Evaporation and Intermolecular Attractions

BACKGROUND

A substance absorbs energy from its surroundings as it changes from the liquid to the gas phase. The absorption of heat by the evaporating substance causes its surroundings to cool—this process is called evaporative cooling. Humans experience this when they sweat.

Why is evaporation an endothermic process? The ***intermolecular attractions*** (attractions between the molecules) in the liquid state have to be broken to undergo the phase change and this is accomplished by the absorption of energy as heat. Thus, **there is a relationship between the intermolecular attractions in a liquid and the ability of the liquid to evaporate.**

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.

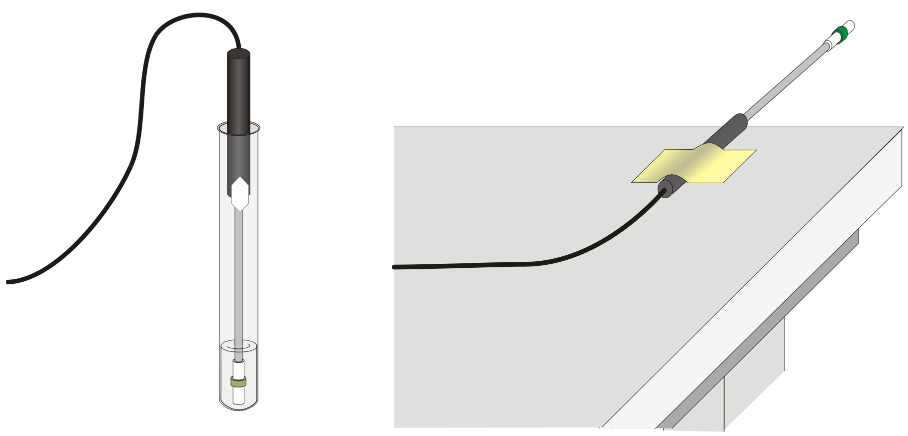


Figure 1

PROCEDURE (READ BEFORE FILLING IN DATA)

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.

2. Connect the probes to the computer interface. 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 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.

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. Click the Statistics button, 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 filter paper as directed by your instructor.

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.

REPORT SHEETS

DATA TABLE (FOLLOW THE STEPS OUTLINED IN THE PROCEDURE!)

Substance	Formula	T_1 (°C)	T_2 (°C)	ΔT ($T_1 – T_2$) (°C)		
ethanol	C_2H_5OH				**For directions on predictions, see step 10!**	
1-propanol	C_3H_7OH				Predicted ΔT (°C)	Explanation
1-butanol	C_4H_9OH					
n-pentane	C_5H_{12}					
methanol	CH_3OH					
n-hexane	C_6H_{14}					

FOLLOW UP QUESTIONS

1. Using the chemical formulas above, draw the structures of the two alkanes, n-pentane and n-hexane and the structures of all of the alcohols.

2. Two of the liquids, n-pentane and 1-butanol, had nearly the same molecular weights, but significantly different ΔT values. Which has stronger intermolecular forces? What about its structure leads to the stronger forces?

3. Which of the alcohols studied has the strongest intermolecular forces of attraction? The weakest intermolecular forces? Explain these results in terms of the structures of the alcohols.

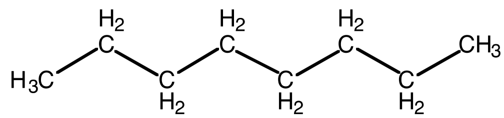
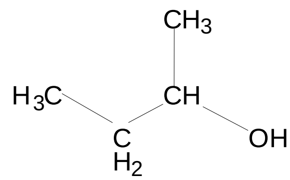
4. Which of the alkanes studied has the stronger intermolecular forces of attraction? The weaker intermolecular forces? Explain these results in terms of the structures of the alkanes.

5. Plot a graph of ΔT values of the four alcohols versus their respective molecular weights. Plot molecular weight (independent variable) on the horizontal axis and ΔT (dependent variable) on the vertical axis. MAKE SURE YOU LABEL YOUR AXES AND PROVIDE A TITLE.

6. What does this plot tell you about the relationship between molecular weight and the strength of intermolecular forces? Summarize this relationship in your own words:

Pre-Lab Assignment

1. What are some structural features of a substance that might influence its ability to evaporate? For instance, compare the two substances below and **list at least three different structural features** that might lead to differences in their properties:

Compound	**Formula**	**Structure**
octane	C_8H_{14}	
2-butanol	$C_4H_{10}O$	

2. A substance evaporates from the surface of a temperature probe. What do you think happens to the temperature of the probe—does it increase or decrease? Explain.

3. What does the term “volatility” mean? What does it mean for Substance A to be more volatile than Substance B?

4. The temperature of the probe changes as the substance evaporates. The more evaporation there is, the greater the change in temperature. Which will produce a larger change in temperature (ΔT): a more volatile substance or a less volatile substance? Explain.

5. Based on #4 above, true or false: A large change in temperature (ΔT) indicates that strong attractions are present in the evaporating substance. **Explain**.