Lab 8. Evaporation and Intermolecular Attractions

Prelab Assignment

Before coming to lab:

- Complete *in your lab notebook* the following sections of your report for this lab exercise *before* attending lab: Title, Introduction, Materials/Methods and Data Table (see step 1 of the procedure). An outline or flow chart of the procedure is appropriate for the Materials/Methods section. Ensure that the table of contents of your lab notebook is current.
- Read the lab thoroughly and answer the **pre-lab questions** that appear at the end of this lab exercise.

Purpose

In this experiment you will examine the molecular structures of alkanes and alcohols for the presence and relative strengths of two intermolecular forces, dispersion forces (London forces) and hydrogen bonding. You will then measure the relative strengths of these forces by observing the temperature change each compound engenders as it evaporates.

Introduction

When a liquid evaporates the ***intermolecular*** forces holding the molecules together must be overcome for the molecules to escape into the vapor phase. Thus the rate at which a liquid evaporates is related to the strength of the intermolecular forces, and therefore the energy that must be added to separate the molecules.

In this experiment a temperature probe will be wetted in various liquids, and then each liquid allowed to evaporate when the probe is removed from the liquid. This evaporation is an endothermic process that results in a temperature drop. As suggested above, the magnitude of a temperature drop, and thus the energy taken up, is related to the strength of intermolecular forces of attraction. In this experiment, you will observe temperature changes caused by the evaporation of several liquids, and then relate the temperature changes to the strength of intermolecular forces of attraction. You will then use these first 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, C_nH_{2n+2}***, and ***alcohols***. Examples of compounds we will use are the alkanes ***n–pentane***, C_5H_{12}, and ***n–hexane***, C_6H_{14}, and the alcohols ***methanol***, CH_3OH, and ***ethanol***, C_2H_5OH. As you see from the formulas, alcohols contain the ***hydroxyl functional group***, –OH, in addition to the carbon and hydrogen atoms in the alkanes.

Procedure (You will work with a partner in this experiment.)

1. ***Before coming to lab construct a ruled data table in your lab notebook with rows and columns for the items indicated below:***

   Rows for….
   - Ethanol
   - n-propanol
   - n-pentane
   - 1-butanol
   - n-hexane
   - Methanol
   - Water.

   Columns for….
   - The name of the liquid, alkane or alcohol
   - Its chemical formula
   - Its structural, or Lewis, formula
   - The molar mass of the liquid
   - The type(s) of intermolecular forces present in the liquid
   - ΔT, the change in temperature due to evaporation (predicted)
   - ΔT, the change in temperature due to evaporation (Experimental)

2. ***Prepare the computer for data collection*** by connecting two "*Go-Links*" to the USB ports near the keyboard and then connect a temperature probe to each "*Go-Link*." Now open *Logger Pro 3.5* and then open the file "*09 Evaporation*" from the "*Chemistry with Computers*" folder. The vertical axis of the graph will have temperature scaled from 5 to 30^{o}C. The horizontal axis will have time scaled from 0 to 250 seconds. Do the following to extend the collection time to 600 seconds:
   - Under "Experiment" on the Menu Bar at the top of *Logger Pro*, select "Data Collection" and then change the length of time to 600 seconds. Now click "Done."
   - To recalibrate the graph, click on the 250 at the end of the x-axis and enter 600 to set the maximum time at 600 seconds.

3. Wrap Probe 1 and Probe 2 with square pieces of filter paper secured by small rubber bands. 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. *Use filter paper of the same size (4 cm long) for all trials below*!

Ethanol vs. 1-propanol

4. Place 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 45 seconds, begin data collection by clicking on the "Collect" button. Monitor the temperature for at least fifteen 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 tabletop.
7. When both temperatures have reached *minimums* and have begun to increase, click on "Stop" to end data collection. Click on the graph, and choose "Statistics" from the "Analyze" menu. Record the minimum and maximum temperature for Temp 1 (ethanol) and Temp 2 (1–propanol). Since the precision of the temperature probes is ±0.2 ^{o}C, ***all temperatures should be recorded to 0.1 ^{o}C***.

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.

n-Pentane vs. 1-butanol

10. Based on the ΔT values you obtained for these two alcohols, predict the size of the ΔT value for ***1–butanol***. Record your predicted ΔT, and explain how you arrived at this answer. Do the same for ***n–pentane***. It is not important that you predict the exact ΔT values; 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.

n-Hexane vs. methanol

12. Based on the ΔT values you have obtained for all four substances, predict the ΔT values for methanol and n–hexane. Record your predicted ΔT, and then explain how you arrived at this answer.

13. Test your prediction in Step 12 by repeating Steps 3–9, using ***methanol*** with Probe 1 and ***n–hexane*** with Probe 2.

Water vs. methanol

14. Repeat the experiment a final time using ***methanol*** and ***wate***r. Remember to make a prediction before you conduct the experiment.

Analysis of Results and Report

As a part of your lab write-up and analysis be sure to answer the following questions:

1. Prepare a bar graph of the ΔT values of the four alcohols *vs.* their respective molecular weights. Plot molecular weight on the horizontal axis and ΔT on the vertical axis. You may use the graph paper in your lab notebook for this graph or *Excel*—your choice.

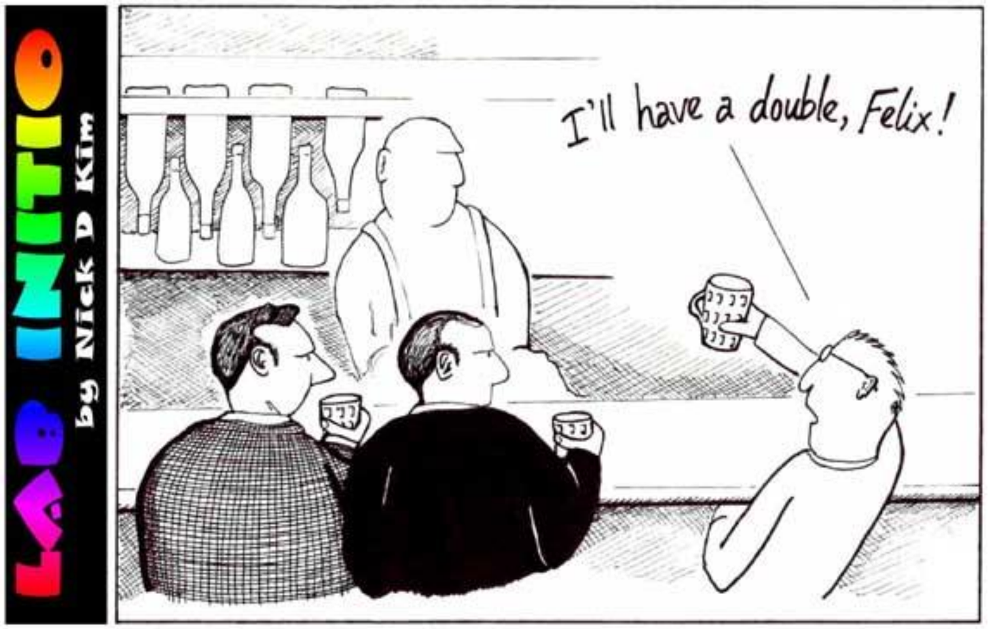
2. Which of the alcohols studied has the strongest intermolecular forces of attraction? The weakest intermolecular forces? Explain citing specific numerical results from this experiment as support while discussing the nature of intermolecular forces involved.

3. Which of the alkanes studied has the stronger intermolecular forces of attraction? The weaker intermolecular forces? Explain citing specific numerical results from this experiment as support while discussing the nature of intermolecular forces involved.

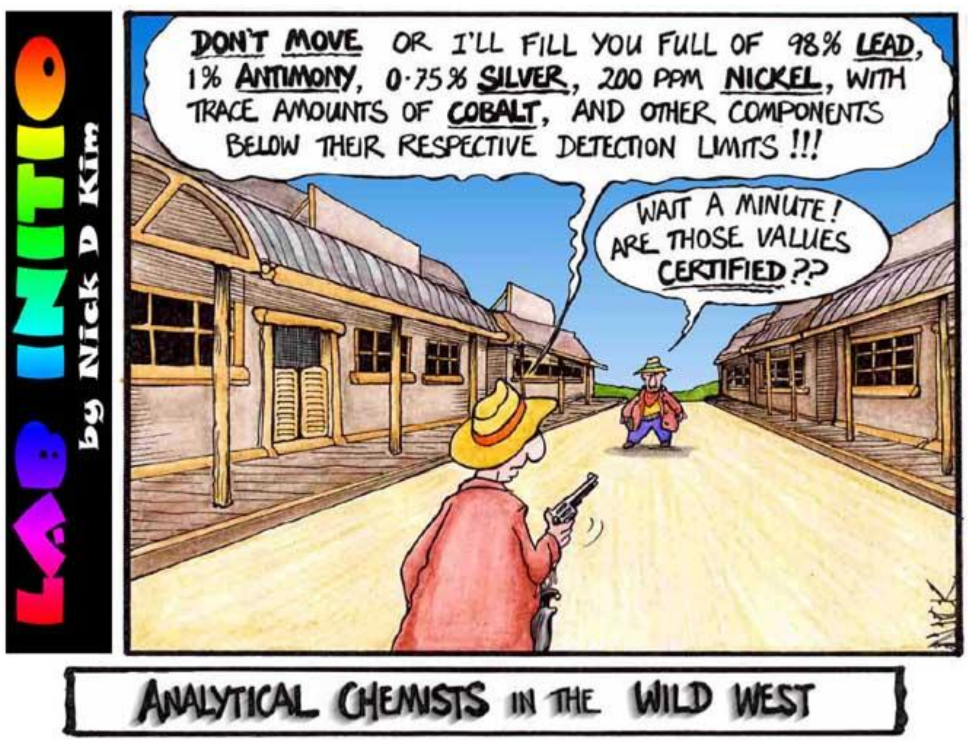
4. Two of the liquids, n–pentane and 1–butanol, have nearly the same molecular weights, but had significantly different ΔT values. Explain the difference in ΔT values of these substances, based on their intermolecular forces.

Acknowledgement: This lab is adapted from similar labs produced by my colleagues at GRCC, Roger Knutsen and Mary Whitfield.

On the lighter side…



Cambridge, 1953. Shortly before discovering the structure of DNA, Watson and Crick, depressed by their lack of progress, visit the local pub.



Lab 8. Evaporation and Intermolecular Attractions **Name____________________________**
Prelab Questions **Team ____Date ________Section ____**

Instructions: Complete the following questions and hand in at the start of your lab period.

1. Draw the structure of each compound below. Use your knowledge of intermolecular forces of attraction to predict the compound from each pair below that you would expect to have the higher boiling point (circle the name of the one in each pair with the higher BP). Briefly explain your reasoning—***indicate the intermolecular attractions involved***.

   a. **Propane, $CH_3CH_2CH_3$** **or** **Butane, $CH_3CH_2CH_2CH_3$**

   b. **Dimethyl ether, CH_3OCH_3** **or** **Diethyl ether, $CH_3CH_2OCH_2CH_3$**

   c. **Acetic Acid, CH_3COOH** **or** **Acetaldehyde, CH_3CHO**

2. Draw the structure of methane (CH_4) and chloroform ($CHCl_3$). Use your knowledge of intermolecular forces of attraction to predict which compound has a larger heat of vaporization (ΔH_{vap}). *Explain your reasoning fully discussing all intermolecular forces involved*.