Intermolecular Forces Lab Activity
(Background / Instructions)

Experimental Questions (things to think about)

· Which types of compounds have the strongest intermolecular forces?

· How can certain physical properties give an indication of the strength of IMFs of compounds?

Learning Goals

· Relate molecular polarity to the intermolecular forces of the molecule.
· Relate intermolecular forces of the molecule to physical properties such as evaporation and viscosity.

Background

In today's lab we will examine the attractive forces that hold molecules together and the disruptive forces that break them apart. The forces between molecules that hold molecules together are called Intermolecular Forces (IMF) and are comprised of London dispersion forces (LDF), dipolar forces, and hydrogen bonding (H-bonding). The forces that break molecules apart are related to the temperature of the object. You will explore the effect of polarity on the strength of IMF and how the IMF is related to physical properties such as melting point, boiling point, state of matter, and viscosity of liquids.

All material is held together by attractive forces but there is always some disruptive force present that can break it apart. When an object is a solid at a given temperature it means that the attractive forces must be greater than the disruptive forces. When something is a gas at any temperature it means that the disruptive forces much be much greater than the attractive forces. Finally, when the forces of disruption and attraction are on about the same level the substance will exist as a liquid. There are only two ways that elements are held together: sharing of electrons (as in covalent bonding) or by plus to minus charge or partial charge interactions (as in ionic compounds or intermolecular forces).

Cohesive forces are attractive forces between particles. They are what hold particles together. They are weak in gases and get progressively stronger as we go from liquid to solid. Recall that the force of attraction decreases with increasing distance of separation or decreasing charge. There are forces that result from particle motion that work in opposition to the cohesive forces. They are known as the **disruptive** forces (forces that tend to separate molecules). The two main types of disruptive forces are the motion of atoms or molecules or the repulsion of like charges. All atoms are always in motion. Externally an atom or molecule can travel in a straight line (called translational motion) and it can spin (called rotational motion). Internally when atoms are bonded together they also will move back and forth relative to one another (this is called vibrational motion). The bonds are like little springs that can move slow or fast but are always in motion. There is an energy associated with each of the three types of motion called vibrational, rotational and translational energy and all of these are forms of kinetic energy. The temperature of an object is proportional to the average of all its kinetic energies.

$$T \sim K.E. = \frac{1}{2} m v^2 \text{ (where m = mass and v = velocity)}$$

This means that at the same temperature all objects have the same average kinetic energy. At the same temperature smaller objects must have a faster velocity and larger objects must have a lower velocity for them to have the same average kinetic energy. Remember that the faster an object is moving the easier it is to break away from attractive forces and the slower the object is moving the easier it is to be trapped by the attractive forces. Solids, since they are not moving or rotating, the only motion left is vibrational.

As stated above, disruptive forces are associated with kinetic energy, which is a measure of the movement of the particle and is associated with the temperature of the sample. We all know that at the same temperature, heavier molecules move slower. When the disruptive forces are greater than the cohesive forces, we can have a change of state (e.g. liquid → gas). It takes energy to make this transition, and since the energy is used to evaporate the molecules, the remaining liquid gets cooler. This is called **evaporative cooling**.

Procedure

Read lab instructions on the following pages. Record your data on the Data Collection pages.

<u>Station 1</u>: IMFs of water, hexane, ethanol and acetone

Predicting polarity based on models

Obtain a model set and after drawing the Lewis structure for the following compounds in the appropriate spaces in the following table, examine each model, sketch its 3-D shape, look at the intramolecular bonds to see if any of them are polar and then look at the shape of the molecule to see if the molecule is **polar**. You should now be able to predict the type of intermolecular forces and how the properties will vary between the molecules that you will be testing.

Compounds to be studied:

Water, H_2O

Hexane, $CH_3(CH_2)_4CH_3$

Ethanol, CH_3CH_2OH

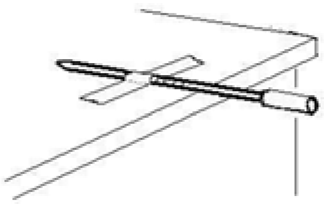
Acetone, 

<u>Station 2</u>: Evaporation Rate

This experiment may be conducted as a group of four - one person per substance (hexane, water, ethanol, acetone).

1. Obtain 4 pieces of filter paper and five rubber bands to attach the paper to your thermometer.
2. Attach filter paper to end of the thermometer at the bulb with a rubber band and then dip into the test tube containing the compound to be studied (hexane, water, ethanol, or acetone). When the temperature has stabilized, record the temperature while the paper on the thermometer is still submerged in the liquid. This is the measurement for time = 0.0 min.

3. Your time starts when you pull it out of the liquid. Tape the thermometer to the lab bench so that the paper is hanging off the bench and you can read the thermometer. Note: If there is a big drop hanging from the paper when you pull it out then touch the drop to the side of the test tube to get rid of it.



4. Record the temperature with the correct significant figures every thirty seconds for 8 min, then summarize all results in Results Table 1 of Data Analysis.

<u>Station 3</u>: Additive Attractive Forces of Hydrocarbons and Alcohols

This station will demonstrate the effect of length and type of force relative to the state of the material (solid, liquid, gas) at the same temperature (room temperature).

ü Pick up each Erlenmeyer flask and swirl it.

ü Make a note of the state (solid, liquid, gas) of the material and qualitatively comment on its viscosity, if it is a liquid.

ü Note also the number of carbons (chain length) it takes to have a liquid, viscous liquid, and solid, and note the forces involved, in **Data Table 2**.

Figure 1. Hydrocarbons: Erlenmeyer flasks that contain compounds of **just C's and H's**

methane	**butane**	**pentane**	**hexane**	**mineral oil (paraffin oil)**	**paraffin wax**
CH_4	C_4H_{10}	C_5H_{12}	C_6H_{14}	~ $C_{18}H_{38}$	~ $C_{24}H_{50}$
CH_4	$CH_3(CH_2)_2CH_3$	$CH_3(CH_2)_3CH_3$	$CH_3(CH_2)_4CH_3$	$CH_3(CH_2)_{16}CH_3$	$CH_3(CH_2)_{22}CH_3$

Figure 2. Alcohols: Erlenmeyer flasks that contain compounds with **one OH per C**
(use the name in bold)

Official Name **Common Name** **Alternative name**	**methanol** methyl alcohol (wood alcohol)	1,2-ethandiol **ethylene glycol** (anti-freeze)	1,2,3-propantriol **glycerol** (glycerin)	**glucose** dextrose (blood sugar)
Formula	CH_4O	$C_2H_6O_2$	$C_3H_8O_3$	$C_6H_{12}O_6$
Structural Formula				

<u>Station 4</u>: Viscosity

You will study a number of tubes, each containing a liquid and a marble. When you invert the tube, the marble will fall to the bottom. The rate of fall depends on the viscosity of the liquid which is dependent on intermolecular forces. The falling marble must break connections as it travels down. The stronger the connections the slower the marble goes. Record the relative speed of the marble and put the substances in order of fastest (least viscous) to slowest (most viscous). If you get any that are really close, try starting them at the same time as in a race.

Note: To the water was added a drop of blue food coloring and to ethanol was added one drop of red food coloring. This will not affect the viscosity of either one.