Evaporation of Alcohols
Vernier Data-Collection Activity

3778

INTRODUCTION

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.

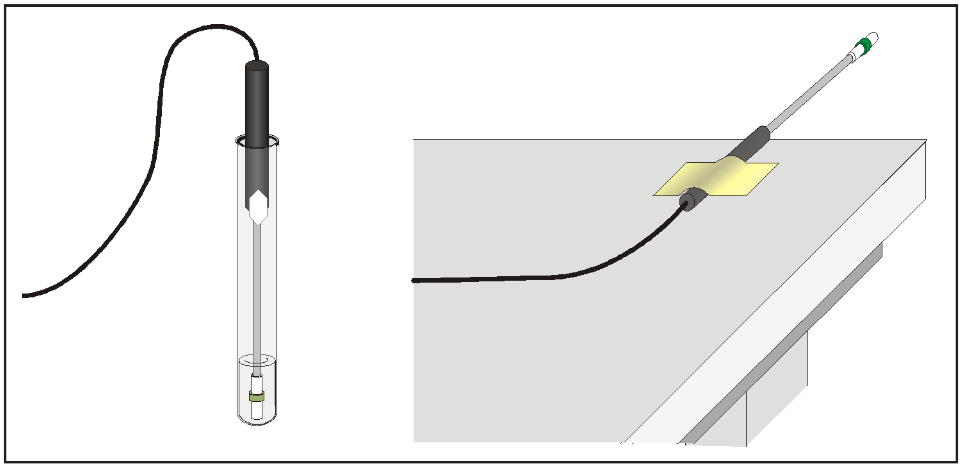

Figure 1

MATERIALS

- TI-83 Plus or TI-84 Plus graphing calculator
- EasyData application
- CBL 2 or LabPro
- 2 Temperature Probes
- 6 pieces of filter paper (2.5 cm X 2.5 cm)
- 2 small rubber bands
- masking tape
- methanol (methyl alcohol)
- ethanol (ethyl alcohol)
- 1-propanol
- 1-butanol
- n-pentane
- n-hexane

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PRE-LAB EXERCISE

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.

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.

Turn on the calculator and connect it to the CBL 2 or LabPro. Plug Temperature Probe 1 into Channel 1 and Temperature Probe 2 into Channel 2 of the interface.

3.

Set up EasyData for data collection.

- **a.** Start EasyData if it is not already running.
- **b.** Select (File) from the Main screen, and then select **New** to reset the application.
- **c.** Select (Setup) from the Main screen, and then select **Time Graph**…
- **d.** Select (Edit) on the Time Graph Settings screen.
- **e.** Enter 3 as the time between samples in seconds and select (Next).
- **f.** Enter 80 as the number of samples and select (Next) (data will be collected for 4 minutes).
- **g.** Select (OK) to return to the Main screen.

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 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.

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, select (Start) to begin collecting temperature data. A live graph of temperature vs. time for both Probe 1 and Probe 2 is being plotted on the calculator screen. The live readings are displayed in the upper-right corner of the graph, Probe 1 first, Probe 2 below. 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.

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8.

Data collection will stop after 4 minutes (or select Stop to stop before 4 minutes has elapsed). On the displayed graph of temperature vs. time, each point for Probe 1 is plotted without a marker, and each point for Probe 2 with a square. As you move the cursor right or left, the time (X) and temperature (Y) values of each Probe 1 data point are displayed above the graph. Based on your data, determine the maximum temperature, t_1, and minimum temperature, t_2. Record t_1 and t_2 for Probe 1.Press ▾ to switch the cursor to the curve of temperature vs. time for Probe 2. Examine the data points along the curve. Record t_1 and t_2 for Probe 2.

9.

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

10.

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

11.

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.

12.

Select Main to return to the Main screen. Test your prediction in Step 11 by repeating Steps 4–10 using 1-butanol with Probe 1 and n-pentane with Probe 2. **Note**: After selecting Start to begin data collection, select OK to overwrite the latest run and start data collection.

13.

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.

14.

Select Main to return to the Main screen. Test your prediction in Step 13 by repeating Steps 4–10, using methanol with Probe 1 and n-hexane with Probe 2. **Note**: After selecting Start, select OK to overwrite the latest run and start data collection.

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? 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.

4.

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.

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DATA TABLE

Substance	Formula	Structural Formula	Molecular Weight	Hydrogen Bond (Yes or No)
ethanol	C_2H_2OH			
1-propanol	C_3H_7OH			
1-butanol	C_4H_9OH			
n-peptane	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-peptane			
methanol			
n-hexane			

Predicted Δt (C°)	Explanation