All chromatography works on much the same principle. The methods depend on the differential solubility or absorptivity of the substances to be separated relative to the two phases between which they are to be partitioned. In this experiment, two types of Solid-liquid chromatography are presented: column chromatography and Thin- layer chromatography (TLC).

*Stationary phase (Adsorbents):*

Column chromatography is a technique based on both absorptivity and solubility. It is a solid-liquid phase-partitioning technique. The solid may be almost any material that does not dissolve in the associated liquid phase; the most commonly used solids are silica gel $SiO_2.xH_2O$, also called silicic acid, and alumina $Al_2O_3.xH_2O$. These compounds are used in their powdered or finely ground forms.

*Interactions:*

The most important interactions are those typical of polar organic compounds. Either these forces are of the dipole- dipole type or they involve some direct interaction (coordination, hydrogen bonding, or salt formation). These types of interactions are illustrated in Figure 2.1, which for convenience shows only a portion of the alumina structure. Similar interactions occur with silica gel. The strengths of such interactions vary in the following approximate order:

Salt formation > coordination > hydrogen bonding> dipole-dipole > van der Waals

Strength of interaction varies among compounds. For instance, a strongly basic amine would bind more strongly than a weakly basic one (by coordination). In fact, strong bases and strong acids often interact so strongly that they dissolve alumina to some extent.

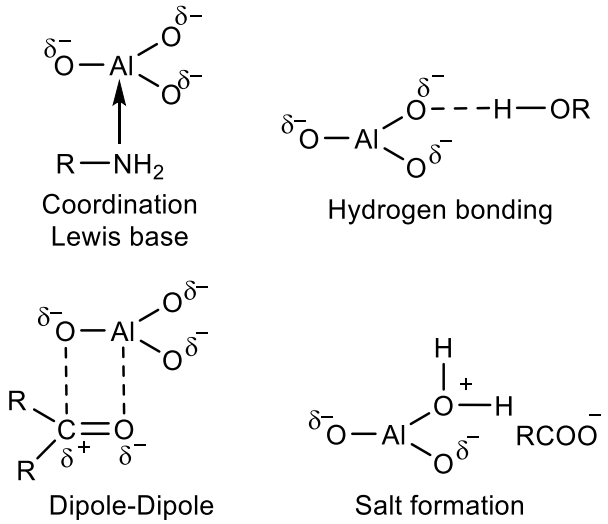



Figure 2.1: Interaction between silica gel and polar organic compound

*Parameters Affecting Separation*

The versatility of column chromatography results from the many factors that can be adjusted. These include

1. Adsorbent chosen
2. Polarity of the solvents chosen
3. Size of the column (both length and diameter) relative to the amount of material to be chromatographed
4. Rate of elution (or flow)

**2.1 Thin-layer Chromatography (TLC)**

TLC is a simple, quick, and inexpensive procedure that gives the chemist a quick answer as to how many components (qualitative analysis) are in a mixture. TLC is also used to support the identity of a compound in a mixture when the $R_f$ of a compound is compared with the $R_f$ of a known compound (preferably both run on the same TLC plate)

TLC is a very important technique for the rapid separation and qualitative analysis of small amounts of organic compounds. It is ideally suited for the analysis of mixtures and reaction products in experiments. This technique is closely related to column chromatography. In fact, TLC can be considered to be a type of column chromatography. TLC plates are coated with silica gel. In order to visualize UV-active organic compounds. The

silica gel is coated with a layer of fluorescent dye. Therefore, UV-active compounds can be detected under UV light and non-UV-active compounds are also seen.

Retention Factor ($Rf$) is a measurement of how far up a plate the compound travels. $Rf$ value is calculated by the distance of the center of the spot from the baseline (*P* or *SM*) divided by the distance of the solvent front from the baseline (*S*).

$$Rf = \frac{\textbf{the distance of the center of the spot from the baseline } (P)}{\textbf{the distance of the solvent front from the baseline } (S)}$$

In general, the eluting strength of commonly used solvents for normal phase chromatography where the stationary phase is silica gel neutral alumina ($SiO_2$/$Al_3O_3$) and the mobile phase is increasing order proceeds as follows:

hexane < cyclohexane < toluene < diethyl ether < dichloromethane <
ethyl acetate < acetone < ethanol < methanol < acetic acid.

The TLC developing procedure, followed by virtually every modern instrument, involves three basic steps:

*1. Prepare the developing tank*

The developing tank for TLC can be a specially designed chamber or a beaker with a watch glass on the top. Pour the mobile phase into the chamber to a depth of just less than 0.5 cm. Cover the beaker with a watch glass, swirl it gently, and allow it to stand while you prepare your TLC plate.

*2. Prepare the TLC plate*

TLC plates used are 2.5 cm x 5 cm sheets. Each large sheet is cut horizontally into plates which are 2.5 cm tall by various widths; the more samples you plan to run on a plate, the wider it needs to be. Handle the plates carefully so that you do not disturb the coating of adsorbent or get them dirty

*3. Spot the TLC plate*

The sample should be soluble in a solvent. Usually dissolve about 1 mg in 1 mL of a volatile solvent such as ethyl acetate or methylene chloride works well for TLC.

Take a micro capillary, Dip the micro capillary into the solution and then gently touch the end of it onto the proper location on the TLC plate.

*4. Develop the plate*

Place the prepared TLC plate in the developing tank, cover the tank with the watch glass, and leave it undisturbed on your bench top. The solvent will rise up the TLC plate by capillary action. Make sure the solvent does not cover the spot.

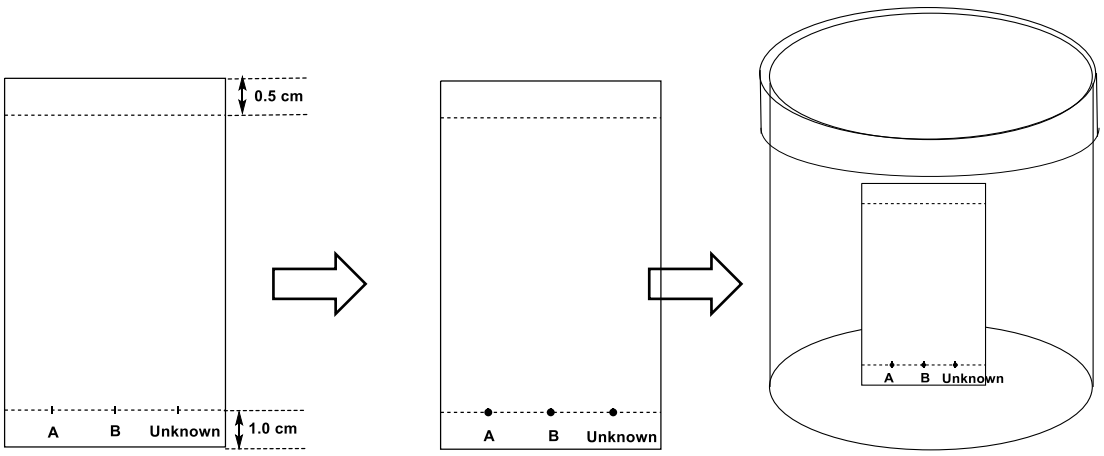
Allow the plate to develop until the solvent is about half a centimeter below the top of the plate. Remove the plate from the beaker and immediately mark the solvent front with a pencil. Allow the plate to dry.

*5. Visualize the spots*

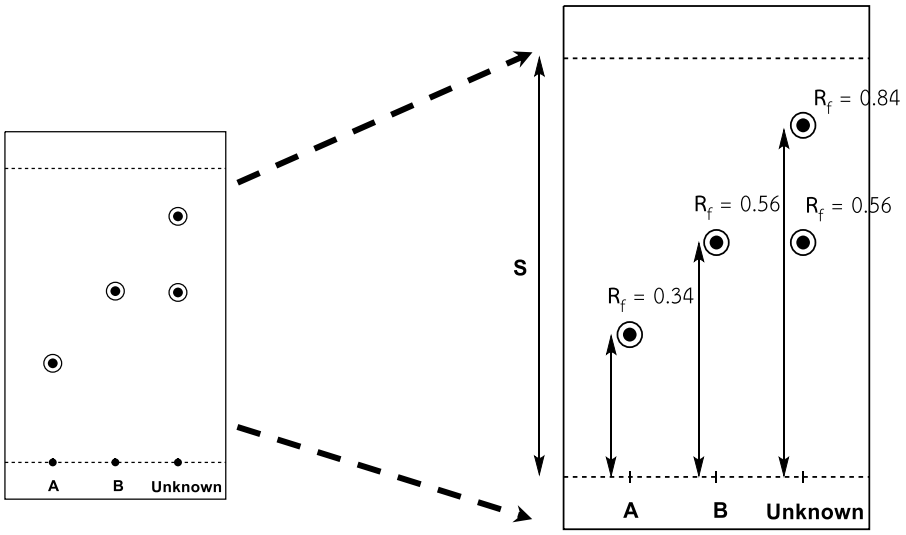
If there are any colored spots, **circle them lightly with a pencil**. Most samples are not colored and need to be visualized with a UV lamp. Hold a UV lamp over the plate and circle any spots you see. If samples are not visualized in UV light select one reagent for detect it.

Beware! UV light is damaging both to your eyes and to your skin! Make sure you are wearing your goggles and do not look directly into the lamp. Protect your skin by wearing gloves.

If the TLC plate runs samples which are too concentrated, the spots will be streaked and/or run together. If this happens, you will have to start over with a more dilute sample to spot and run on a TLC plate




a b c




d e

Figure 2.2: TLC preparation (a-b), Development (c) and Location (d-e)

If there are not visualize in UV light. The reagent that can be used to detect organic compound is as follows

A: Iodine ($I_2$)

Everything stains yellow. Add Solid $I_2$ to a developing chamber. The spots will fade, but the plate can be redeveloped.

B: *p*-Anisaldehyde Stain

The greatest advantage is that stains have different colors and are manifested on TLC on heating for different molecules.

C: Hanessian stain

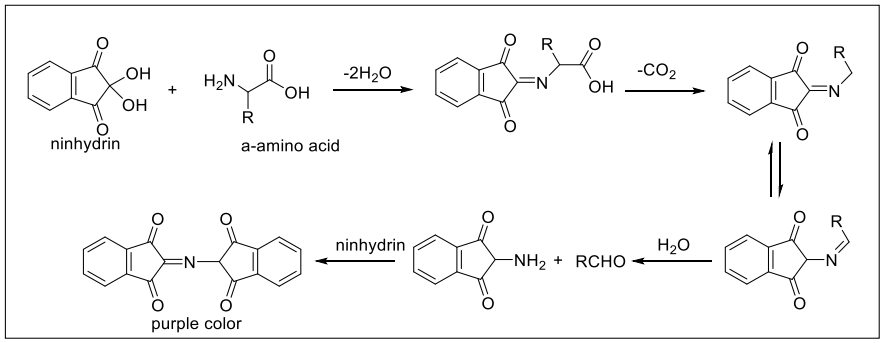
One of the most sensitive stains which detects most functional groups. The disadvantage is that everything stains blue.

D: $KMnO_4$

It can detect molecules with an oxidizable functional group. Everything stains yellow and the spots will be indistinguishable from the background.

E: Ninhydrin Stain

Especially sensitive to amino acids including amines and anilines




Scheme 2.1: The formation with Ninhydrin

**2.2 Column Chromatography (CC)**

Column chromatography is a method used to purify individual chemical compounds from mixtures of compounds. It is often used for preparative applications on scales from micrograms up to kilograms. The main advantage of column chromatography is the relatively low cost and disposability of the stationary phase used in the process. The latter prevents cross-contamination and stationary phase degradation due to recycling.

The classical preparative chromatography column, is a glass tube with a diameter from 5 mm to 50 mm and a height of 5 cm to 1 m with a tap and some kind of a filter at the bottom. Two methods are generally used to prepare a column: the dry method, and the wet method.

**For the dry method**, the column is first filled with dry stationary phase powder, followed by the addition of mobile phase, which is flushed through the column until it is completely wet, and from this point is never allowed to run dry.

**For the wet method**, a slurry is prepared of the eluent with the stationary phase powder and then carefully poured into the column. Care must be taken to avoid air bubbles. A solution of the organic material is pipetted on top of the stationary phase. This layer is usually topped with a small layer of sand or with cotton or glass wool to protect the shape of the organic layer from the velocity of newly added eluent. Eluent is slowly passed through the column to advance the organic material. Often a spherical eluent reservoir or an eluent-filled and stoppered separating funnel is put on top of the column.

The individual components are retained by the stationary phase differently and separate from each other while they are running at different speeds through the column with the eluent. At the end of the column they elute one at a time. During the entire chromatography process the eluent is collected in a series of fractions. Fractions can be collected automatically by means of fraction collectors. The productivity of chromatography can be increased by running several columns at a time. In this case multi stream collectors are used. The composition of the eluent flow can be monitored and each fraction is analyzed

for dissolved compounds, e.g. by analytical chromatography, UV absorption, or fluorescence. Colored compounds (or fluorescent compounds with the aid of an UV lamp) can be seen through the glass wall as moving bands.

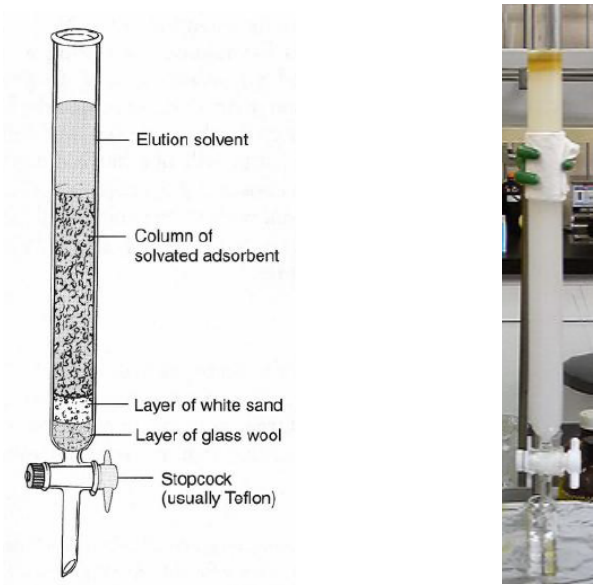



Figure 2.3: Chromatographic column

As the components of the mixture are separated, they begin to form moving bands (or zones), with each band containing a single component. If the column is long enough and the other parameters (column diameter, adsorbent, solvent, and flow rate) are correctly chosen, the bands separate from one another, leaving gaps of pure solvent in between. As each band (solvent and solute) passes out from the bottom of the column, it can be collected before the next band arrives. If the parameters mentioned are poorly chosen, the various bands either overlap or coincide, in which case either a poor separation or no separation is the result. A successful chromatographic separation is illustrated in Figure 1.3.

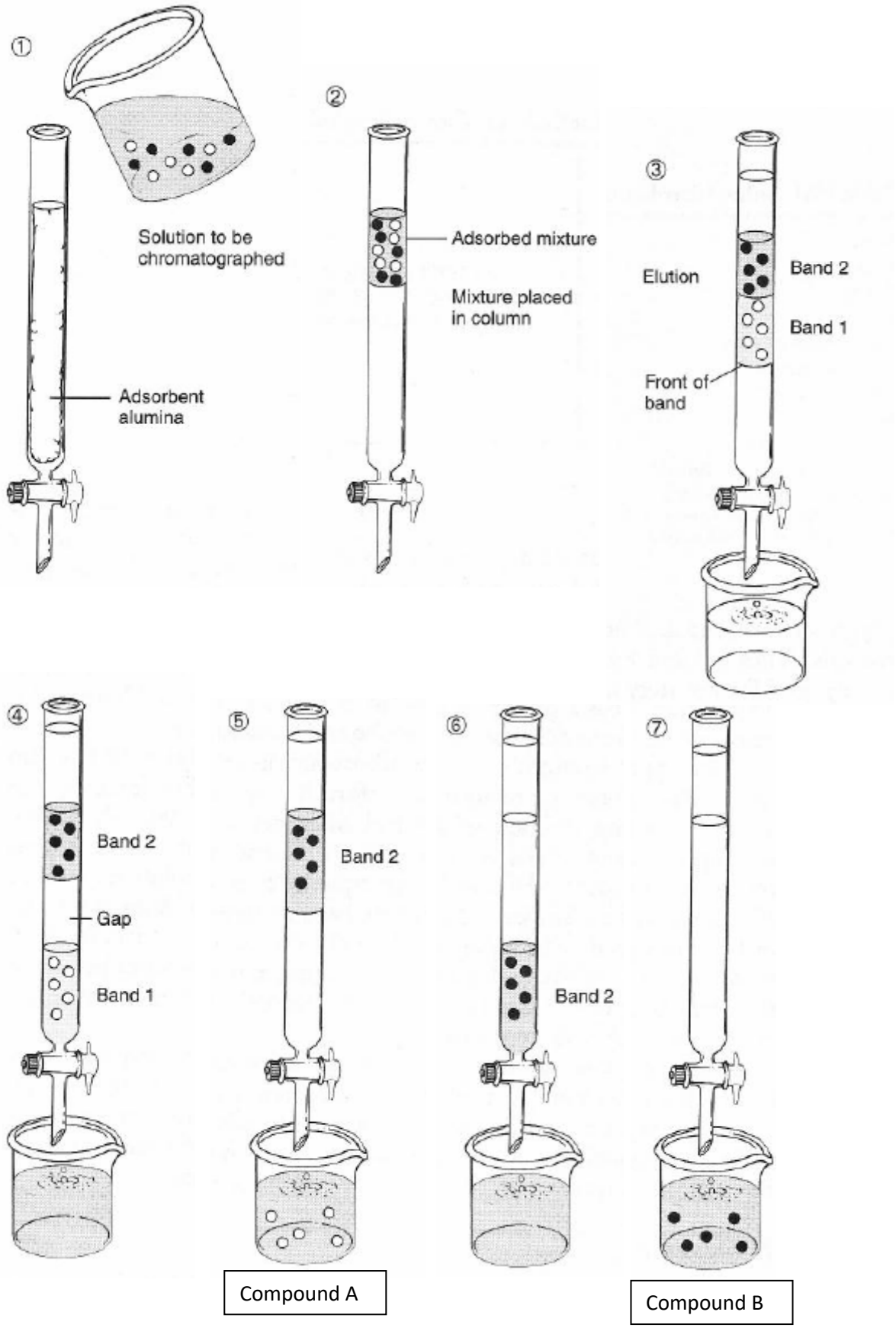



Figure 2.4: Sequences of steps in a chromatographic separation

**Procedures 1 (TLC)**

The following procedures can be used to identify an unknown organic mixture and separation of plant pigments.

*1. Preparation of the developing tank*

- 10 mL of mobile phase is a 20:80 mixture of ethyl acetate and hexane. Pour "mobile phase" into a tank.

*2. Preparation of TLC*

- With a lead pencil, draw a base line and solvent font line.
- Along this line, mark off tick marks 0.5 cm apart. 4 tick marks.
- Using a glass capillary tube, dip a small volume of:
    1) $\beta$-naphthol solution
    2) Diphenylamine solution
    3) Unknown No. ....X....
    4) Pigment plant
- Gentle touching the capillary to one of the tick marks.
- Allow the spots to dry before developing the chromatogram.

*3. Development of the chromatogram*

- Put the TLC at the development tank. Cover it.
- Let the solvent run up the chromatogram until get the solvent front (top of the chromatogram). At this point remove the TLC.

*4. Location of the organic compound of chromatogram*

- Put the chromatogram into UV box. The spots are visible.
- Circle spots with a pencil. Mark the center of each spot, as best you can judge and record color of the spot.

**Procedures 2 (Column Chromatography)**

*1. Packing the Column: Slurry Method*

1. Combine the solid stationary phase (Silica gel) with a small amount of solvent (.....) in a Erlenmeyer flask
2. Position a plug of cotton with solvent in the bottom
3. Pour this homogeneous mixture into the column as carefully as possible using a spatula to scrape out the solid as you pour the liquid.
4. Once the column is loaded, open the stopcock and allow the solvent level to drop to the top of the packing, but do not allow the solvent layer to go

below this point. Allowing this solvent level to go below the stationary phase should always be avoided.

*2. Adding the Sample*

The sample can be loaded directly to the top of the column.

1. Use a minimum amount of a polar solvent, 5-10 drops to dissolve the mixture.
2. The solution is then carefully added to the top of the column using a dropper without disrupting the flat top surface of the column (A thin horizontal band of sample is best for an optimal separation).
3. Continuously add the solvent eluent while collecting small fractions at the bottom of the column. Using a dropper to add the first bit of solvent on top of the packing, and sample will minimize disturbance of the column and diluting the sample.
4. Collecting small fractions (1-3 mL) or as your observe (color band).

*3. TLC*

Identification of a fractions band using TLC plate. Using a glass capillary tube, dip a small volume of the collecting fractions

1. Developing the chromatogram in development tank using mobile phase system, visualize with UV light.
2. Draw TLC plate with located spot and $R_f$ of organic compound (each spot). Compare fractions band spot. Explain why

**For your report**

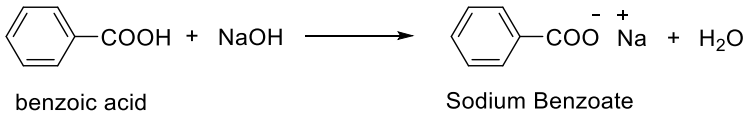
1. Draw TLC plate with located spot and $R_f$ of organic compound (each spot)
2. Based on your results, how many components are in unknown No....and pigment plant.
3. Compare the unknown No...X.... and pigment plant spot with standard $\beta$-naphthol solution and Diphenylamine. Explain why.

# Experiment 3

## Acid-Base Extractions, Separations and Drying Agents

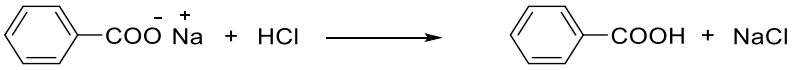
A commonly used method for separation a mixture of organic compounds is known as liquid-liquid extraction. Most reactions of organic compounds require extraction at some stage of product purification. In this experiment you will use extraction techniques to separate a mixture of an organic acid, a base, and a neutral compound. Organic acids and bases can be separated from each other and from neutral compounds by extraction using aqueous solutions of different pH values.

**Organic acids:** Most organic carboxylic acids are insoluble or slightly soluble in water, but these compounds are highly soluble in dilute aqueous sodium hydroxide because the acid is deprotonated by the base producing the sodium carboxylate salt.



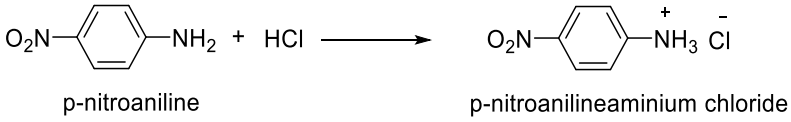

Scheme 3.1: Benzoic acid in NaOH solution

The carboxylic acid can be selectively isolated by dissolving the mixture in an organic solvent that is immiscible with water, and then extracting the solution with sodium hydroxide. The basic aqueous solution containing the carboxylate salt is acidified, causing the sodium carboxylate salt to convert back to the carboxylic acid, which is not water soluble. The acid will precipitate from the solution, as shown here.



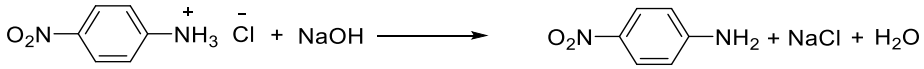

Scheme 3.2: Sodium benzoate in HCl solution

**Organic bases** (e.g., amines): that are insoluble in water can be separated by extraction with hydrochloric acid. Addition of HCl to the amine produces the corresponding ammonium salt, which is soluble in water but not in organic solvents.



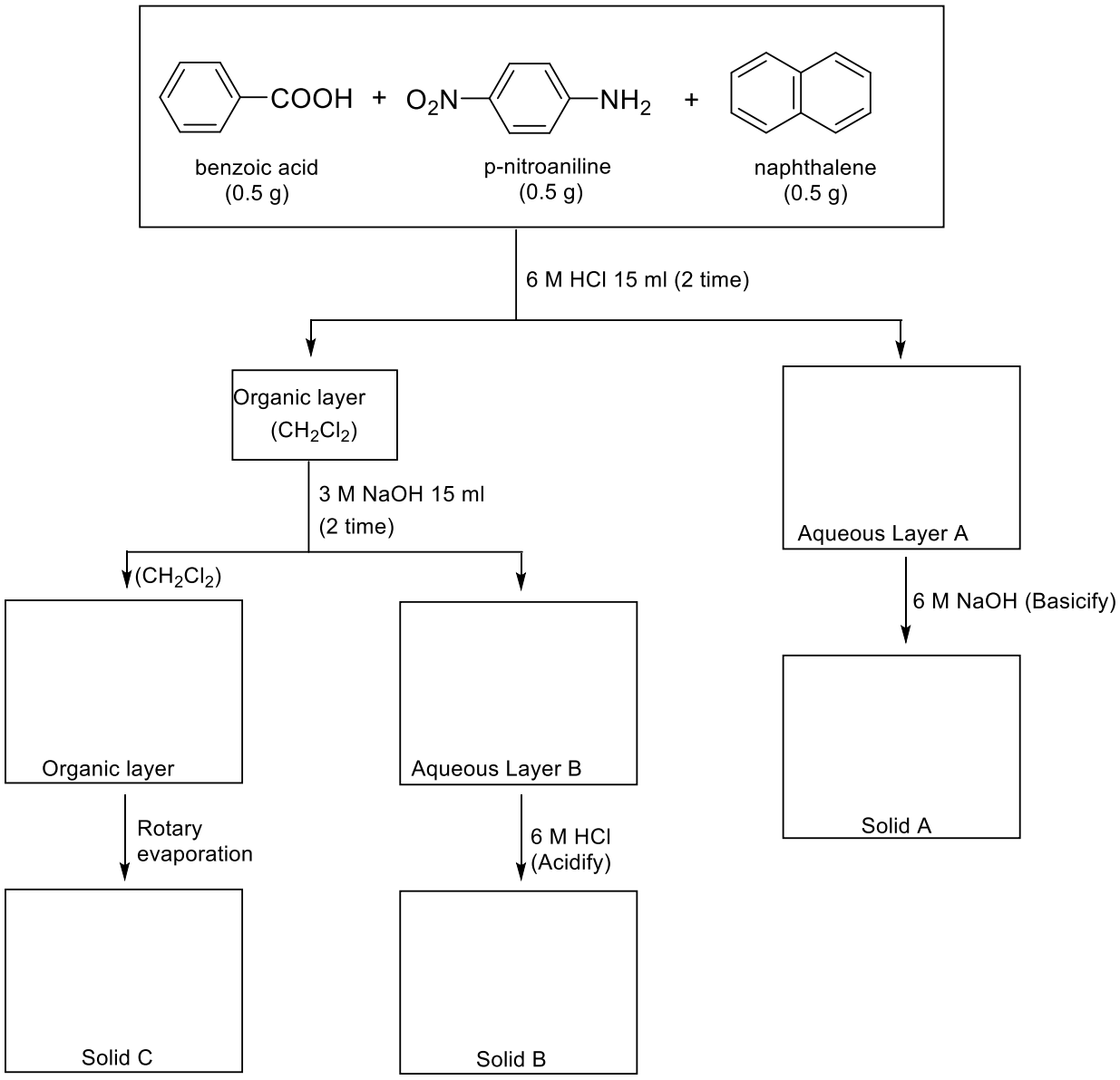

Scheme 3.3: *p*-nitroaniline in HCl solution

The amine can be recovered from the aqueous solution by treatment with a base, converting the ammonium salt back to the amine. The amine is not water-soluble and will precipitate, as shown here.




Scheme 3.4: *p*-nitroaniline ammonium chloride in NaOH solution

Using your understanding of these properties, separation of a mixture containing a carboxylic acid, an amine, and a neutral compound can be carried out via sequential acid and base extractions. The precipitates will be collected and characterized by melting temperature analysis.




Scheme 3.5: Acid-base Extractions

**Procedures**

*Part 1: Extraction*

1. Weigh 1.50 g of the mixture sample. Transfer the mixture to a 100 mL separation funnel and dissolve it in 30 mL of dichloromethane (DCM).

2. Clamp the support ring onto a ring stand and place the separation funnel into the ring. Add 10 mL of 6.0 M hydrochloric acid (HCl).

3. Gently shake several times, open the stopcock to release the pressure. Place the funnel on a support ring and allow the solvent and aqueous layer to separate.

4. Open valve of separator funnel; keep the **lower organic layer** (DCM layer) into a 50 mL Erlenmeyer flask. And drain the **upper aqueous layer A** into the Erlenmeyer flask

5. Repeat the extraction with another 10 mL of 6.0 M hydrochloric acid (HCl), draining the second aqueous layer into the same Erlenmeyer flask **(*Aqueous layer A*)**. And save the organic layer (DCM layer) in the separator funnel for later use.

- Cool the flask containing the acidic aqueous extracts **(*Aqueous layer A*)** into an ice water bath. Slowly add 6.0 M sodium hydroxide (NaOH) until the aqueous layer is basic. Use pH paper to test. (*Solid appear*)
- Collect the ***Solid A*** using vacuum filtration and save the solid for TLC analysis in Part II.

6. Extract the Organic layer (DCM layer) in the separator funnel with 10 mL of 3.0 M sodium hydroxide (NaOH). Drain the aqueous layer into a 50 mL Erlenmeyer flask **(*Aqueous layer B*)**. Repeat the extraction with another 10 mL of 3.0 M sodium hydroxide (NaOH). Save the Organic layer (DCM layer) in the separator funnel.

- Cool the flask containing the basic aqueous extract **(*Aqueous layer B*)** in an ice water bath. Slowly add 6.0 M hydrochloric acid (HCl) until the aqueous layer is acidic. Use pH paper to test.

- Collect the ***Solid B*** using vacuum filtration and save the solid for TLC analysis in Part II.

7. Add 20 mL of saturated aqueous sodium chloride solution to the organic layer remaining in the separator funnel and shake gently. Allow the layers to separate.

8. Open valve; keep the organic layer into an Erlenmeyer flask containing approximately 1 g of anhydrous sodium sulfate ($NaSO_4$) and allow it to stand for about 10 minutes, swirling occasionally **(*Organic layer C*)**.

9. Gravity filter into a clean 100 mL round-bottom flask. Evaporate the DCM in the Rotary evaporator **(*Solid C*)**.

10. Weigh the recovered solid and record the Mass, Calculate **% recovery** and Save the solid for the TLC analysis in Part II.

*Part 2: Qualitative with TLC*

1. Obtain a small amount of the isolated solid (A-C) dissolve in a small amount of DCM solvent. And spot on TLC plate with standard benzoic acid, *p*-nitroaniline and naphthalene.
2. Developing the chromatogram in development tank using mobile phase system EtOAc : Hexane (30:70), visualize with UV light.
3. Report sheet. R□ of organic compounds
4. Complete the box in Scheme 3.1

**For your report**

1. Calculate the percent yield of your product.
2. Complete the boxes in Scheme 3.5. Explain why.
3. Based on your results, Draw TLC plate and identify the product.

# Experiment 4

# Alkane, Alkene and Alkyne

## Alkane

Alkanes and cycloalkanes are saturated hydrocarbons which contain only hydrogen and carbon connected together by only single bonds. They are generally chemically inert, however, the reaction of alkanes can occur at appropriate conditions. In halogenation reaction, light or elevated temperature is needed as a catalyst to facilitate the reaction. Hydrogen atom will be substituted by halogen atom such as bromine (Br) or chlorine (Cl).

$$R\text{-}H + X_2 \xrightarrow[\text{or heat}]{\text{light}} R\text{-}X + HX$$

Order of reactivity of halogen are as following; $X_2$; $F_2 > Cl_2 > Br_2$, however, $I_2$ is not reacting. This reaction is purposed to take place through free-radical mechanism.

There are various products from this halogenation reaction depended on stability of radical intermediate and possibility of each hydrogen atom on deprotonating step. As an example;

$$2CH_3\text{-}CH_2\text{-}CH_3 \xrightarrow[\text{light}]{Cl_2} CH_3\text{-}CH_2\text{-}Cl + \underset{\displaystyle Cl}{\overset{\displaystyle CH_3\text{-}CH\text{-}CH_3}{|}} + 2HCl$$

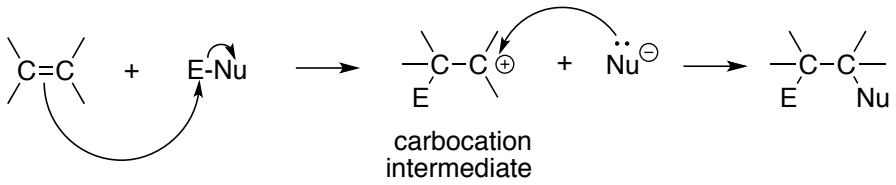
This reaction is called “ Substitution reaction” when a hydrogen atom of alkane is replaced by halogen atom to give a mix of halogenated compounds and an acid. This acid can be tested by placing wetted Litmus paper over reaction tube which turns from blue to red in the presence of acids.

## Alkene

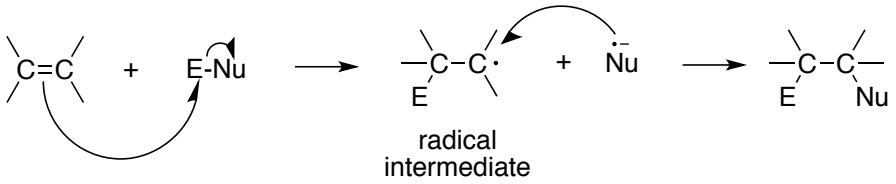
Alkenes and cycloalkenes are classified as unsaturated hydrocarbons which contain double bonds ($1\sigma$-bond+$1\pi$-bond). This group of hydrocarbons is generally reactive in chemical reactions especially addition reactions of electrophilic reagents to the double bonds as following;

π-electron of alkene will act as a nucleophile reacting with an electrophile (A-B) to give a saturated product. Mechanism of this reaction are generally founded in two ways, ionic addition reaction and free radical addition reaction depending on reaction conditions and reagents.

Ionic mechanism,

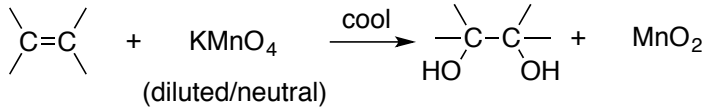



Free radical mechanism



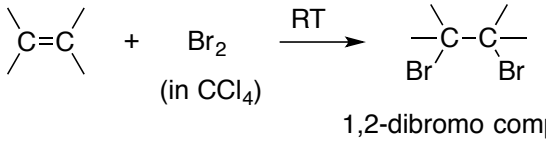

Unlike substitution reactions, addition reactions do not require catalyst. Various types of reagents can react with alkene such as $H_2$, $Br_2$, $Cl_2$, HX, $H_2O$ and $KMnO_4$, etc.

**a) Oxidation by potassium permanganate ($KMnO_4$)**



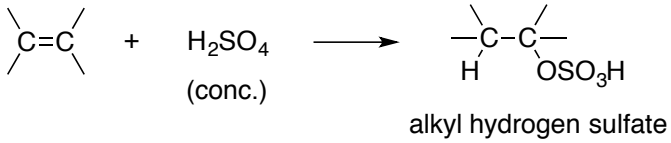

Oxidation of unsaturated compounds by a strong oxidant $KMnO_4$ causes the decoloration of $KMnO_4$ and formation of brown precipitate of manganese dioxide ($MnO_2$). This method is used as a qualitative test for unsaturation called "Baeyer's Test for unsaturation". Saturated compounds and aromatic compounds will be negative to this test.

**b) Addition reaction with bromine**



Decoloration of bromine by unsaturated compounds is an addition reaction forming 1, 2-dibromo compound. Unlike the substitution reaction of alkanes with bromine, HBr will not be produced from this reaction.

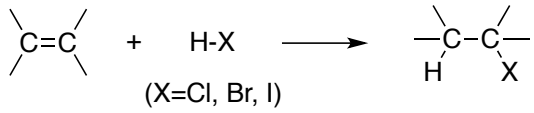
**c) Addition reaction with sulfuric acid**



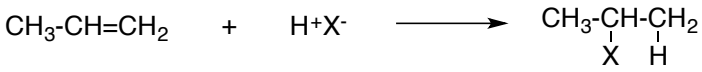

alkyl hydrogen sulfate

Alkene reacts with concentrated $H_2SO_4$ to produce alkyl hydrogen sulfate and heat which unlike alkane. This reaction can be used to distinguish alkane from alkene.

**d) Hydrohalogenation of alkene**

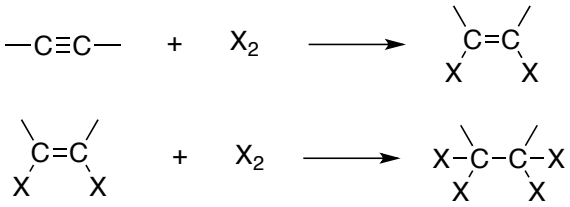



Hydrohalogenation is an addition reaction of HX to alkene which generates alkyl halide. When adding HX to unsymmetrical alkene, the reaction follows Markovnikov's rule which hydrogen will first add to the least substituted carbon generated the most stable carbocation then halide anion will add to the carbocation.

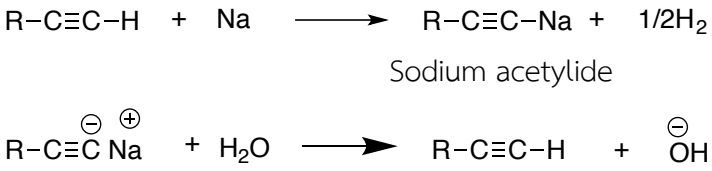



<u>Alkyne</u>

Alkyne contains triple bonds which composes of one $\sigma$-bond and two $\pi$-bonds. They are very reactive to the reactions including addition reactions same as alkenes but the reaction can occur twice (have two $\pi$-bonds to add). The reaction mechanism is the same as what happen in alkene.



For terminal alkyne which has a hydrogen attach to the *sp*-carbon, this hydrogen is acidic and reactive with metals such as Na, K, Ag, etc., generating flammable hydrogen gas and sodium acetylide. When adding water to the resulting solution, acetylide anion will deprotonate hydrogen from water and generates hydroxide anion which is basic and changes red litmus paper to blue.

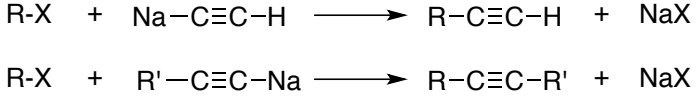



Acetylene gas can be freshly prepared in laboratory from the reaction of calcium carbide ($CaC_2$) with water. This reaction gives pungent smell of hydrides of P, As and S while pure acetylene gas does not smell. Acetylene gas will be purged into the reaction vessel containing other reagents (HX = HCl, HBr and HI) to pursue the reaction.

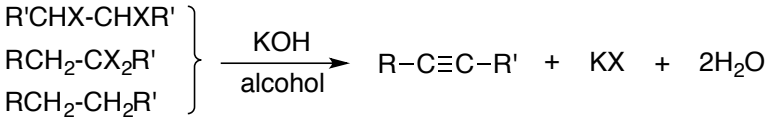
*The generation of acetylene gas*

Other alkynes can be prepared from various reactions such as following;

a) Alkylation of acetylene or monoalkylated acetylene using alkylating agent such as;



b) Elimination of two moles of HX from dihalides using alcohol, KOH or $NaNH_2$



c) Elimination of four halogen atoms from tetrahalides using Zinc/alcohol

$$RCX_2\text{-}CX_2R + 2Zn \xrightarrow{\text{alcohol}} R{-}C{\equiv}C{-}R' + 2ZnX_2$$

**Procedures**

Reagents and equipment

- Equipment
  1. test tube
  2. dropper
  3. beaker
  4. gas collecting kit
- Reagents
  1. An alkane
  2. An alkene
  3. concentrated $H_2SO_4$
  4. 0.3% $KMnO_4$
  5. 1% $I_2$/KI
  6. $CaC_2$
  7. $H_2O$
  8. Ethanol
  9. Benzene
  10. Na metal

Procedure

**Part 1** Alkane vs. Alkene

A. Solubility test

Put 1.0 mL of water, ethanol and benzene in three separated test tubes then add 3 drops of an alkane (drop-wise) into each tube, observe and record the result. Repeat the whole experiment with an alkene.

B. Decoloration of iodine

Put 1.0 mL of an alkane into two test tubes. Put 5 drops of 1% $I_2$/KI into each tube, cap each tube with a wooden cork and gently check the tubes. Put one tube in dark cupboard and put another tube under light (or sunlight) for 15 minutes. Compare color of each tube and record the results. Put wetted blue litmus paper on top of the tubes to test for HBr, record your observation. Repeat the whole experiment with an alkene.

C. Decoloration of $KMnO_4$ (neutral)

Put 0.5 mL of an alkane into a test tube together with 0.5 mL of 0.3% $KMnO_4$. Check the tube and record your observation. Repeat the whole experiment with an alkene.

D. Addition reaction of $H_2SO_4$

Put 1.0 mL of an alkane into a test tube, slowly add 1.0 mL of conc. $H_2SO_4$. Check the tube and record your observation. Is there any heat generated? Repeat the whole experiment with an alkene.

**Part 2** Reactions of Alkyne

A. Reaction with iodine

In hood, purge acetylene gas generated from gas collecting kit into 1.0 mL of $I_2$/KI solution in test tube. Shake the tube and record your observation.

B. Baeyer's Test for unsaturation

In hood, purge acetylene gas generated from gas collecting kit into 0.5 mL of 0.3% $KMnO_4$ solution in test tube. Shake the tube and record your observation.

C. Acidity test

Put 0.5 mL of benzene into test tube. Purge acetylene gas into the solution then put a small piece of Na metal. Pour the mixture onto a watch glass (put undissolved Na metal in ethanol), leave benzene evaporates to dryness. Record the observation then add 4-5 drops of water, test basicity by litmus paper then record the result.

CAUTION! Put remaining undissolved Na metal in ethanol. DO NOT dispose it in the sink since Na vigorously reacts with water which can catch fire or cause skin and eye damage.

**For your report**

1. Report results of each testing of alkane alkene alkyne and Unknown
2. Write reactions of each compound in each testing
3. Discuss how each compounds react differently/similar on each test

# Experiment 5

## Stereochemistry, Addition Reaction: Camphor Reduction

Reactions and interconversions of compounds in the monoterpene series have been of great importance in studying the mechanism of carbocation rearrangements and the stereoselectivity of various reagents and synthetic reactions. Typical monoterpenes are the ketone camphor and the corresponding epimeric alcohols borneol and isoborneol.

In this experiment, you will reduce camphor, a naturally occurring ketone, using sodium borohydride ($NaBH_4$). Camphor is an example of a bridged bicyclic molecule: a molecule with multiple rings that share non-adjacent atoms called bridgeheads. Camphor is a substituted bicyclo2. 2. 1] heptane. The enclosed numbers represent the size of the "bridges" that are attached to the bridgeheads.

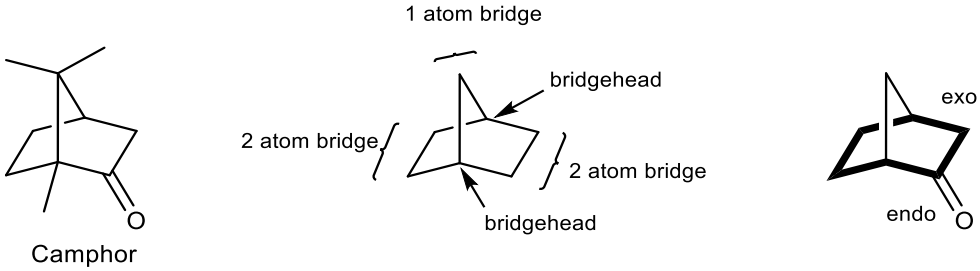
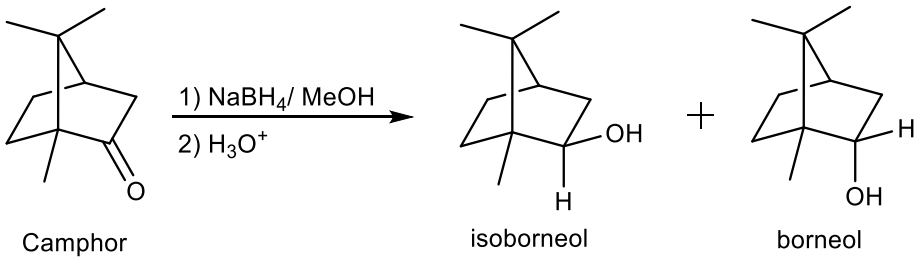



Figure 5.1: The Bridges bicyclic molecule

Bridged bicyclic systems of camphor have rigid conformations. The six- membered ring highlighted in the figure is in a boat conformation (recall the chair conformation of cyclohexane). When there is a planar functional group like an alkene or a carbonyl, the faces are defined as **exo** and **endo**, referring to the "**outside**" and "**inside**" of the boat-shaped ring. Reacting partners can approach from either of these faces, resulting in different products.

There are many reagents that are useful for the reduction of various carbonyl compounds. The complex hydrides $NaBH_4$ and $LiAlH_4$ are among the most useful reagents available for the conversion of carbonyl compounds to alcohols. Sodium borohydride is the less reactive of the two; for example, esters and acids are not affected. Sodium borohydride is very convenient to use, since reactions can be carried out in aqueous or alcoholic solutions. The reduction of bicyclic ketones such as camphor and norcamphor with these hydrides is quite stereoselective, with one of the two diastereomeric alcohols being formed in over nine times the amount of the other.




Scheme 5.1: The reduction reaction of camphor

***Procedure***

1. Weigh 1.00 g of camphor and dissolve in 25 mL anhydrous MeOH in 100 mL of round-bottom flask.
2. Add 0.62 g of $NaBH_4$ to the camphor solution, stirring the reaction mixture during the addition.
3. Attach an air condenser and gently reflux the mixture for 10 min.
4. After cooling the reaction mixture to room temperature, carefully add 10 mL of ice-cold water.
5. Extracted with 15 mL of dichloromethane (two times) and dry the solution over $Na_2SO_4$.
6. Remove the solvent by rotary evaporator or gently evaporate the solvent on a hot plate under the hood.
7. Recrystallize with MeOH and collect the solid with vacuum filtration.
8. Determine the weight of the dry solid and calculated %yield.
9. Identify the product with TLC use mobile phase as EtOAc: Hexane (20:80) and visualize with *p*-Anisaldehyde solution.

**For your report**

1. Calculate the percent yield of your product.
2. Draw the mechanism of Major and Minor products. Explain why.
3. Based on your results, draw TLC plate, and identify the major product as either the endo or exo product. Explain why?

# Experiment 6

## Extractions and Crystallization of Caffeine Part 1

The primary method for purify organic compounds is recrystallization. The reaction mixtures or natural product mixtures always contain impurities. The impurities may include some combination of insoluble, soluble, and colored impurities. The solubility of organic compounds is an important thing to consider

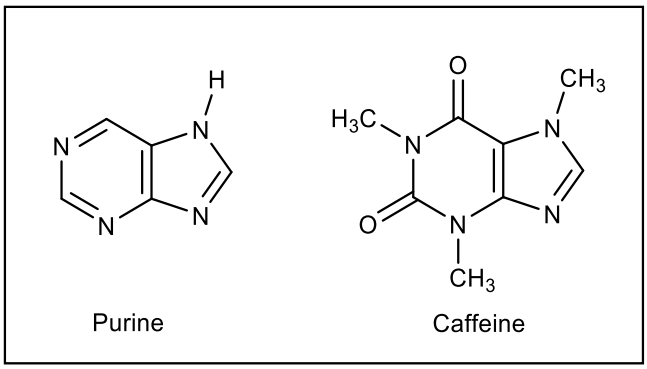



Figure 6.1: Structure of Purine and Caffeine

Caffeine is an alkaloid compound. Alkaloids are nitrogen containing basic compounds that are found in plants. They usually taste bitter and often are physiologically active in humans. The names of some of these compounds are familiar to you even if the structures aren't: nicotine, morphine, strychnine, and cocaine. The role or roles these compounds play in the life of the plants in which they are found is not well understood. In some cases they may act as pesticides; nicotine is found in tobacco and has been sprayed onto other plants, in which it is not normally found, to function as an insecticide. The structure of caffeine is shown to the right of Figure 6.1. It can be considered to be constructed from the purine ring system, which is important biologically, being found in nucleic acids and elsewhere.

Caffeine is found in a number of foods ingested by people. Caffeine acts as a stimulant. It stimulates the heart, respiration, the central nervous system, and is a diuretic. Its use can cause nervousness, insomnia and headaches. It is physically addictive. A person who drinks as few as 4 cups of coffee a day and who attempts to stop " cold turkey" may experience headache, insomnia, and possibly nausea as the result of withdrawal.

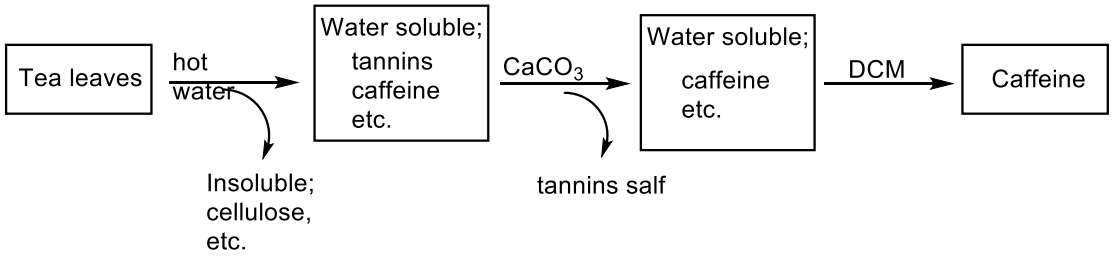
Table 6.1: The amount of caffeine in coffee tea

| Type of coffee and tea | Quantity (mg/30 mL) |
|---|---|
| Coffee, espresso | 40-75 |
| Mcdonald's brewed | 6 |
| Mcdonald's Mocha | 7 |
| Starbucks Latte | 9 |
| Starbucks brewed | 20 |
| Black tee | 2-8 |
| Green tea | 0-2 |
| Lipton brisk lemon | 1 |
| Coca-Cola | 2-3 |
| 7UP | 0 |
| Pepsi | 3-4 |

Adapted from Journal of Food Science, 2010; Pediatrics, 2011; USDA National Nutrient Database for Standard Reference, Release 23, 2010; Journal of Analytical Toxicology, 2006; Starbucks, 2011; McDonald's, 2011

Tea has been consumed as a beverage for almost 2,000 years, starting in China. It is a beverage produced by steeping in freshly boiled water the young leaves and leaf buds of the tea plant, *Camellia sinensis*. Today, two principal varieties are used, the small-leaved China plant (*C. sinensis sinensis*) and the large-leaved Assam plant (*C. sinensis assamica*). Hybrids of these two varieties are also grown. The leaves may be fermented or left unfermented. Fermented teas are referred to as black tea, unfermented teas as green tea, and partially fermented teas as oolong. As trade routes opened to Asia in the 17th century, tea was imported to Europe.

Today, you are going to make a small but strong cup of tea and extract the caffeine from it.




Scheme 6.1: Extraction of tea leaves

**Procedures**

*Part 1: Dissolution of Caffeine in Water*

1. Weigh about 15.00 g of tea and 4.00 g of calcium carbonate ($CaCO_3$) in the 250 mL beaker. Record actual weight.
2. Add 100.00 mL of distilled water to the beaker.
3. Boil on hot plate for 15-20 minutes while stirring occasionally.
4. After the boiling period is over, filter the hot solution with cotton to remove any solid particles. Leave it to room temperature.

*Part 2: Transfer of Caffeine from water to dichloromethane (DCM) (Extraction)*

1. Extraction with 40.0 mL of DCM 2 time.
2. Save the Organic layer (DCM layer) in the Erlenmeyer flask.
3. Add anhydrous $MgSO_4$ to remove water.
4. Carefully drain the DCM solution (about 40 mL) in Erlenmeyer **flask A** and **B**.
5. Remove the DCM from Solution **flask A** and **B** using hot plate in the fume Hood (BP. of DCM is 39.6 $^{O}$C). Reduce the solution down to about 2 mL and then remove from the hot plate.

   *"**For Flask B,** transfer to culture dish and Keep for Experiment 7"*

*Part: 3 Crystallization of Caffeine **Flask A** (dissolve at hot but non-dissolve at cool)*

1. Dissolve the crude **Flask A** with hot acetone ($CH_3COCH_3$) on hot plate. Until, The solid completely dissolves.
2. Remove from the hot plate. Allowing the hot mixture to slowly cool to room temperature and cooling further in an ice bath. Crystals will appear. If not, remove the acetone with hot plate.
3. Collect the caffeine crystal with vacuum filtration. Record actual weight. What was your percentage yield of caffeine in tea leaves?

**For your report (Write report of Caffeine Part1+2 together)**

1. Record physical appearance and actual weight of caffeine from two methods (recrystallization and sublimation)
2. Calculate %yield of caffeine in tea leaves separated by two methods
3. Compare the result of two method. What is the better process for caffeine purification? Explain why?

# Experiment 7

# Sublimation: Caffeine Part 2 amd Simple Distillation of Mixed Compounds

## 7.1 Sublimation: Caffeine Part 2

The sublimation process is the transition of a substance from a solid phase to an immediate gas phase, where it does not pass through a transitional liquid phase.

Normally the sublimation process is used to purify the crude substance without decomposition and the impurities cannot sublimate. Sublimation is much easier than evaporation from the melt, because the pressure of their triple point is very high, and it is difficult to obtain them as liquids.

Sublimation is a faster method of purification than recrystallization but not so selective. It is most effective in removing a volatile substance from a nonvolatile substance, particularly a salt or other inorganic material. Sublimation is also effective in removing highly volatile bicyclic or other symmetrical molecules from less volatile reaction products such as borneol, isoborneol and camphor.

In this experiment, Caffeine can be purified by sublimation process because of the properties of caffeine, M.P. 235-238 °C and B.P. 178 °C that mean caffeine does not pass through a transitional liquid phase.

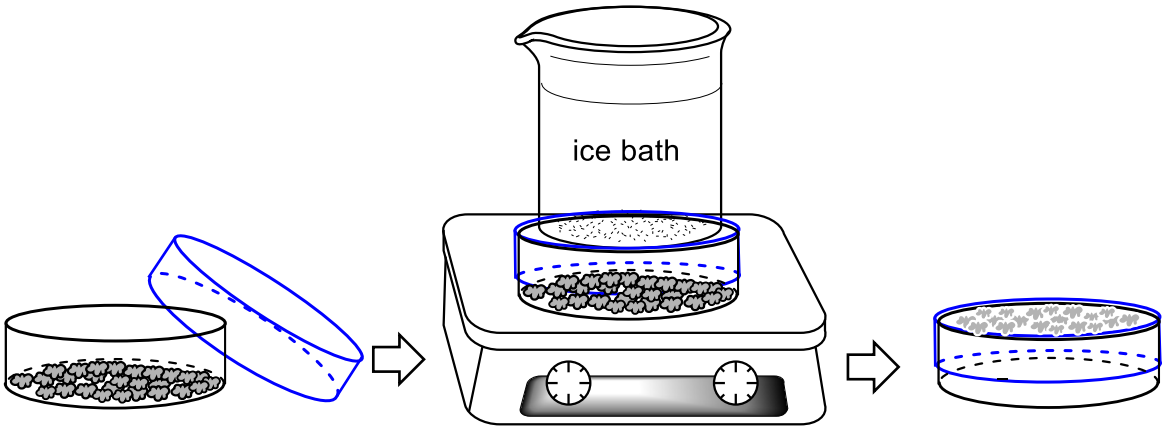



Figure 7.1: Sublimation of caffeine with Culture dish

**Procedures**

*From Experiment 6 caffeine extracted Flask B*

1. Close the culture dish with the lid of the culture dish (weigh it), put on the hot plate.
2. Take the ice bath (beaker) on the top culture dish.
3. Gently warming, white crystal will appear on top lid of the culture dish.
   Remove from the heat plate **(Caution!!!)**
4. Record actual weight of lid culture dish. Collect the caffeine crystal,
   What was your %yield of caffeine in tea leaves?
5. Comparisons the result with experiment 6. What is the better process for caffeine purification? Explain why?

## Write Part 7.1 report combines with Experiment 6

### 7.2 Simple Distillation of Mixed Compounds

Distillation is the process of vaporizing a liquid, condensing the vapor, and collecting the condensate in another container. It is very useful for separating, identification and purification a liquid mixture. When the components have different boiling points, or when one of the components will not distill. It is one of the principal methods of purifying a liquid. Four basic distillation methods are available to the chemist:

1. Simple distillation
2. Steam distillation (experiment 8)
3. Fractional distillation
4. Vacuum distillation (distillation at reduced pressure)

**Separation and Purification:** It is a physical process used to separate from a mixture by the difference in how easily they vaporize. As the mixture is heated, the temperature rises until it reaches the temperature of the lowest boiling substance in the mixture, while the other components of the mixture remain in their original phase in the mixture. The resultant hot vapor passes into a condenser and is converted to the liquid, which is then collected in a receiver flask. The other components of the mixture remain in their original phase until the most volatile substance has all boiled off. Only then does the temperature of the gas phase rises again until it reaches the boiling point of a second component in the mixture, and so on. **Identification:** The boiling point of a substance is a useful physical property for the characterization of pure compounds.

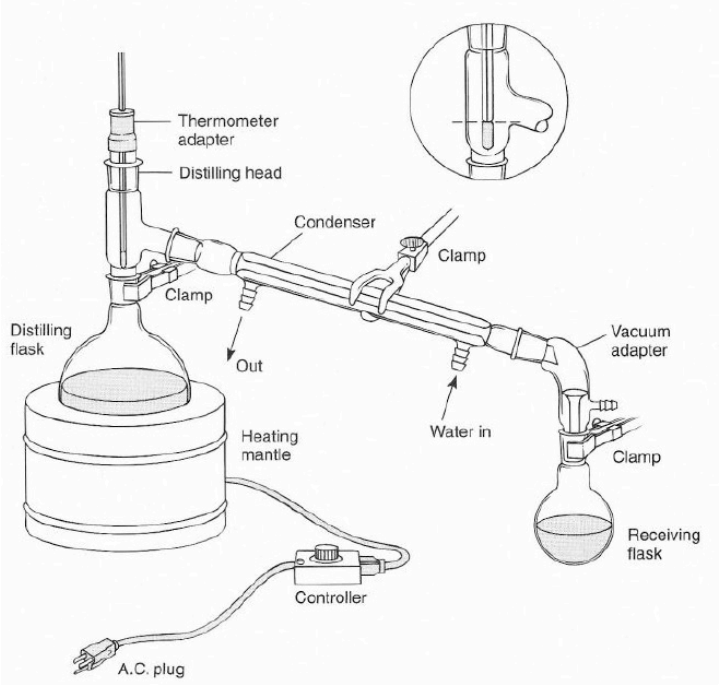



Figure 7.2: Simple distillation or Fractional distillation apparatus

**Procedures**

*Purification of mixtures liquid A and B (1:1)*

1. Obtain 30.0 mL of liquid mixtures in 100 mL round-bottom flask.
   Add a few of boiling chips
2. Assemble a simple distillation apparatus as shown in Figure 7.2
   (the bulb of the thermometer must be below the arm of the distillation head)
3. Slowly heat the heating mantle.
   - The lower boiling component is distilled, the boiling point of the mixture in the distillation flask will increase. *"the temperature remains constant"*
   - Record the temperature after the first drop is collected. Collect it until the **temperature changes**. Keep Liquid A and record the volume of Liquid A.
4. Increase heating, Record the temperature after the first drop is collected.
   Keep Liquid B and record the volume of Liquid B.
   **!!!DO NOT DISTILL TO DRYNESS!**

**For your report (Only Part 7.2)**

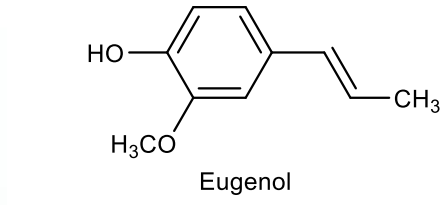
1. Record volume and distilling temperature of Liquid A and B.
2. Calculate the percentage of Liquid A and Liquid B in the liquid mixture.
2. Conclude what is organic compounds of the liquid A and B? (Table 1.2 p.19). Explain why?

# Experiment 8

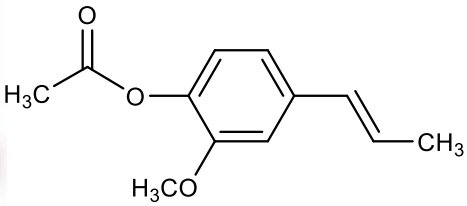
## Stream Distillation of an Essential Oil: Eugenol oil/Citronella oil

Eugenol oil can be extracted from Clove trees (กานพลู or *Eugenia caryophyllata* tree) which is made up of the extract of dried flower buds and leaves. Normally, Clove contains 85-90% Eugenol and 9-10% Eugenol acetate. It is used for the purposes of food flavoring, cosmetic, dermal drug delivery, dental, aromatic, soaps detergents.

(https://www.popayaherb.com/product/กานพลู/ (Accessed on July, 16 2020)




Eugenol

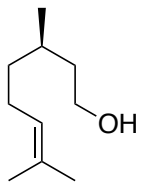



Eugenol acetate

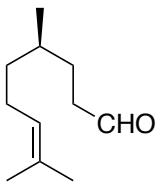
Figure 8.1: Clove, Eugenol and Eugenol acetate structure.

Citronella oil (น้ำมันตะไคร้หอม) consists of citronellol, citronellal, geraniol, limonene and methyl isoeugenol. It is used as a flavoring agent in goods and beverages. It also has various medicinal uses such as anti-bacterial, anti-fungal and anti-inflammatory activities.

(https://puechkaset.com/ตะไคร้/ (Accessed on July 16, 2020)




Citronellol




(+)-Citronelal

Figure 8.2: Citronella grass (lemon grass), Citronellol and (+)-Citronellal structure

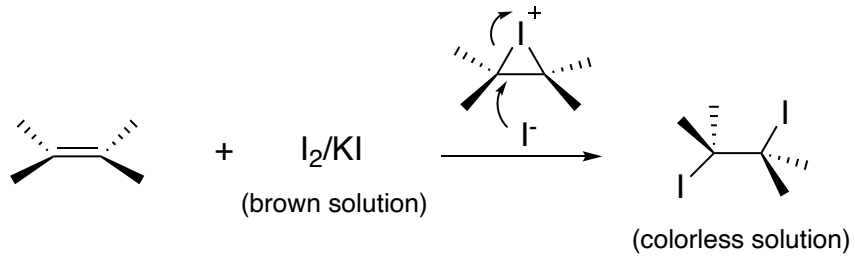
Distillation can also be performed on mixtures in which the two compounds are not miscible. This process is called co-distillation. When one of the compounds is water, the

process is called steam distillation. The apparatus like simple distillation as show in Figure 7.2 (Experiment 7).

Simple and fractional distillations are carried out on miscible mixtures. Ideal mixtures follow Raoult's law: the total vapor pressure of the system is determined by adding together the products of the vapor pressure and the respective mole fraction of each compound.

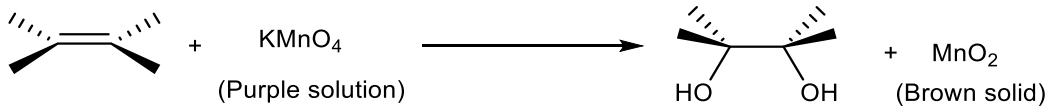
Characterization of Eugenol, it contains double bond (alkene) and an aromatic hydroxyl group (phenol). These functional groups provide the basis for simple chemical tests used to characterize the clove oil.

Characterize double bone with $I_2$ reaction;



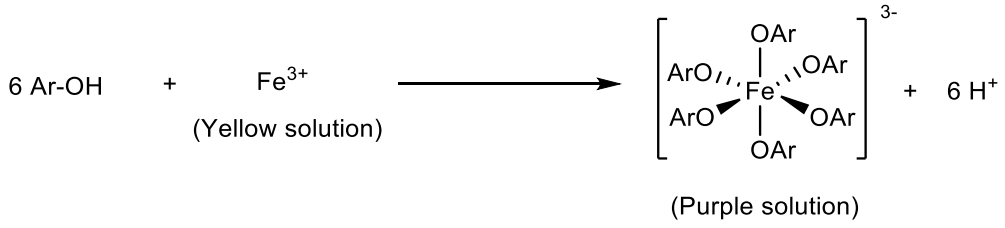

Scheme 8.1: $I_2$ addition reaction

Characterize double bone with $KMnO_4$ oxidation reaction;



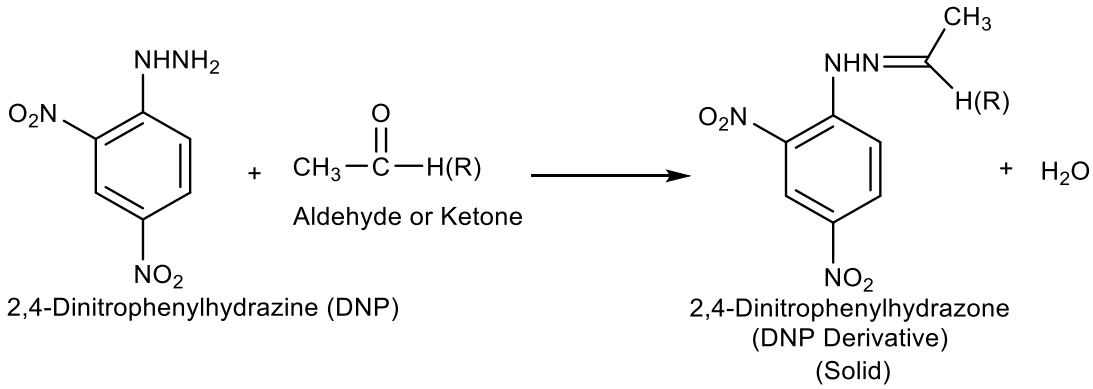

Scheme 8.2: $KMnO_4$ oxidation reaction

Characterize phenol complex with $FeCl_3$ reaction; Phenols (ArOH) react with the $Fe^{3+}$ ion in iron(III) chloride ($FeCl_3$) to give complexes that are blue, green, red, or purple.




Scheme 8.3: Phenol complex with $Fe^{3+}$

Aldehydes and ketones react with 2,4-dinitrophenylhydrazine (DNP) to form yellow, orange or reddish-orange precipitates, whereas alcohols do not react. Formation of a precipitate therefore indicates the presence of an aldehyde or ketone. The precipitate from this test also serves as a solid derivative.




Scheme 8.4: Reaction of 2,4-DNP with aldehyde or ketone

In this experiment, you will carry out steam distillation of eugenol oil from dried ground cloves or citronella oil from fresh citronella grass and characterizations of eugenol oil or citronella oil.

## Procedures

*Part I: Steam Distillation*

1. Weight 30 g of dried cloves or citronella grass then transfer to 500 mL round-bottom flask. Add 250 mL of distilled water and a few of boiling chips.
2. Assemble the distillation apparatus (Figure 7.2).
3. Heat the mixture. Adjust the heat to maintain a distillation rate of approximately 1 drop per second.
4. Stop the distillation when approximately 150 – 200 mL of distillate has been collected. **!!!DO NOT DISTILL TO DRYNESS!!!**.
5. Use a dropper to remove water (lower layer) as much as you can.
6. Add anhydrous $MgSO_4$ for remove water.
7. Drain the oil to bottle (weigh it).
8. Report the weight and percent yield of clove oil.

*Part II: Characterization*

1. Dissolve 3 drops the clove oil or citronella oil with 5 drops of methanol into four test tubes.
2. Add 5 drops of $I_2$ in KI solution to tube 1. Gently swirl and record your observation.
3. Add 5 drops of $KMnO_4$ solution to test tube 2. Gently swirl and record your observation.
4. Add a 5 drops of $FeCl_3$ solution to test tube 3. Gently swirl and record your observation.
5. Add a 5 drops of 2,4-DNP solution to test tube 4. Gently swirl and record your observation.
6. Identification the functional group of clove oil or citronella oil. Explain why?

**For your report**

1. Record weight of clove oil/citronella oil
2. Calculate %yield of oil in dried clove/lemon glass
3. Report result of characterizations, write reaction, identify the functional groups in the oils and explain the result

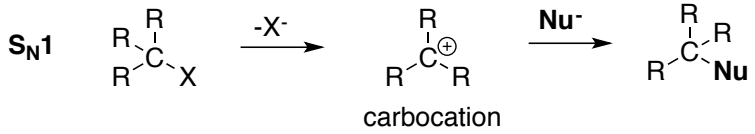
# Experiment 9

# Williamson reaction and identification of ether synthesis: Paracetamol derivative

## Nucleophilic substitution reactions

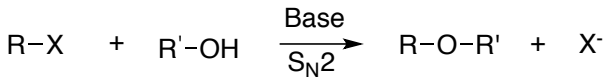
The discovery of the nucleophilic substitution reaction of alkyl halides was in 1895 by the work carried out by the German chemist Paul Walden. The reaction name has been called since this transformation involves the substitution of halide with a nucleophile. Nucleophilic substitution reactions are one of the most common and versatile reaction types in organic chemistry.

There are two types of mechanisms of nucleophilic substitution reactions varies by kinetic of the reactions. Concerted mechanism of $S_N2$ is second-order reaction which the rate is linearly dependent on the concentrations of two species; substrate and nucleophile. While stepwise mechanism of $S_N1$ is a first-order reaction which the concentration of nucleophile does not affect the rate of the reaction. Most nucleophilic substitutions take place by the $S_N2$ pathway.

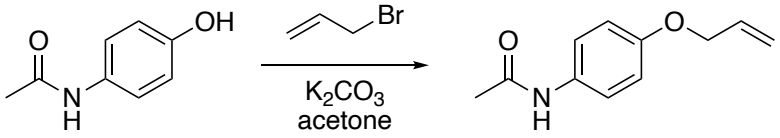



## Williamson Ether Synthesis

Discovered in 1850 by Alexander Williamson, the Williamson ether synthesis is an organic reaction of displacement of a halide (R-X where X= Cl, Br, I) by a deprotonated alcohol or alkoxide anion (R'-$O^-$) to form an ether. This typically involves the reaction of an alkoxide with a primary alkyl halide via an $S_N2$ mechanism. This reaction is still today one of the simplest and most reliable ways to synthesize an ether.




The starting material of today experiment is N-(4-hydroxyphenol)-acetamide, also known as Paracetamol or acetaminophen. It is an analgesic (a medication that reduces or eliminate pain) and an antipyretic (a medication that reduce fevers) that found in many over-the counter drugs. Today experiment product, Phenacetin was once used as a medication for reliving pain and fever, but it has been banned in the U.S. since 1931 due to its serious health concerns.




Paracetamol

The phenol of paracetamol is a relatively poor nucleophile. However, the presence of the base (potassium carbonate) causes the deprotonation of paracetamol and generates its conjugate base. This new generated specie called phenoxide anion which is more potent nucleophile than the starting alcohol. This phenoxide anion then displaces an iodide atom of ethyl iodide via backside attack in a concerted process as described as $S_N2$ reaction resulted in generation of a paracetamol derivative.

**Procedure**

*Synthesis of Paracetamol derivative*

Weigh grinded Paracetamol 100 mg and place it in a dry round-bottom flask along with anhydrous potassium carbonate 180 mg and 10 mL of acetone. Add 0.1 mL of ethyl iodide into the flask. Attach an air condenser (or water-cooled condenser without connection to water), add boiling chips and reflux for an hour. After an hour, monitor the reaction by TLC.

After the completion, cool the flask to room temperature, add 10.0 mL of DCM to dissolve the products. Extract with 10 mL of 1M aqueous NaOH solution. Shake the flask well to make a good extraction, then use dropper to remove the aqueous layer into another container. Repeat the extraction two more times with each 10 mL of 1M NaOH. Collect the aqueous layer until the end of the experiment (*DO NOT* Throw away any extracts).

Dry the organic layer with anhydrous magnesium sulfate for 5 minutes. After drying period, remove the solution into a tared beaker. Carefully rinse the containers to transfer all products with 1 mL DCM. Evaporate the solvent on a hot plate. Weigh the beaker and subtract the mass of empty beaker to calculate the mass of product. Calculate %yield of product.

**For the report**

1. Write reaction scheme and mechanism of the reaction
2. Calculate percent yield of the product
3. Discuss how TLC used to monitor the reaction. Include sources of error that occurred during the experiment.

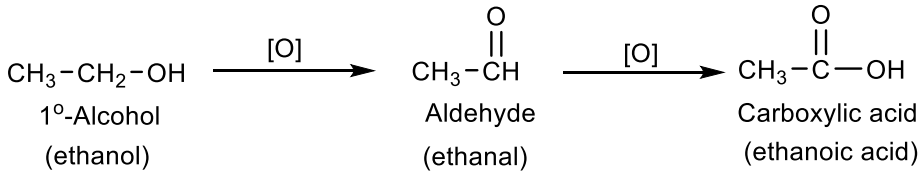
# Experiment 10

# The Oxidation of 1°-, 2 ° –Alcohol and Identification of Aldehyde and Ketone with 2,4-DNP

Identifications of simple chemical reactions that produce color changes or form precipitates, can be used to differentiate alcohols, aldehydes, and ketones and also to provide further structural information.

The oxidation [O] of primary and secondary alcohols is oxidized by $K_2Cr_2O_7$ to carboxylic acids and ketones respectively.

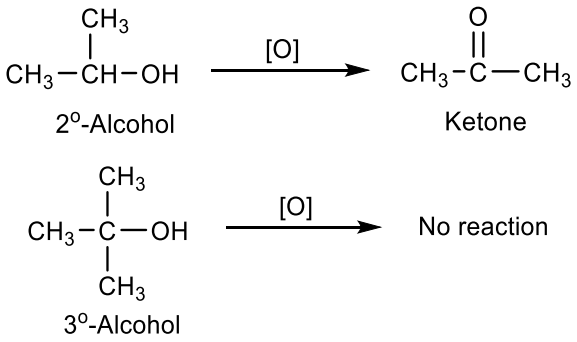
Primary alcohols can be oxidized to aldehydes and to carboxylic acids. The equation for the oxidation of ethanol to the ethanal is shown below.




Scheme 10.1: The oxidation of primary alcohol (ethanol)

When preparing aldehydes in the laboratory, you will need to distil the aldehyde from the reaction mixture as it is formed. This prevents the aldehyde from being oxidized further to a carboxylic acid. When making the carboxylic acid, the reaction mixture is usually heated under reflux before distilling the product off.

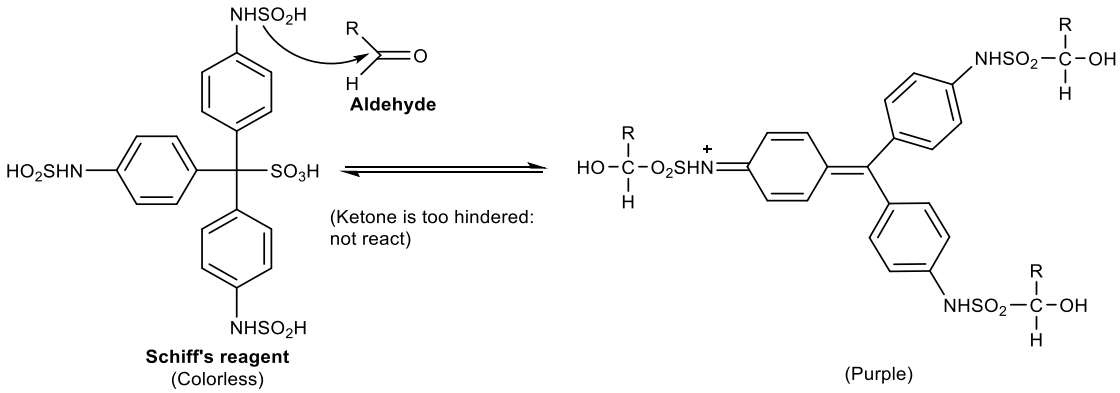
Secondary alcohols can be oxidized to ketones. Unlike aldehydes, ketones are not oxidized further. Tertiary alcohols can't be oxidized




Scheme 10.2: The oxidation of secondary alcohol (2-propanol)

Aldehydes react with Schiff's reagent to produce a color change (purple). The sulfur in the bisulfite ion acts as a nucleophile and adds to the carbonyl carbon. Because this is such a bulky nucleophile, it will add only to a relatively steric unhindered carbonyl. This requires that the carbonyl be part of an aldehyde in which one of the R groups is the very small

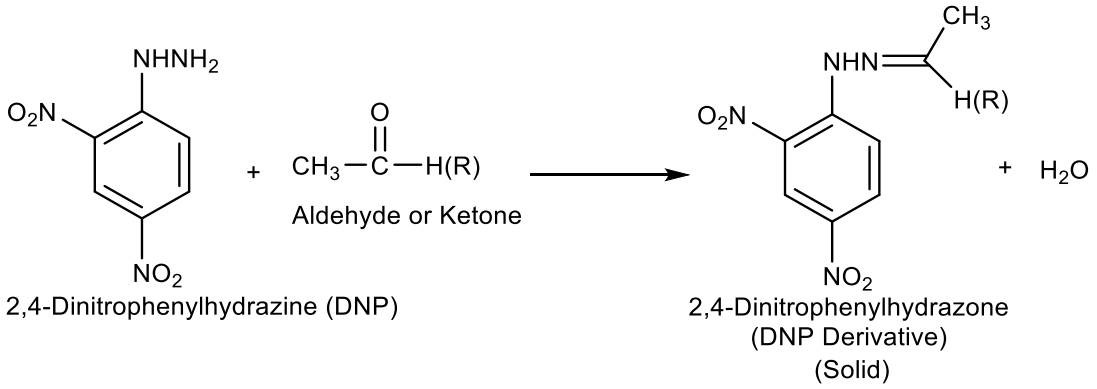
hydrogen, or a ketone having small R and R' groups. A ketone having large groups attached to the carbonyl will not react with bisulfite.




Scheme 10.3 The Schiff's reagent of aldehyde

In the same way, the Schiff' s reagent acts as a nucleophile that adds to the carbonyl group of an aldehyde. Because this nucleophile is extremely bulky, a ketone, which is more steric crowded than an aldehyde at the carbonyl carbon, does not react with Schiff's reagent, and thus does not produce the purple color. Production of the purple color therefore indicates that the unknown is an aldehyde

Aldehydes and ketones react with 2,4-dinitrophenylhydrazine (DNP) to form yellow, orange or reddish-orange precipitates, whereas alcohols do not react. Formation of a precipitate therefore indicates the presence of an aldehyde or ketone. The precipitate from this test also serves as a solid derivative.




Scheme 10.4: The combination of DNP and aldehyde or ketone

Table 10.1 The Melting point (M.P.) of 2,4-dinitrophenylhydrazone (DNP derivative)

| Aldehyde | M.P. (°C) | Ketone | M.P. (°C) |
|---|---|---|---|
| Pentanal | 98 | 2-Butanone | 115 |
| Hexanal | 107 | Acetone | 128 |
| Butanal | 123 | 2-pentanone | 144 |
| Propanal | 155 | 3-pentanone | 156 |
| 2-methylpropanal | 187 | cyclohexanone | 162 |

In this experiment, the primary and secondary alcohol are oxidized to aldehyde or ketone then complex with 2,4- dinitrophenylhydrazine (DNP) and identify 2,4-dinitrophenylhydrazone derivatives (DNP derivatives) by melting point.

**Procedures**

*Part I: Oxidation reaction of 1° - or 2°-alcohol*

1. Place 2.0 mL of conc. $H_2SO_4$ and saturated $K_2Cr_2O_7$ into a 50 mL round-bottom flask.
2. Stir the mixture for 3 minutes in an ice-water bath.
3. Slowly add 4.0 mL of Unknown alcohol No... and stir for 5 minutes.
4. Add 10.0 mL of distilled water.
5. Assemble the distillation apparatus (Figure 7.2). Distillation the mixture until organic layer appears and Keep Liquid A (6 mL) (ketone or aldehyde)

*Part II: Functional group classification with Schiff's reagent*

1. Add 3 drops of Liquid A and 2.0 mL of distilled water in test tube
2. Slowly add 10 drops of Schiff's reagent into test tube.
   Gently swirl and record the color of the mixture solution.
3. Is it a positive test? Why?
4. Conclusion. Liquid A is? (aldehyde or ketone) and type of alcohol (1° or 2°)

*Part III:* Synthesis of 2,4-dinitrophenylhydrazone (DNP derivative)

1. Place 10.0 mL of 2,4-dinitrophenylhydrazine in a 50 mL Erlenmeyer flask
2. Slowly drop a Liquid A. Stir gently with a glass stirring rod
3. Collect the precipitate by vacuum filtration.

4. Recrystallize the product using ethyl alcohol.
   *"dissolve at hot but non-dissolve at cool"*
5. Collect the precipitate by vacuum filtration (weight).
6. Determine the M.P. of DNP Derivative
7. What is actually of aldehyde or ketone of Liquid A. and 1° or 2° of alcohol.
   Compare with Table 10.1.

**For your report**

1. Record result of functional group testing. Conclude what is Liquid A is? (aldehyde or ketone) and type of alcohol (1° or 2°)
2. Record M.P" of DNP derivatives. What is the actual aldehyde/ketone of Liquid A? Compare with Table 10.1 and What is the starting alcohol?
3. Write the reaction starting from a given unknown alcohol (of your own group) to the final DNP product and explain all the reactions happened.

# Reference

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