Experiment

9

Evaporation and Intermolecular Attractions

In this experiment, Temperature Probes are placed in various liquids. Evaporation occurs when the probe is removed from the liquid's container. This evaporation is an endothermic process (REMEMBER: endothermic means that the reaction absorbs heat from its surroundings, which is the probe) that results in a temperature decrease of the probe. The magnitude of a temperature decrease is, like viscosity and boiling temperature, related to the strength of intermolecular forces of attraction. In this experiment, you will study temperature changes caused by the evaporation of several liquids and relate the temperature changes to the strength of intermolecular forces of attraction. You will use the results to predict, and then measure, the temperature change for several other liquids.

You will encounter two types of organic compounds in this experiment—alkanes and alcohols. The two alkanes are n-pentane, C_5H_{12}, and n-hexane, C_6H_{14}. In addition to carbon and hydrogen atoms, alcohols also contain an –OH group bonded to a C atom in the molecule. Methanol, CH_3OH, and ethanol, C_2H_5OH, are two of the alcohols that we will use in this experiment. You will examine the molecular structure of alkanes and alcohols for the presence and relative strength of two intermolecular forces—hydrogen bonding and dispersion forces.

OBJECTIVES

In this experiment, you will

- Study temperature changes caused by the evaporation of several liquids.
- Relate the temperature changes to the strength of intermolecular forces of attraction.

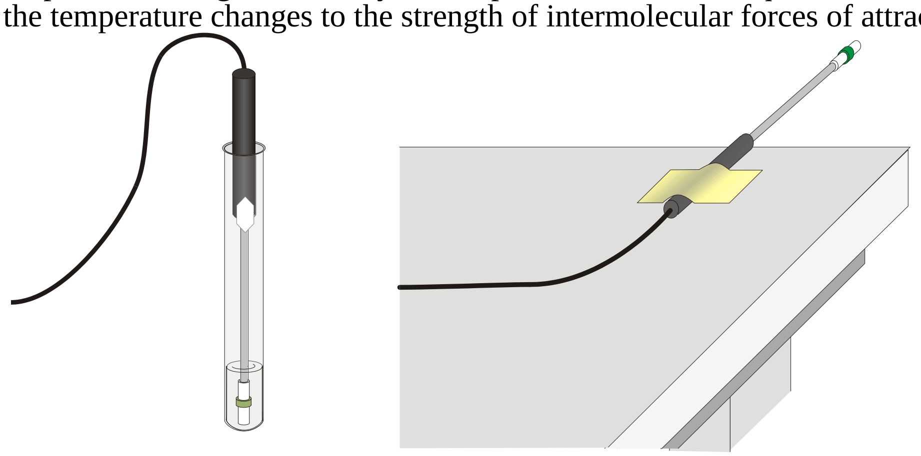

Figure 1

MATERIALS

computer	methanol (methyl alcohol)
Vernier computer interface	ethanol (ethyl alcohol)
Logger*Pro*	1-propanol
two Temperature Probes	1-butanol
6 pieces of filter paper (2.0 cm × 1.5 cm)	n-pentane

2 small rubber bands
masking tape
n-hexane

PRE-LAB EXERCISE

Prior to doing the experiment, complete the Pre-Lab table. The name and formula are given for each compound. Determine the molecular weight of each of the molecules. Dispersion forces exist between any two molecules, and generally increase as the molecular weight of the molecule increases. Next, examine each molecule for the presence of hydrogen bonding. Before hydrogen bonding can occur, a hydrogen atom must be bonded directly to an N, O, or F atom within the molecule. Tell whether or not each molecule has hydrogen-bonding capability. **Hand this pre-lab exercise in to your instructor during the lecture on the day before your lab is scheduled. Your instructor will GRADE these and hand them back to you for the experiment.**

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** The compounds used in this experiment are flammable and poisonous. Avoid inhaling their vapors. Avoid contacting them with your skin or clothing. Be sure there are no open flames in the lab during this experiment. Notify your instructor immediately if an accident occurs. It is recommended that you wear gloves.

2. Connect the probes to the computer interface. One probe should be connected to Channel 1 and one to Channel 2. Prepare the computer for data collection by opening the file “09 Evaporation” from the *Chemistry with Vernier* folder.

3. Wrap Probe 1 and Probe 2 with the pieces of filter paper provided (2.0 cm x 1.5 cm) and secure them by small rubber bands as shown in Figure 1. Roll the filter paper around the probe tip in the shape of a cylinder. Hint: First slip the rubber band up on the probe, wrap the paper around the probe, and then finally slip the rubber band over the wrapped paper. The paper should be even with the probe end.

4. Stand Probe 1 in the ethanol container and Probe 2 in the 1-propanol container. Make sure the containers do not tip over.

5. Prepare 2 pieces of masking tape, each about 10 cm long, to be used to tape the probes in position during Step 6.

6. After the probes have been in the liquids for at least 30 seconds, begin data collection by clicking Collect. **Monitor the temperature for 15 seconds to establish the initial temperature of each liquid.** Then simultaneously remove the probes from the liquids and tape them so the probe tips extend 5 cm over the edge of the table top as shown in Figure 1.

7. When both temperatures have reached minimums and have begun to increase, click Stop to end data collection. If the temperature does not start to rise, data collection will stop automatically after 5 minutes. This is OK. Click the Statistics button, STAT, then click OK to display a box for both probes. Record the maximum (t_1) and minimum (t_2) values for Temperature 1 (ethanol) and Temperature 2 (1-propanol). Label each curve on the graph with the name of the substance, using text annotation (from the Insert menu at the top of the graph). From the Experiment menu at the top of the graph, select **store latest run**. This will allow us to have all the curves on one graph and make visual comparisons clearer. **Make sure you do this before moving on to Step 11 below.**

8. For each liquid, subtract the minimum temperature from the maximum temperature to determine Δ*t*, the temperature change during evaporation.

9. Roll the rubber band up the probe shaft and dispose of the filter paper as directed by your instructor.

10. Based on the Δ*t* values you obtained for these two substances, plus information in the Pre-Lab exercise, *predict* the size of the Δ*t* value for 1-butanol. **Keep in mind that where the attraction between molecules is stronger, the evaporation will be slower and the Δt will be smaller.** Compare its hydrogen-bonding capability and molecular weight to those of ethanol and 1-propanol. Record your predicted Δ*t*, then explain how you arrived at this answer in the space provided. Do the same for n-pentane. It is not important that you predict the exact Δ*t* value; simply estimate a logical value that is higher, lower, or between the previous Δ*t* values.

11. Test your prediction in Step 10 by repeating Steps 3-9 using 1-butanol for Probe 1 and n-pentane for Probe 2. Remember to label these 2 new curves and to "Store the latest run" before doing Step 13.

12. Based on the Δ*t* values you have obtained for all four substances, plus information in the Pre-Lab exercise, predict the Δ*t* values for methanol and n-hexane. Compare the hydrogen-bonding capability and molecular weight of methanol and n-hexane to those of the previous four liquids. Record your predicted Δ*t*, then explain how you arrived at this answer in the space provided.

13. Test your prediction in Step 12 by repeating Steps 3-9, using methanol with Probe 1 and n-hexane with Probe 2. Again label each curve and "store latest run"

PROCESSING THE DATA

1. Two of the liquids, n-pentane and 1-butanol, had nearly the same molecular weights, but significantly different Δ*t* values. Explain the difference in Δ*t* values of these substances, based on their intermolecular forces.

2. Which of the alcohols studied has the strongest intermolecular forces of attraction? The weakest intermolecular forces? Explain using the results of this experiment.

3. Which of the alkanes studied has the stronger intermolecular forces of attraction? The weaker intermolecular forces? Explain using the results of this experiment.

PRE-LAB

Substance	Formula	Molecular Weight	Hydrogen Bond (Yes or No)
ethanol	C_2H_5OH		
1-propanol	C_3H_7OH		
1-butanol	C_4H_9OH		
n-pentane	C_5H_{12}		
methanol	CH_3OH		
n-hexane	C_6H_{14}		

DATA TABLE

Substance	t_1 (°C)	t_2 (°C)	Δt (t_1–t_2) (°C)
ethanol			
1-propanol			
1-butanol			
n-pentane			
methanol			
n-hexane			

Predicted Δt (°C)	Explanation