Lab # 10: Intermolecular Forces of Attraction Lab
Accelerated Chemistry I

There are different kinds of intermolecular forces of attractions: dispersion forces, dipole-dipole interactions and hydrogen bonds (which are a special type of dipole-dipole interaction). Physical properties of compounds vary significantly based upon the type of intermolecular force of attraction between molecules. These forces determine if a substance is a solid, liquid or gas at room temperature. For example water, H₂O, is a liquid at room temperature because of the strong hydrogen bonds between the water molecules. However H₂S, dihydrogen sulfide, which looks chemically very similar to water (S is right below O on the periodic table), is a gas at room temperature. This is because instead of hydrogen bonds, the H₂S molecule is a non-polar molecule and instead exhibits much weaker dispersion forces.

Intramolecular forces exist between bonding atoms within a molecule or ionic crystal, rather than between molecules. Covalent and ionic bonds are examples of intramolecular forces.

In this lab, by using your powers of observation, and by conducting a few simple tests, you will identify a series of unknowns and explain what types of intermolecular forces are present in the substances.

### Structures and Properties of Types of Substances

<table>
<thead>
<tr>
<th>Type</th>
<th>Structural Units</th>
<th>Forces between units</th>
<th>Properties</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular</td>
<td>Nonpolar Molecules</td>
<td>Dispersion</td>
<td>Low mp, bp; often a gas or a liquid at room temp; nonconductor; insoluble in water, soluble in organic solvents</td>
<td>H₂, CCl₄</td>
</tr>
<tr>
<td>Molecular</td>
<td>Polar molecules</td>
<td>Dispersion, Dipole-dipole Hydrogen Bonds</td>
<td>Similar to nonpolar but generally higher mp and bp, more likely to be water soluble</td>
<td>HCl, NH₃</td>
</tr>
<tr>
<td>Network Covalent</td>
<td>Atoms</td>
<td>Covalent Bond (Intramolecular)</td>
<td>Hard, very high mp. Nonconductors: Insoluble in common solvents</td>
<td>C, Si, SiO₂</td>
</tr>
<tr>
<td>Ionic</td>
<td>Ions</td>
<td>Ionic Bond (Intramolecular)</td>
<td>High mp. <strong>Conductors only in molten state or water solution.</strong> Often insoluble in organic solvents</td>
<td>NaCl, MgO</td>
</tr>
<tr>
<td>Metallic</td>
<td>Cations, mobile electrons</td>
<td>Metallic Bond (Intramolecular)</td>
<td>Variable mp. Good conductors in solid state. Insoluble in common solids</td>
<td>Na, Fe</td>
</tr>
</tbody>
</table>
Pre-lab

Compare the properties of each by answering the following questions with molecular-polar, molecular-nonpolar, ionic, metallic and/or network covalent (Remember “molecular” is a synonym for “covalent”):

1. Which has the highest melting point? ___________________

2. Which has the lowest melting point? ___________________

3. What type(s) of intermolecular force(s) does water have? __________________________

4. Which types of substances generally dissolve in water? __________________________

5. Which types of substances generally do not dissolve in water? _____________________

6. Is it possible that a substance that should dissolve in water will not dissolve in a small amount of water if you add too much substance? Explain.

7. Which types of substances will dissolve in cyclohexane (C₆H₁₂)? Which do not?

8. Why should the probes on the conductivity tester be cleaned before each substance is tested?

Procedure

At each of the stations either follow the procedure or simply observe the containers (vials) and identify the unknowns.

Station #1 (Yellow station)

1. There should be four vials labeled – DD, EE, FF, GG. Match these to the four unknowns. All of these compounds are molecular hydrocarbons. Identify each using intermolecular bonding concepts.

   a. CH₄ __________
   
   b. C₆H₁₈ __________
   
   c. C₁₆H₁₈ __________
   
   d. C₂₅H₅₂ __________

   i. What is the relative order of melting points of the unknowns?
   
   ii. How is viscosity (resistance to flow) related to strength of intermolecular forces? Provide examples by using the compounds observed in your response. Include the type of IMF experienced in your response.
Station #2 (Orange station)

2. There should be three vials labeled – PP, QQ, RR. Match these to the three unknowns.

   a. Ethane C$_2$H$_6$ __________
   b. Ethanol (Alcohol) C$_2$H$_5$OH __________
   c. Ethylene Glycol CH$_2$OHCH$_2$OH __________

   i. Which of these exhibit hydrogen bonding? Use the compound as part of your answer.

   ii. How is viscosity (resistance to flow) related to hydrogen bonds? Provide examples by using the compounds observed in your response.

Station #3 (Blue station)

3. There should be eight vials labeled – CaCl$_2$, MgCl$_2$, AlCl$_3$, CCl$_4$, CoCl$_2$, CuCl$_2$, NiCl$_2$, MnCl$_2$.
   Hint: Use the periodic table.

   a. These compounds all contain chlorine. They are solids except ____________ because all of the solids are ____________ compounds.

   b. What type of intramolecular force holds the liquid compound together? What type of intermolecular force exists between the molecules? How does this explain why this compound is a liquid and not a solid?

   c. What is the significance of color? Can you explain any observable pattern?

Station #4 (Green station)

4. There should be three vials labeled – C$_2$H$_6$, C$_2$H$_5$OH, NaCl.

   a. List these compounds in order of increasing melting point.

   b. Describe how you made the melting point predictions. (Be sure to go beyond discussing their states of matter at room temperature. Discuss using principles of inter- and intramolecular forces.)
Station #5 (Indigo station)

5. There should be three vials labeled – A, B and C. Identify the unknowns based upon look and smell. (Remember the technique to safely smell unfamiliar chemical substances.)

   a. Menthol, C_{10}H_{20}O – An ingredient in “menthol-eucalyptus” cough drops. 

   b. Para-dichlorobenzene, C_{6}H_{4}Cl_{2} – Used in mothballs, diaper pail deodorizers and urinal cakes.

   c. Camphor, C_{10}H_{16}O – An ingredient in “Vicks Vaporub”

Station #6 (Red station)

6. There should be four vials labeled – 2F, 2G, 2H and 2I. Identify each of the following. For type of substance use molecular polar, molecular non-polar, ionic, metallic or network covalent.

<table>
<thead>
<tr>
<th>ID</th>
<th>Type of substance</th>
<th>Inter/Intramolecular force</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO_2</td>
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<tr>
<td>H_2O</td>
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<tr>
<td>SiO_2</td>
<td>Network Covalent</td>
<td>Covalent Bonds(Intramolecular)</td>
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<td>CaO</td>
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</tbody>
</table>

Station #7 (Violet station)

7. There should be three vials labeled – W, X and Y. Identify the following mixtures:

   a. SiO_2 (sand) & H_2O

   b. CH_3OH (methanol) & H_2O

   c. C_{6}H_{12} (Hexene) & H_2O

What helped you identify these?
Station #8 – Identification of Solids

Correct identification of unknowns will require understanding of how IMF affect physical properties such as melting point and solubility. There are two sets of unknowns. Your group will get either set A or set B.

SET A: Iron(II)ammonium sulfate hexahydrate (NH₄)₂Fe(SO₄)₂•6(H₂O); Sucrose (C₁₂H₂₂O₁₁); Silicon dioxide (SiO₂); Sodium chloride (NaCl); Zinc; Iodine; and Parafilm (C₂₀H₄₂)

SET B: 1. Copper(II) sulfate (CuSO₄); Sucrose (C₁₂H₂₂O₁₁); Silicon dioxide (SiO₂); Sodium chloride (NaCl); Iron; Iodine, and Parafilm (C₂₀H₄₂)

1. SOLUBILITY IN A POLAR SOLVENT

   a) To test solubility of the unknowns in water (polar solvent), place a match-head sized sample of the substance in the well of a well plate and fill the well ¾ full with distilled water. Stir with a toothpick. **Use a new toothpick with each substance.** Record whether or not the compound dissolves in water.

2. SOLUTION CONDUCTIVITY (Complete together with Solubility in Polar Solvent.)

   b) First, you must obtain a baseline for the conductivity of the distilled water you will be using to dissolve the unknowns. Theoretically distilled water should not conduct because all dissolved ions have been removed. However, the process is not always perfect and a small concentration of dissolved ions may remain. Fill a well of your well plate about half-full with the distilled water. Use the conductivity tester to test its conductivity. Observe and note if it does in fact conduct, slightly. If it does, this is your baseline to which you will compare other results.

   c) To test whether a distilled water solution of an unknown substance conducts electricity insert the conductivity tester into the distilled water solutions you made in Step 1. Be sure to only submerge the tips of the electrodes. (Note: After each use of the conductivity tester, the two probes should be cleaned thoroughly by rinsing with the distilled water so you do not contaminate). Record whether or not the water solution of the substance conducts.

3. SOLUBILITY IN A NONPOLAR SOLVENT

   d) To test solubility of the unknowns in lamp oil, (C₁₂H₂₆, a non-polar solvent), place a match-head size sample of the solute in a well of the well plate and using a Beral pipet and add a few drops of lamp oil. Stir with a toothpick. Record whether or not the substance dissolves in this nonpolar solvent.

4. MELTING POINT

   a. To test melting point, put a tiny amount (about the size of rice grain) of each of the compounds on a piece of Al foil. You must carefully organize the substances so they do not mix. You may wish to gently mark the foil. Place on a hotplate in the fume hood. Observe the order of melting; the way the substances may change is also useful information. It is possible that a few of the substances will not melt at this temperature; this is also useful information. Remove the foil with tongs and set aside until cool; dispose into trash. Record observations in data table.
# Data Table

<table>
<thead>
<tr>
<th>Sample Set</th>
<th>Appearance</th>
<th>Soluble in Water?</th>
<th>Water solution conducts electricity</th>
<th>Soluble in lamp oil?</th>
<th>Melting Point</th>
</tr>
</thead>
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# Conclusions

Identify each sample in station #8

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________