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 changes 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

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

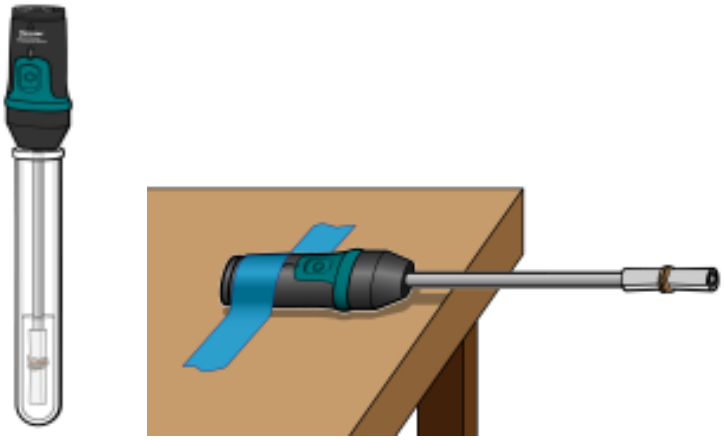

Figure 1

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
2 Go Direct Temperature Probes
methanol (methyl alcohol)
ethanol (ethyl alcohol)
1-propanol
1-butanol
n-pentane
n-hexane
6 pieces of filter paper (2.5 cm × 2.5 cm)
2 small rubber bands
masking tape

PRE-LAB EXERCISE – SEE BELOW FOR TABLE FOR PRELAB

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. Set up the data-collection equipment.

   a. Launch Graphical Analysis.

   b. Connect the Temperature Probes to your Chromebook, computer, or mobile device.

   c. Click or tap the meters and identify which probe is Probe 1 and which probe is Probe 2.

3. Click or tap Mode to open Data Collection Settings. Change End Collection to 240 seconds. Click or tap Done.

4. Wrap the tips of the probes 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.

DANGER: *Denatured ethanol,* CH_3CH_2OH: *Highly flammable liquid and vapor. Keep away from heat, sparks, open flames, and hot surfaces. Do not eat or drink when using this product—harmful if swallowed. Causes skin and serious eye irritation. May cause respiratory irritation. Avoid breathing mist, vapors or spray. Causes damage to organs. Addition of denaturant makes the product poisonous. Cannot be made nonpoisonous*.

DANGER: *1-Propanol: Keep away from heat, sparks, open flames, and hot surfaces—highly flammable liquid and vapor. Do not eat or drink when using this product—harmful if swallowed. Causes mild skin irritation and serious eye damage. May be harmful if inhaled. May cause drowsiness or dizziness*.

6. Prepare two 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, click or tap Collect to start data collection. Monitor the temperatures 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.

8. Data collection will stop after 4 minutes, or you can stop data collection before 4 minutes has elapsed if the lowest temperature has been reached. Examine the graph of temperature *vs*. time. 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.

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

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 5–9 using 1-butanol with Probe 1 and n-pentane with Probe 2.

    DANGER: *1-Butanol,* C_4H_9OH: *Keep away from heat, sparks, open flames, and hot surfaces—highly flammable liquid and vapor. Toxic if swallowed, in contact with skin, or if inhaled. Do not eat or drink when using this product. Do not breathe mist, vapors, or spray. Causes skin and serious eye irritation. Causes damage to organs*.

    DANGER: *n-Pentane,* $CH_3(CH_2)_3CH_3$: *Keep away from heat, sparks, open flames, and hot surfaces—highly flammable liquid and vapor. Do not eat or drink when using this product—harmful if swallowed or in contact with skin. Avoid breathing mist, vapors or spray. May cause drowsiness or dizziness*.

12. Based on the Δt values you 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 5–9, using methanol with Probe 1 and n-hexane with Probe 2.

DANGER: *Methanol,* CH_3OH: *Keep away from heat, sparks, open flames, and hot surfaces—highly flammable liquid and vapor. Toxic if swallowed, in contact with skin, or if inhaled. Do not eat or drink when using this product. Do not breathe mist, vapors, or spray. Causes skin and serious eye irritation. Causes damage to organs*.

DANGER: *Hexanes,* C_6H_{14}: *Keep away from heat, sparks, open flames, and hot surfaces—highly flammable liquid and vapor. Do not eat or drink when using this product. Avoid breathing mist, vapors, or spray. May be fatal if swallowed and enters airways. May cause damage to organs. Causes skin and eye irritation. May cause drowsiness or dizziness. Suspected of damaging fertility or the unborn child. Do not handle until all safety precautions have been understood*.

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.

PRE-LAB

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}			

DATA TABLE [IN YOUR NOTEBOOK…OF COURSE, SET UP FOR TWO TRIALS OF EACH]

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
1-butanol		
n-pentane		
methanol		
n-hexane		