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 pentane, C_5H_{12}, and 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.
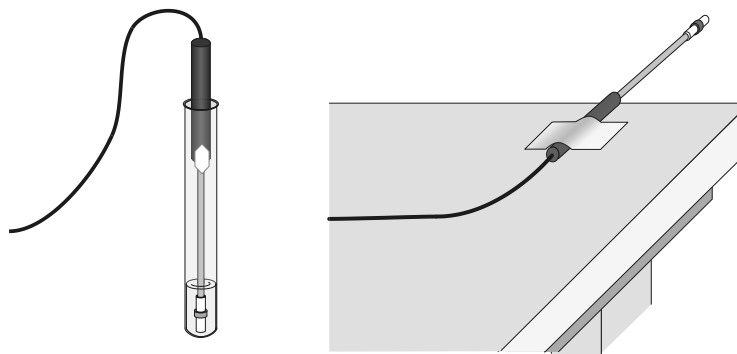

Figure 1

MATERIALS

TI-Nspire handheld **or**	methanol (methyl alcohol)
computer and TI-Nspire software	ethanol (ethyl alcohol)
data-collection interface	1-propanol
2 Temperature Probes	1-butanol
6 pieces of filter paper (2.5 cm x 2.5 cm)	n-pentane
2 small rubber bands	n-hexane
masking tape	

PRE-LAB QUESTIONS

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, or F atom within the molecule. Tell whether or not each molecule has hydrogen-bonding capability.

Substance	Formula	Structural formulas	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}			

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 teacher immediately if an accident occurs.

2. Connect the Temperature Probes to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.

3. Choose New Experiment from the 🔬 Experiment menu. Choose Collection Setup from the 🔬 Experiment menu. Enter **240** as the experiment duration in seconds (4 minutes). The number of points collected should be 481. Select OK.

4. Wrap Probe 1 and Probe 2 with square pieces of filter paper secured 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 on the probe, wrap the paper around the probe, and then finally slip the rubber band over the paper. The paper should be even with the probe end.

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

6. Prepare 2 pieces of masking tape, each about 10 cm long, to be used to tape the probes in position during Step 7.

7. After the probes have been in the liquids for at least 30 seconds, start data collection (▶). A live graph of temperature vs. time for both Probe 1 and Probe 2 is being plotted on the screen. Live readings are also displayed. 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. **Note:** avoid moving near the sensors as air movement can affect your results.

8. Data collection will stop after 240 seconds. Click any data point and use ► and ◄ to examine the data pairs on the displayed graph. Based on your data, determine the maximum temperature, t_1, and minimum temperature, t_2 for both probes. Record t_1 and t_2 for each probe in the data table.

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

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. 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. Click the Store Data button (✔). Repeat Steps 5–9 using 1-butanol with Probe 1 and n-pentane with Probe 2.

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. Click the Store Data button (✔). Repeat Steps 5–9, using methanol with Probe 1 and n-hexane with Probe 2.

DATA

Substance	t_1 (°C)	t_2 (°C)	$\Delta t\ (t_1-t_2)$ (°C)
ethanol			
1-propanol			
1-butanol			
n-pentane			
methanol			
n-hexane			

Predicted Δt (°C)	Explanation

PROCESSING THE DATA

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.

   a. Insert a new problem in the document, then Insert a new DataQuest App into problem 2. Click on the Table View tab (▦) to view the Table.
   b. Double click on the *X* column to access the column options. Enter **Molecular Weight** for the Name, **Weight** for the short name, and **amu** for the units. Change the Display Precision to 0 decimal places. Select OK.
   c. Double click on the *Y* column to access the column options. Enter **ΔT** for the column name. Enter °**C** as the units. Select OK.
   d. Using the data recorded in the tables, enter the values in the DataQuest Table.
   e. Click on the Graph View tab (⌇) to view the graph.

QUESTIONS

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? 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.