Exploring Intermolecular Forces*

Objective: **Intramolecular forces** are forces acting on atoms WITHIN ionic crystals or molecules. Intramolecular forces are responsible for many macroscopic properties such as electrical conductivity, hardness, and luster. Other properties of matter such as boiling point, vapor pressure, and surface tension are best explained by the forces action between molecules (**intermolecular forces**). In this experiment the surface tension of three liquids (water, isopropyl alcohol and glycerol) will be compared in order to assess the strength of their intermolecular forces. The intermolecular forces of these three substances will be further studied using a molecular model kit. Using the models, the nature of the attractive forces for various substances will be examined.

Materials:

3 Erlenmeyer flasks with stoppers	3 petri dishes	pepper shaker	3 plastic pipets
5+ paper clips	liquid detergent	wax paper or 3 pennies	forceps

3 100 ml beakers containing: water, isopropyl alcohol and glycerol (aka glycerin)

Prelab Questions:

How can VSEPR models help predict intermolecular bonding? Answer these pre-lab questions BEFORE beginning the experiment.

1. Predict whether the following molecules are polar or nonpolar. Justify your answer using VSEPR models. Draw them and fully explain your reasoning!

a) oxygen difluoride, OF_2 b) methane, CH_4

c) carbon disulfide, CS_2 d) fluoromethane, CH_3F

e) hydrogen peroxide, H_2O_2 f) ammonia, NH_3

2. As noted by your teacher a couple of minutes ago, the weakest attraction between molecules are collectively called Van der Waals forces. For each of the above substances, list the kinds of attractive forces between molecules that are *expected.*

Molecule	LDF	Dipole-dipole	H-Bonds
Oxygen difluoride			
methane			
Carbon disulfide			
Fluoromethane			
Hydrogen peroxide			
Ammonia			

3. What two conditions are necessary for molecules to be polar?
4. If water had a linear molecular shape, would the molecule be polar or nonpolar? Explain your answer.
5. When will hydrogen bonding occur? Give an example of a liquid other than water, in which this type of force is important.

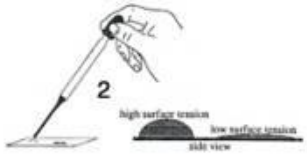
Procedure:

In this experimental you will be comparing three liquids, isopropyl alcohol, water and glycerol.

Part 1: Surface tension and vortex. When a liquid is swirled, a vortex is developed in which the surface level of the center of the liquid is substantially below the surface level of the perimeter. The greater the surface tension, the longer the vortex will remain after you have stopped swirling the container.

Fill one flask half-full with isopropyl alcohol, another with water, and yet another with glycerol. (Remember to fill the flasks only half-full). Stopper the flasks to prevent vapors from polluting the room. Try to swirl each flask with the same intensity and record the time it takes for the vortex to disappear. Which liquid appears to have greater surface tension and greater intermolecular forces? Record your answer for Part 1.

Part 2: Surface tension and droplet shape: Using an eyedropper or pipet, transfer one drop of each fluid to a sheet of wax



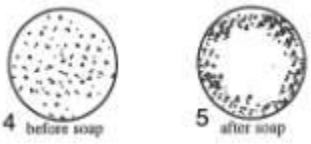
paper. The liquid with greater surface tension will maintain a higher profile and will not spread out as much as the one with lower surface tension. Which liquid appears to have the greater surface tension and greater intermolecular forces? Record your answer for Part 2.

Part 3: Surface tension and impenetrability: Liquids with strong intermolecular bonding will be less penetrable than those with weaker intermolecular bonding. Try to float a paper clip on water, isopropyl alcohol, and glycerol by gradually lowering a dry paper clip into each liquid on a cradle fashioned from another paper clip (Figure 3). It may be best to use a small beaker and some forceps for this procedure. Which liquid appears to have the greater surface tension and greater intermolecular forces? Record for Part 3.


3

Part 4: Visualization of surface tension: The surface of a liquid with strong hydrogen bonding will exhibit great tension much like the head of a drum that has been pulled tight. If a drumstick ruptures the head of a drum, the sides recoil under the tension. In a similar manner, if a chemical ruptures the surface tension of a fluid, the "skin" of the liquid will recoil away from the point where the chemical was applied.

Fill one Petri dish with water, another with isopropyl alcohol, and the third with glycerin. Sprinkle crushed pepper on the surface of both. The pepper will be more likely to float on the fluid with greater surface tension (Figure 4). Cover the tip of a paper clip with liquid dish soap and hold over the center of each Petri dish until a drop of soap falls into the liquid. If the surface of the liquid is under tension, the pepper will recoil towards the sides immediately (see picture). Which liquid appears to have the greater surface tension and greater intermolecular forces? Record your conclusion for Part 4.



Part 5: Create models of the isopropyl alcohol (C_3H_8O), water, and glycerol ($C_3H_8O_3$) using the molecular modeling kits in the lab. What are the structural features of the three molecules? Draw the 3-D picture of each molecule!

6. Are all of the above chemicals polar? Rank these chemicals from least polar to most polar and justify your answer **based on your models**.

7. What type of intermolecular forces (LDF, D-D, H-bonds) would you expect for each molecule **based on your models**? Create a table similar to the one you used in Prelab Question #2 above.

8. Is your answer in #7 consistent with your **laboratory observations**? Support your statements for each of the three liquids with references to specific observations you made during the lab.

Final Questions

9. Which of the liquids you tested (isopropyl alcohol, water and glycerol), displayed the greatest surface tension (greatest intermolecular forces)?
10. Which of the liquids you tested (isopropyl alcohol, water and glycerol), do you think will boil most easily? Why? Be specific.
11. You may have noticed mosquitoes, water striders, and other insects walking on the surface of a pond. Why don't they sink?

Parts of this lab have been taken and adapted from the original source at:

*http://www.miramar.sdccd.cc.ca.us/faculty/fgarces/zCourse/Spring05/Ch100_MM/Ch100_Lab/Lab_Online/d_expt/Ex10_CausesIMF/IMForcesFactors_OL.html