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 that results in a temperature decrease. 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 the -OH functional group. 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.

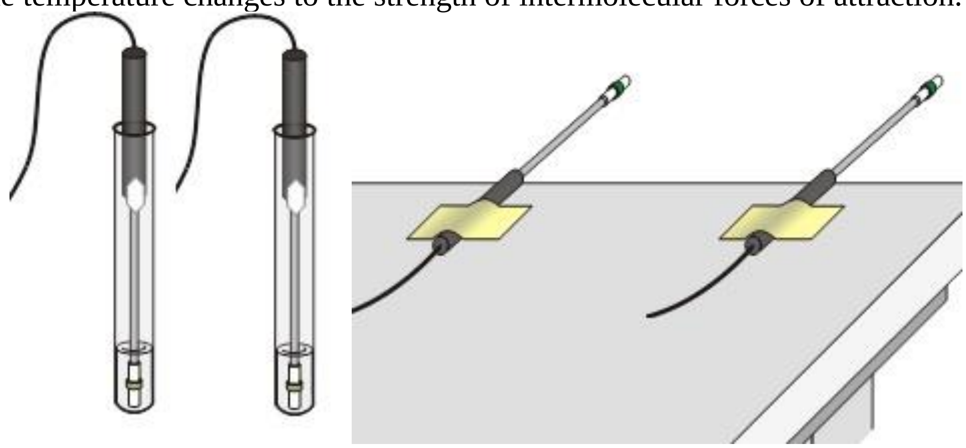

Figure 1

MATERIALS

computer
Vernier computer interface
LoggerPro
two Temperature Probes
2 small rubber bands
masking tape
6 strips of paper about 2.5 cm long(cut from roll of chromatography paper)
methanol (methyl alcohol)
ethanol (ethyl alcohol)
1-propanol
1-butanol
n-pentane
n-hexane

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.

2. Connect the temperature probes to the computer interface (channels 1 and 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 strips of paper about 2.5 cm in length and secure them by wrapping with 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. Try to avoid covering up the paper with the rubber band and keep as much of the paper exposed to the air as possible.

4. Get out your yellow plastic test tube rack and obtain the ethanol and 1-propanol test tubes. TEMPORARILY REMOVE THE STOPPERS FROM THE TEST TUBES and Stand Probe 1 in the ethanol container and Probe 2 in the 1-propanol container. Make sure the test tubes are supported in the rack and 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**. **REPLACE THE STOPPERS IN BOTH TEST TUBES IMMEDIATELY!** These liquids evaporate FAST!

7. When both temperatures have reached minimums and have begun to increase, click Stop to end data collection. 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).

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

9. Roll the rubber band up the probe shaft and dispose of the paper by placing it in the waste beaker located in the fume hood.

10. Based on the Δt values you obtained for these two substances, plus information in the Pre-Lab exercise, *predict* the size of the Δt value for 1-butanol. Compare its hydrogen-bonding capability and molecular weight to those of ethanol and 1-propanol. Record your predicted Δt, 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 Δt value; simply estimate a logical value that is higher, lower, or between the previous Δt 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.

12. Based on the Δt values you have obtained for all four substances, plus information in the Pre-Lab exercise, predict the Δt 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 Δt, 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.

PRE-LAB EXERCISE

EVAPORATION AND INTERMOLECULAR ATTRACTIONS

NAME________________________________DATE________________

Prior to doing the experiment, complete the Pre-Lab table. The name and formula are given for each compound. Draw a structural formula for a molecule of each compound. Then 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, Cl, or F atom within the molecule. Tell whether or not each molecule has hydrogen-bonding capability.

Substance	Formula	Structural Formulas (Draw in the space below)	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}			

REPORT SHEET

EVAPORATION AND INTERMOLECULAR ATTRACTIONS

NAME___________________________**DATE**______________

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

PROCESSING THE DATA

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

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

3. The weakest intermolecular forces? **Explain using the results of this experiment.**

4. Which of the alkanes studied has the stronger intermolecular forces of attraction? **Explain using the results of this experiment.**

5. Which of the alkanes studied has the weaker intermolecular forces? **Explain using the results of this experiment.**

6. Graphs (2)
   - **Print and attach your graph** showing all 6 cooling curves from this experiment. Each line should have a label identifying the substance it represents.
   - Plot a graph of Δt values of the **four alcohols** **versus their respective molecular weights**. Plot molecular weight on the horizontal axis and Δt on the vertical axis. **Attach the graph to this report.**