Experiment 2: Recrystallization & Melting Point

Part A: Choosing a Solvent
Part B: Purification of Phenacetin

Reading: Mohrig, Hammond & Schatz
Ch. 15 pgs 183-197
Ch. 10 pgs 104-113
Ch. 14 pgs 174-182

Recrystallization

• Most important method for the purification of organic solids
• Separation of compounds based on differences in solubility between the compound of interest and its contaminants
• Basic technique:
  1. dissolve impure sample in an "appropriate" hot solvent
  2. cool solution slowly to induce crystal growth
  3. filter resulting mixture to isolate crystals
• Scale: 5-10 mg
discovery based research - a new material prepared in a lab
1,000 kg *
commercial applications - sugar refining, synthesis of pharmaceutical agents, etc.

Recrystallization

• Molecular selection - based on size, shape, & functionality

<table>
<thead>
<tr>
<th>Solution</th>
<th>Growing Crystal</th>
</tr>
</thead>
<tbody>
<tr>
<td>slow</td>
<td>pure substance</td>
</tr>
<tr>
<td>aggregation begins</td>
<td></td>
</tr>
</tbody>
</table>

molecules deposit on growing surface in orderly manner, excluding those of different size of shape

Recrystallization

• Molecular selection - based on size, shape, & functionality

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<tr>
<td>slow</td>
<td>pure substance</td>
</tr>
<tr>
<td>if deposition occurs too quickly, an impure substance can result</td>
<td></td>
</tr>
</tbody>
</table>

crystal defects
incorporated impurities
**Recrystallization Steps**

1. Choose an appropriate solvent
   - compound (solid) should be soluble when solvent is hot
   - compound should be insoluble when solvent is cold
   - may require some trial & error

2. Dissolve impure compound in the minimum amount of hot solvent
   - too much solvent & compound may not come out when cool

3. Decolorize solution if needed with activated charcoal (Norit)
   - skip this step if no/few colored impurities are present
   - be sure your compound is not supposed to be colored!

4. Filter off any insoluble materials
   - insoluble impurities and/or activated charcoal
   - done while solution is hot

5. Slowly cool the resulting solution to induce crystallization
   - first cool to room temperature, then in an ice bath
   - if no crystals form: scratch flask with glass rod or add a seed crystal to the solution
   - these methods provide a nucleation point for crystallization

6. Collect and wash the crystals
   - collection typically by filtration (large quantities)
   - for small quantities can remove solvent with a pipet
   - wash crystals with a small amount of ice cold solvent
   - filtrate ("mother liquor") can be concentrated to get "2nd crop"

7. Dry the crystals thoroughly
   - apply vacuum & continue suction until crystals are dry
   - dry crystals further under vacuum in a side arm test tube
   - can also press solids between two pieces of filter paper

**Factors that Influence Melting Point**

Factors that influence melting point temperatures:

1. Intermolecular forces
   a. Van der Waals interactions
      very weak
   b. dipole-dipole interactions
      result from polarization of bonds
   c. hydrogen bonding
      compounds having O-H or N-H bonds
   d. ionic forces
      very strong

2. Shape
**Factors that Influence Melting Point**

- **strength & nature of intermolecular interactions impact melting point temperature**
  
  For melting to occur, surface molecules must have enough energy to break free. Stronger intermolecular interactions = more energy required for molecules to “escape”. Translates to a higher mp.

- **structural features that influence how molecules pack together impact melting point temperature**
  
  Symmetrical compounds typically have higher melting points. Features that disrupt crystal lattice lower melting point.

**Melting Point as an Indicator of Purity**

- **In a pure sample, all surface molecules need the same energy to escape.**
  
  Leads to a narrow melting point range.

- **In an impure sample, intermolecular forces are disrupted in the region of the impurity. Less energy thus required for surface molecules to break free.**
  
  Crystal begins to liquefy at a lower temperature.

- **Still some regions without impurities. Additional energy required for surface molecules in these regions to break free.**
  
  End result is that melting point range is broadened.

**Next Week**

**Experiment 2: Recrystallization & Melting Point**

- **A. Choosing a Solvent**
  
  Identify an appropriate solvent for the recrystallization of phenacetin

- **B. Purification of Phenacetin**
  
  Purify the impure solid. Evaluate success by melting point & TLC.

**Experimental Details - Part A**

- **A. Choosing a Solvent**
  
  - Prepare a hot water bath. Begin heating as soon as you arrive in lab.
  
  - Put a spatual tip of the impure compound into a small test tube. No need to get an accurate mass.

  - To the 1st tube, add 0.5-1 mL of one of the solvents to be tested. 10-20 drops (1 drop = ca. 0.05 mL).

  - Evaluate behavior: upon addition of solvent, when hot, when cold. If compound dissolves upon addition, no need to go further.

  - If solids remain, heat in hot water bath to near boiling. Do NOT boil all your solvent away! If solids dissolve upon warming, cool in an ice bath (= ice/water bath).

  - Repeat using other solvents.

  - Identify the best solvent for recrystallization.

**Lab Reports are due at the beginning of your regular lab session**
**Finding a Recrystallization Solvent**

- **"Good" recrystallization solvent**
  - [Images of cold, hot, and cold solutions]

- **"Poor" recrystallization solvent**
  - [Images of cold, hot, and cold solutions]

**Experimental Details - Part B**

B. Purification of Phenacetin

- dissolve impure compound in hot solvent
  - get an exact mass (not necessarily 1.00g)
  - always use an Erlenmeyer flask
  - use a boiling stick (prevents "bumping")
  - be sure the solvent is hot before adding more
  - use the minimum hot solvent (+ ca. 1mL)

- no decolorization is needed this week
- once solids dissolve, cool slowly to room temperature; then in an ice bath
  - may need to tap/scratch flask w/glass rod to initiate crystal formation

- collect crystals by vacuum filtration; wash with ice cold solvent; dry
- analyze purity by mp and TLC
  - can do in any order, BUT:
  - be sure your compound is dry before taking a melting point
- submit recrystallized product to your TA

**Some Pointers: Recrystallization**

- Don’t get impatient; cool your solution SLOWLY!
  - crystals will be bigger (and thus easier to isolate)
  - crystals will be more pure

- Don’t throw anything away!
  - if it's in there, we can get it back

- Have you added too much solvent?
  - how do you know?
    - no crystals form on cooling, even after the flask is scratched
  - what should you do?
    - concentrating the solution slightly then cool again
    - no need to evaporate to dryness

**Technique: Vacuum Filtration**

- method of choice for collecting organic solids

- Set up as shown at right
  - clamp the flask securely!

- Turn on vacuum (or water aspirator)
- Swirl flask containing crystals
- Quickly pour mixture into funnel
- Wash crystals with ice cold solvent
- Scrape crystal until "dry"
- Disconnect vacuum line
- Turn off vacuum
- Dry crystals further as needed

- order is important!!

[Diagram of vacuum filtration setup]
**Technique: Drying the Crystals Further**

- Assemble as shown at right
  - clamp the test tube securely!
- Attach vacuum
- Continue until sample is dry
- Ideally, dry the entire sample
to get an accurate % recovery/% yield
- If time is at a premium, REMEMBER:
dry a small amount of sample(e.g. for mp)

**Technique: Melting Point**

- Prepare sample
- Place loaded capillary in Mel-Temp apparatus (closed end down!)
- Turn on the unit ("3" is a good starting point)
- Heat slowly through the melting point range (~ 1°C per minute)
- Observe carefully - record temp at first sign of moisture; then again as soon as all solid has melted
  - this is your mp range
- Turn off Mel-Temp to cool
- Discard your sample (glass waste)
- Repeat if time permits

**Melting Point Sample Preparation**

- Obtain a melting point capillary tube
- Place press open end of capillary into sample
  - sample on watch glass, filter paper, or in vial
  - forces sample into the capillary
  - not too much! 1-3 mm is fine
- Invert capillary & tap closed end gently on benchtop to compact sample
  - can also drop through glass or plastic tube
- Proceed with melting point

**Some Pointers: Melting Point**

- Dry your sample thoroughly
  - residual water/solvent is an impurity!
- Don't heat the sample too quickly
  - likely to overshoot true mp range
- Don't overfill the capillary
  - results in uneven heating
- Pack sample well in capillary tube
  - loose sample will also heat unevenly
- Never remelt a sample
  - heating may cause a chemical change!
- If the mp of your sample is unknown, first do a rapid, preliminary run
  - gets you in the ball park; cool MelTemp ca. 20°C below prelim mp
  - take 2nd reading (slow) to get an accurate mp value
Writing the Lab Report: General

Parts of the Report (see pg 9 of the lab manual!)

A. Title Page

B. Purpose

C. Results & Discussion

D. Conclusion

E. Appendices

Appendix A: Calculations
Appendix B: Spectra
Appendix C: Answers to Questions
Appendix D: Notebook Pages (attached by TA)

Writing the Lab Report: General

Parts of the Report

A. Title Page

B. Purpose

C. Results & Discussion

D. Conclusion

E. Appendices - You may not have material for each appendix every time

Appendix A: Calculations
- show one example of every calculation that you did
- include the equation used as well as the actual numbers
- don't forget the units!
- additional info needed for synthetic experiments (see lab manual)

Appendix B: Spectra (IR spectra, GC trace, etc.)

Appendix C: Answers to assigned questions

Appendix D: Experimental (your notebook pages)
- attached by your TA after your report is submitted

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Writing the Lab Report: General

Format
- Follow the instructions carefully!
  - see the "Lab Report" section (pg. 9)
  - see instructions found at end of each experiment
- Reports must be typed and double spaced with 1” margins
  - use 12 pt font ➔ Times or Arial
- Schemes & Figures may be neatly hand drawn
- Five page limit
  - does not include title page or appendices
  - pages in excess of 5 will not be graded
- A general template is available on the course website

Writing the Lab Report: Thin Layer Chromatography

Purpose
- poor: to learn about TLC
- better: to understand the factors that influence Rf values (list?) and to use TLC to identify the components of commercial food dyes

Results & Discussion
- divide the discussion into 4 parts (one for each section)
- for each part: report your Rf values in a Table
  - DO NOT: discuss the procedure or include raw data!
  - DO NOT: show calculations or draw your TLC plate here!
- discuss your results, for example:
  - Part A:
    - discuss relationship between Rf and length of TLC plate
      - what do you expect to see? should the Rf change?
      - must answer this question before you analyze your data
      - what did you actually observe? report your actual findings
      - do your results agree with your expectations? yes or no
      - why or why not? be specific
      - if needed, identify possible sources of error
Writing the Lab Report: *Thin Layer Chromatography*

**Conclusion**
- based on what you actually found, rather than on what you think you should have found
- should be brief (2-3 sentences)
- relate back to purpose

**Appendices**
- Appendix A: Calculations
  - only need to show one Rf calculation
    complete with the equation & appropriate units
- Appendix C: Answers to Questions
  post-lab questions from the website (Course Materials/Questions)
- Appendix D: Experimental
  notebook pages appended by your TA