Name ___________________________

Lab 1: Evaporation & Intermolecular Attraction:Water As An Evaporative Coolant

Objectives

- To establish the relationship between the rate of evaporative cooling and the strength of intermolecular forces of attraction.
- To examine the effects of hydrogen bonding and London Dispersion Forces (LDF) on the rate of evaporation of a liquid.

Introduction

Endothermic animals maintain homeostasis in their body temperatures by sweating to release excess heat. The evaporation of liquid from the skin surface requires thermal energy, which is supplied by the organism's body.

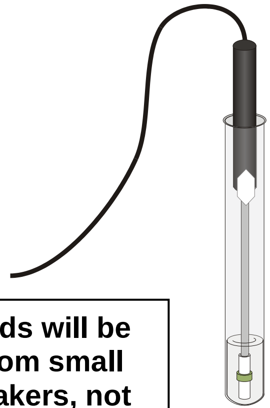
In this experiment, temperature probes are placed in various liquids. Evaporation occurs when the probe is removed from the liquid's container. Again, this endothermic process results in a temperature decrease. **The magnitude of a temperature decrease is directly related to the strength of intermolecular 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, specifically hydorgen bonding and London dispersion forces.

In this procedure, you will encounter six liquids: water (H_2O), four different alcohols, and pentane (C_5H_{12}), an alkane. An alkane is a hydrocarbon containing only single carbon-carbon bonds. Alcohols, you will remember, contain the -OH functional group bonded to one of the carbon atoms found in the molecule. For naming and identification purposes, the carbon atom to which this -OH group is attached is numbered, when appropriate. The alcohols used in this experiment are methanol (CH_3OH), ethanol (C_2H_5OH), 1-propanol (C_3H_7OH), and 1-butanol (C_4H_9OH). An alkane is an organic hydrocarbon molecule whose atoms are linked by single bonds.

You will examine the molecular structure of water, pentane, and alcohols for the presence and the relative strengths of two intermolecular forces - **hydrogen bonds and dispersion forces** - *as measured by the rate of temperature decrease during evaporation.* A temperature probe, graphing calculator, and LabPro interface will be used to obtain your data on evaporation rates.

<u>Background Information Summary:</u>

- Intermolecular forces of attraction (IMFs) must be overcome in order for the molecule to evaporate
- IMFs include **hydrogen bonds** – which can consistently form when the molecule is held together with *polar covalent bonds* – and LDFs – which can form intermittently whenever electrons in adjacent molecules intermittently cluster



Note: Liquids will be obtained from small bottles / beakers, not from test tubes.

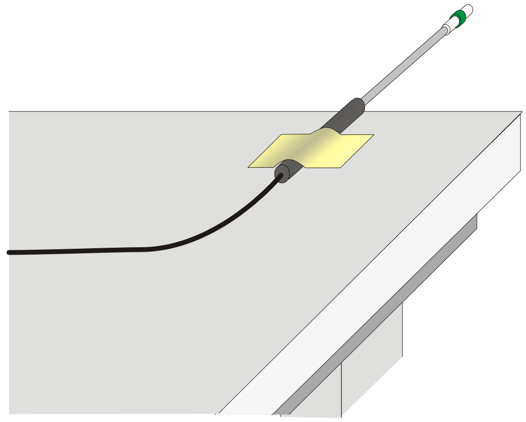


Figure 1

Materials

computer
Vernier computer interface
Logger*Pro*
one temperature probe
small rubber bands
6 pieces of squarefilter paper
(~2.5 cm x ~2.5 cm)

methanol (methyl alcohol)
ethanol (ethyl alcohol)
1-propanol (propyl alcohol)
1-butanol (butyl alcohol)
pentane
distilled water
tape (optional)

Pre-Lab Questions

Prior to doing the experiment, complete the Pre-Lab Table on page 4. The name and formula are given for each compound. Draw the structural formula for one molecule of each compound. Then determine the molecular weight of each molecule. Next, examine each molecule for the presence of hydrogen bonding. Circle all hydrogen atoms that can participate in hydrogen bonding. Tell whether or not each molecule has hydrogen-bonding capability, noting **the number of hydrogen atoms available for H-bonding.**

Consider the following information when you make hypotheses and interpretations during this lab: **London dispersion forces exist between any two molecules, and generally increase as the molecular weight of the molecule increases. Before hydrogen bonding can occur, a hydrogen atom must be bonded directly to an N, O, or F atom within the molecule.**

- Hydrogen weighs 1.008 atomic unit (AU).
- Carbon weighs 12.011 atomic units (AU).
- Oxygen weighs 15.999 atomic units (AU).

Table 1:

Substance	Formula	Molar Mass (g/mol)	Lewis Structure	Molecular Polarity	# of H atoms available to hydrogen bond
methanol	CH_3OH				
ethanol	C_2H_5OH				
1-propanol	C_3H_7OH				
1-butanol	C_4H_9OH				
n-pentane	C_5H_{12}				
n-hexane	C_6H_{14}				
water	H_2O				

Experimental Procedure:

- Open the file "09 Evaporation" from the *Chemistry with Vernier* folder.
- Prepare the temperature probe by inserting a rubber band on the probe, and wrapping a square of filter paper so it is flush with the tip of the probe.
- Apply safety goggles to yo' face. Maintain them especially when bottles are open.
- **One Igor is responsible for holding the bottles upright during this procedure. Until the bottles are safely closed, Igor has no other responsibility!**
- Gently dip the filter paper-covered probe into the ethanol for ~30 seconds. Maintain ~ constant dip times for each liquid.
- Tape or hold the probe off the edge of the lab bench. Then click START to begin data collection. Collect until the sample has reached a temperature minimum (and has begun to increase). Then click STOP.
- For each liquid, subtract the minimum temperature from the maximum temperature to determine **Δ*T*,** the temperature change during evaporation. This will be a negative #, since temperature declined during evaporation.
- Use a paper towel to avoid skin contact with the filter paper. Place used papers on a paper towel for easy non-epidermal disposal. Repeat for 1-propanol.
- Make APPROXIMATE PREDICTIONS for the – Δ*T* for the remaining liquids. *No postdictions please!*
- Record your data.

For each piece of data, consider the influence of both hydrogen bonding and LDF attractions between each molecule.

Data Table: *Evaporation Rates Of Water vs. 4 Alcohols & Pentane*

Substance	**T_1** (°C)	**T_2** (°C)	**ΔT** **(T_2–T_1)** (°C)
ethanol			
1-propanol			
1-butanol			
pentane			
methanol			

After obtaining evaporation data for ethanol and 1-propanol, complete the table below.

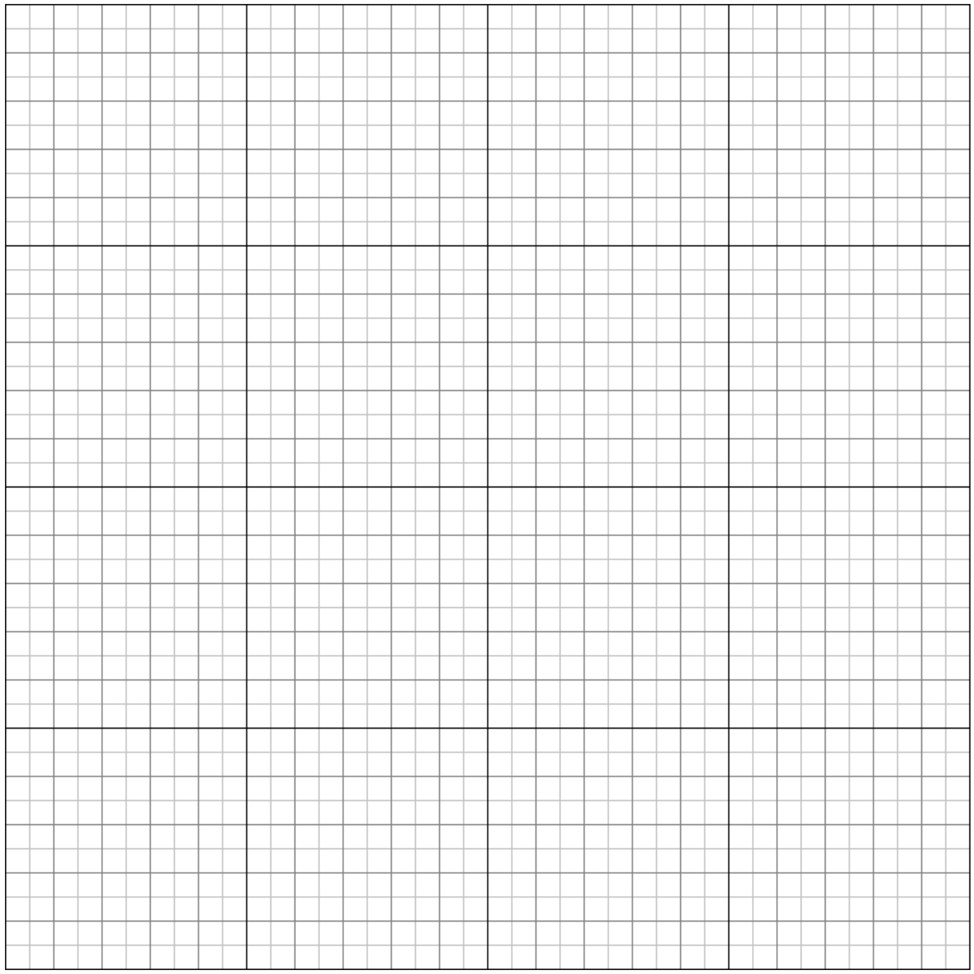
Predicted Temperature Changes During Evaporation: butanol, pentane, methanol, water

Predicted **ΔT** (°C)	**Justification for prediction**

water					

Title:

ΔT value
(absolute value)
(degrees C)



Molecular Weight (AU)

Processing the Data: Use your understanding of our lab to answer the following questions.

1. Plot a graph of *the absolute value of the ΔT values for water, pentane, and the four alcohols versus their respective molecular weights*.
    - Plot molecular weight on the X axis and ΔT on the Y axis.

2. Two of the liquids, pentane and 1-butanol, had nearly *the same molecular weights*, but *significantly different ΔT values*. Explain the difference in ΔT values of these two substances, based on their intermolecular forces of attraction.

3. a) Which of the alcohols studied has the *strongest intermolecular forces of attraction*?

   b) The *weakest intermolecular forces of attraction*?

   c) Explain using the results of this experiment.

4. a) What accounts for water's slow evaporation rate, given its relatively low molecular weight?

   b) Explain using the results of this experiment why *water is an efficient, long term evaporative coolant for endothermic organisms*.