

1. Draw Lewis Structures for the following four alcohols:
a. methanol (CH_3OH)
b. ethanol ($\text{CH}_3\text{CH}_2\text{OH}$)
c. 1-propanol ($\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$)
d. 2-propanol ($\text{CH}_3\text{CHOHCH}_2\text{CH}_3$)
2. What types of intermolecular attractions do each of the alcohols exhibit and how might they affect the tendency for an alcohol molecule to escape from its liquid?
3. Predict which alcohol will produce the largest - and the smallest - temperature drop from evaporative cooling.
4. What molecular structural factors influence boiling point of a liquid?
5. What effect should molar mass and polarity have on intermolecular forces present?

EVAPORATIVE COOLING & INTERMOLECULAR FORCES

Objective:

Explore the relationship between evaporative cooling and molar mass, boiling point, and density by developing and using an experimental technique for measuring degree of evaporative cooling for a series of alcohols.

Theory:

When a metal object (the *CBL* temperature probe) is immersed in a volatile liquid (an alcohol) and then exposed to the air, the surface of the object is observed to become colder. To explain this effect, consider the nature of evaporative cooling. Both the alcohol and the object are at room temperature when the object is immersed in the alcohol. Their temperatures are proportional to the average kinetic molecular energies of the atoms and molecules of which they are composed. When alcohol on the metal surface is exposed to the air, the alcohol molecules with more kinetic energy can escape to the vapor phase and leave the cooler ones behind. As a result, the average kinetic molecular energy of the molecules and atoms on the object's surface drops and the object cools. The alcohol molecules that escape from the surface of the object must have enough kinetic energy to overcome the intermolecular attractions to the other alcohol molecules. Thus, molecules with stronger intermolecular attractions might be expected to undergo a slower rate of escape.

In this lab, we will measure the degree of evaporative cooling (the average temperature drop) of three different alcohols and consider how the results relate to their densities, molecular weights and boiling points. We will predict the degree of cooling of one additional alcohol and then test our predictions. Finally, we will consider how we might explain the results using our model of how these interactions occur on the molecular scale.

Table I contains physical properties for the first series of alcohols.

Table 1. Chemical structure and Physical properties of Three Alcohols

Alcohol	Formula	Molar Mass g/mol	Boiling point °C	Density g/mL
Methanol	CH ₃ OH	32.04	65.0	0.7914
Ethanol	CH ₃ CH ₂ OH	46.07	78.5	0.7873
1-propanol	CH ₃ CH ₂ CH ₂ OH	60.10	97.0	0.8035

Safety Precautions

1. Be sure that no flames are in the experimental area. Alcohol vapors are extremely flammable.
2. Do not breathe the methanol vapors. Methanol has been known to cause blindness when ingested. Prolonged breathing of vapors has the same potential.

Procedure:

Data Collection:

Data will be collected using the CBL temperature probe and time graph. You decide what time intervals are appropriate to use. Repeat the measurement for ethanol until you obtain three reproducible results. Record your technique for obtaining reproducible data on the reporting sheet. Retain at least three reproducible temperature drop measurements for your alcohol. Find the average of the best three trials.

Part I. Developing good techniques

Reproducibility may be a problem. How do you plan to deal with the drop of liquid at the end of the probe? Repeat your measurements of ethanol until you are satisfied that reproducible results have been obtained. Record your technique in your notebook. Collect at least three "reproducible" temperature drop measurements for ethanol.

Part II. Experiments with Three Alcohols

Data collection:

Use the technique you developed in Part I of the lab as well as the same CBL and temperature probe set up, measure the evaporative cooling for the first three alcohols.

Data Analysis:

Create a series of graphs, using Graphical Analysis (instructions for use included). On separate graphs, plot the recorded temperature decrease versus 1) molar mass, 2) boiling point, and 3) density. Determine whether any of the graphs are linear or close to linear. Indicate which physical properties can be correlated to the temperature decrease? Print your data from Graphical Analysis and sketch the graphs with labeled axes in your lab notebook.

Part III. Temperature Drop of 2-propanol.

Using the results of the experiments make a prediction for 2-propanol whose properties are listed below. Record your prediction and then collect evaporative cooling data for 2-propanol.

Figure 2. Physical Properties of 2-propanol

Alcohol	Molar Mass g/mol	Boiling Point	Density g/mL
2-propanol ($\text{CH}_3\text{CHOHCH}_2\text{CH}_3$)	60.1	82.4	0.7855

Data: EVAPORATIVE COOLING AND INTERMOLECULAR FORCES

Part 1 Developing Techniques for Reproducible Data Using Ethanol

Alcohol	Starting Temp	Coolest Temp.	Temp Drop.
Ethanol			
Ethanol			
Ethanol			
Ethanol			
Ethanol			

Briefly describe the method used in your lab notebook.

Part II and Part III Data for Alcohols

Alcohol	Starting Temp	Coolest Temp.	Temp Drop.
Methanol			
Methanol			
Methanol			
1-propanol			
1-propanol			
1-propanol			
2-propanol			
2-propanol			
2-propanol			

Conclusions:

Relate your predictions to the experimental results. Suggest an explanation for any discrepancies between the results and your predictions. Indicate how the results can be explained by your understanding of the intermolecular interactions that are exhibited by the different alcohols. In the experiment, what did you do to assure reproducibility of the data? Were the experimental values in accord with your prediction? Was there a linear relation between the temperature drop and any parameter? Include the graph for any linear relationship(s). Which parameter are you relying on to make predictions? Write a summary statement concerning the relation between the strength and types of intermolecular forces and the results of the evaporative cooling experiment. Attach your graphs to the data sheet and submit when the lab report is due.

LABSETUP: EVAPORATIVE COOLING AND INTERMOLECULAR FORCES

- 9 sets of four vial (16 dram) of methanol, ethanol, n-propanol, isopropanol.
- Kimwipes®
- CBL
- Temperature Probe
- AC Adapter
- TI-Graph Link