**Physical Properties of Organic Compounds**

**Introduction**

In this lab, we will investigate how to measure the physical properties of organic compounds. The properties that we will be concerned with are:

- water solubility of organic solvents
- density of organic solvents
- boiling points of organic solvents
- melting points of organic solids
- solubility of organic compounds in organic solvents and water

In general chemistry, the most common solvent is water. In organic chemistry, however, we use a variety of organic liquids as solvents that you will need to become familiar with. A solvent is any liquid which can be used to dissolve solids, other liquids, or gases. This first part of this lab will introduce you to the common organic solvents.

Some organic solvents are soluble in water, while some are not. It is important to know which ones are insoluble, because they can be used to separate compounds through extraction and washing. Solubility is determined by what intermolecular forces are present, and how strong they are. If a solvent can engage in hydrogen bonding, or has dipole forces, and there aren’t too many nonpolar bonds present, then it will most likely dissolve in water. The strength of the intermolecular forces is often referred to as polarity – polar molecules have strong intermolecular forces, while nonpolar molecules have weak intermolecular forces.

When using a solvent that is insoluble in water, it is also useful to know its density. If it is less dense than water, it will float on top of the water; if it is more dense than water, it will sink to the bottom. Density comes from the amount of space that a molecule takes up compared to the mass of its atoms. Molecules with heavier atoms are denser, while those with lots of hydrogen atoms are less dense.

The boiling point of a solvent is also a useful thing to know. Low boiling solvents are more easily evaporated than high boiling solvents. The boiling point of a solvent is also an important consideration when running a reaction that needs to be heated – the boiling point of the solvent controls the temperature of the reaction. Boiling points of other organic compounds may be used to confirm the identity of the compound. Boiling points are influenced by the molecular weight and the polarity of the molecule.

Melting points are often used to confirm the identity of solid organic compounds. They are easier to measure on a small scale than boiling points. The main factors which affect melting points are the molecular weight and the polarity of the molecule, but they can also be influenced by the symmetry of the molecule (how well it packs into a crystal lattice).

The solubility of organic compounds in water or in organic solvents is a very important practical consideration. Nearly all reactions are run in solution, so it is important to use a solvent that will dissolve the reagents. Solubility of drugs in different body fluids (blood, intracellular fluid, gastric juices, etc) is a primary consideration in the design of pharmaceuticals. Compounds tend to be soluble in liquids that have similar polarities; polar compounds tend to dissolve in polar liquids, and nonpolar compounds tend to dissolve in nonpolar liquids. Ionic compounds dissolve best in water.
To prepare for this lab, please read all of the instructions for this lab and each of the techniques listed below. Then write an introduction in your lab notebook, and copy the table below. Fill out the first two columns. Then answer the on-line questions.

Please read:
• Keeping a Notebook
• Measuring Reagents
• Refluxing a reaction
• Measuring a Boiling Point
• Taking a Melting Point

Procedure

Properties of Organic Solvents:

• The common organic solvents are shown in a table below. Copy this table into your notebook – you will use it to refer back to throughout the semester. Note that when a solvent has alternate names, they are listed with "/" between them. Draw line structures for those with 2 or more carbons. Draw Lewis structures for those with one carbon or none. Then fill in the functional group for each solvent.

<table>
<thead>
<tr>
<th>solvent</th>
<th>description or structure</th>
<th>line structure or Lewis structure</th>
<th>functional group</th>
<th>dielectric constant</th>
<th>water solubility</th>
<th>density</th>
<th>boiling point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. hexane</td>
<td>CH₃(CH₂)₄CH₃</td>
<td></td>
<td></td>
<td>1.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. toluene</td>
<td>C₆H₅CH₃</td>
<td></td>
<td></td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. diethyl ether / ethyl ether / ether</td>
<td>CH₃CH₂OCH₂CH₃</td>
<td></td>
<td></td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. ethyl acetate</td>
<td>CH₃CO₂CH₂CH₃</td>
<td></td>
<td></td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. dichloromethane / methylene chloride</td>
<td>CH₂Cl₂</td>
<td></td>
<td></td>
<td>8.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. acetone</td>
<td>CH₃COCH₃</td>
<td></td>
<td></td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. ethanol / ethyl alcohol</td>
<td>CH₃CH₂OH</td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. methanol / methyl alcohol</td>
<td>CH₃OH</td>
<td></td>
<td></td>
<td>33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. water</td>
<td>H₂O</td>
<td></td>
<td>x</td>
<td>78</td>
<td></td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>
• The dielectric constant is one way to measure the polarity of a solvent. This table has been arranged starting with the least polar and going to the most polar solvents. Record any observations that you can make.

• Test the water solubility and density of the organic solvents in the table as follows. Obtain 8 test tubes and place them in a test tube rack. Using a graduated cylinder, add about 2 ml of water to each test tube (measure the first, then add the same height to the others). Then, using a plastic pipet, add about 1 ml of one of the solvents to one of the test tubes. Stir vigorously with a spatula and observe whether the solvent mixes with the water. If a separate layer forms, also observe whether the organic layer is on the top or the bottom. If you can't tell which layer is which, add a few more drops of water and observe whether it mixes with the top layer or falls to the bottom layer. Record the results in your observations, then add this data to your table.

• Compare the water solubility to the dielectric constant – do you see a connection? Note this in your interpretations. Then copy the density for each solvent from the white board to your table, and compare this information with the solvents’ behavior. When you are finished, pour all of the contents of your test tubes into one beaker - put the water into the inorganic waste and the organic layer (a mixture of the insoluble solvents) into the organic waste. Rinse the test tubes out with acetone and set them in the rack upside down - you will use them again in step 7.

• Chose one of the solvents to measure the boiling point of and write your initials next to it on the white board. Then heat around 3 ml of that solvent to reflux, following the instructions given in "Refluxing a Reaction." Once the solvent is refluxing, measure the temperature according to the instructions in "Measuring a Boiling Point" and write it on the white board.

Melting Points and Solubility of Solid Organic Compounds:

• Chose one of the solid compounds whose structure is written on the white board, and put your initials next to it. Write its name and structure in your notebook. Look up the melting point of this compound in the Aldrich catalogue. Prepare a melting point tube according to the instructions in "Measuring a Melting Point." We will determine melting points from lowest to highest melting (so that there won't be too much down time waiting for the apparatus to cool) - when your turn comes, go to the apparatus and determine the melting point. Write it in your notebook and compare it to the known value. Comment on the purity of your compound. Put melting point tubes in the glass waste when you are finished with them.

• Test the solubility of your compound in each of the solvents in the table by adding 2 ml of one of the solvents to one of the test tubes until you have 9 test tubes with different solvents. Then add approximately 100 mg of the compound to each test tube (measure one, then add about the same amount to each). Stir vigorously, and observe the results. If all or most of the material is still there, this counts as insoluble; if all or most of the material dissolves, this counts as soluble. When you have finished, pour all organic solutions into the organic waste container, rinse the tubes with acetone, then discard the test tubes in the glass waste.

• When everyone has finished, we will discuss the results together. If you finish early, please clean up, then work on your conclusion or the end-of-lab questions below.
Questions

1) Petroleum ether (a solvent which is derived from petroleum) has a dielectric constant of 2.0. Would it be classified as polar or nonpolar? Would you expect it to be miscible or immiscible with water? Why?

2) Only one of the common solvents is more dense than water. Which is it? Explain why it makes sense that this solvent should be unusually dense.

3) Organic liquids A, B, and C have densities of 0.690, 0.955 g/ml, and 1.126 g/ml. A and C are low polarity solvents, while B is a high polarity solvent. When each is added to water, how would you expect them to behave?

4) Why are the boiling points we measured in the lab lower than the ones in the catalogue? Are melting points affected by this issue? Why or why not?

5) Explain the following observations:
   a) ethyl acetate has a higher boiling point than hexane, even though they are approximately the same molecular weight
   b) methanol has a lower boiling point that ethanol even though it is more polar
   c) ethanol has a higher boiling point than ethyl ether even though ethyl ether is heavier

6) The known melting point of 2-methylbenzamide is 140.2°C. If you took the melting point of a sample of this compound, how would you interpret the following results?
   a) 139.2-140.5°C
   b) 137.7-143.2°C
   c) 149.1-150.3°C

7) 2-Methylbenzamide and 3-nitrobenzoic acid both have a melting point of 140.2°C. However, if you mixed them together and took the melting point, it would not be 140.2°C. Why not? (Hint - this is not the result of a chemical reaction!)