**Evaporation & Intermolecular Attractions**

***Adapted from Chemistry with Vernier Experiment 9***

The evaporation of a volatile liquid from the surface of a Temperature Probe 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 investigate factors that determine strengths of intermolecular forces of attraction in alkanes and alcohols and the magnitudes of the temperature changes as these substances evaporate from a Temperature Probe.

Alternative methods of determining the rate of evaporation of liquids is to measure the change in mass over time or measure how long it takes for a specific volume to completely evaporate.

OBJECTIVES

In this experiment, you will

* Use a Temperature Probe to measure temperature.
* Calculate change in temperature, ∆T.
* Calculate the rate of temperature change.
* Compare results with predicted outcomes.

MATERIALS

|  |  |
| --- | --- |
| LabQuest 2 & Temperature Probe | thin-stem pipets |
| ethanol and other liquids, such as | paper towels  |
| water, acetone, hexane, 2-propanol | twist ties |

PROCEDURE

1. Obtain and wear goggles. **CAUTION:** *Some of the compounds you will be using in this experiment are generally 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 instructor immediately if an accident occurs*.

2. Connect the Temperature Probe to the LabQuest 2 and choose New from the File menu. (Alternately, use a thermometer and record the temperature every 15 seconds, then graph your temperature vs. time data.)

3. On the Meter screen, tap Length. Set the data-collection length to 180 seconds. Select OK.

4. Wrap a 3 cm2 piece of paper towel around the end of the temperature probe and use a small twist tie to secure it in place.

5. Set the probe on the edge of the table so the tip extends 5 cm over the edge as shown in Figure 1. You could use a piece of masking tape to fasten the probe in place, if desired.

**Figure 1**

6. When everything is ready, click on the **green arrow** button to begin collecting data. As soon as you see the data points being graphed, use a pipet to add 1 mL (20 drops) of ethanol onto the tip of the temperature probe to wet the paper toweling. An example of the typical type of data collected can be viewed at <https://youtu.be/lRCD28Z_pXk>

7. When the temperature has reached a minimum and has begun to increase, end data collection. If the temperature does not begin to increase, allow data to be collected for the full 150 seconds. To examine the data pairs on the displayed graph, tap any data point. As you tap the data points, the temperature values for the probe are displayed to the right of the graph. Based on your data, determine the maximum temperature, t1, and minimum temperature, t2. (You can also use the Statistics function under the Analyze pull-down menu to determine the minimum and maximum temperature readings.) Record these values. Calculate the ∆t value.

8. Determine the most linear portion of the plot that has the greatest slope. Tap and hold the maximum temperature data point of this portion, then drag across the data to the minimum temperature data point along this line. Record these max and min values in your data table. Calculate the slope for the most linear portion of the plot where the temperature first begins to drop. This can also be done directly by highlighting this linear portion of the curve, then use the **Analyze** pull down menu to draw the **Curve** Fit using a **Linear fi**t line. The y = mx + b equation for the line will be displayed.

9. Tap on the icon of the **Filing Cabinet** to store this run.

10. Unwrap the twist tie and dispose of the filter paper as directed by your instructor, either in a beaker under the fume hood or in a zip-lock freezer bag to minimize vapors in the lab area.

11. Prepare the Temperature Probe for the next run.

1. Warm the Temperature Probe by placing it into a beaker of room-temperature water until its temperature reaches the temperature of the water. The temperature of the probe is displayed on the screen.
2. Use a paper towel to dry the probe. Be careful not to warm the probe as you dry it.

12. Repeat Steps 4–10 for each liquid tested by your team. Print a single graph of all liquids tested.

**PROCESSING THE DATA \***

1. Determine Δ*t*, the temperature change during the evaporation of each of the liquids tested and the slope of the most linear portion of the cooling curve.

2. Draw a structural formula (Lewis Dot Structure) for each of the liquids tested.

3. What type of intermolecular forces would hold the molecules together in each of the liquids? Based on these IMFs, which liquid would be predicted to exhibit the weakest attractive forces?

4. Based on the evaporation rates, rank the liquids from the strongest to weakest attractive forces. Does this agree with your answer to Question 3?

5. A water molecule, H2O, can be represented by the space-filling model shown in Figure 2 below. Using exactly five (5) water molecules, draw a particulate diagram that shows what happens when a drop of water first begins to evaporate.

 *Figure 2: space-filling model for* H2O

**EXTENSION**

1. Draw the Lewis structures for the compounds PF5, XeF4, and SF4. Determine the type of intermolecular forces that would be exhibited by each compound. Then rank the compounds from the weakest to strongest predicted forces. Justify your answers based upon the Lewis structures and polarity of the molecules. To test your predictions, look up the normal boiling points for each of these compounds. The higher the normal boiling point of a liquid, the stronger its intermolecular forces.

**\*Sample data for this lab will be analyzed using Vernier’s Graphical Analysis App (see the following).**

**\*** From Mark’s Google Drive, access the **Evaporation of Organics2.gambl** file by clicking the shareable link <https://drive.google.com/file/d/1o4GIga5tqPX-gDhHYm1dvJmStzHuW7gh/view?usp=sharing>

 Download this file. Launch the Graphical Analysis App, click **choose file**, then select **Evaporation of Organics2.ambl** file from your Downloads folder. Examine and analyze the data from the evaporation of multiple organic compounds by clicking on the y-axis label and selecting which Data Sets to display. Is there a pattern between the rate of evaporation and the type(s) of IMFs present in each compound?

# ****Vernier Experiments and Sample Data Library****

To assist you as you quickly move from the classroom or laboratory setting to online teaching, Vernier Software & Technology is offering the Vernier Experiments and Sample Data Library—a library of over 80 experiments with sample data files covering many subjects that you can distribute to your students at home. Students won’t actually conduct the experiment themselves, but they can follow along with the written procedure and access sample data. Students can then perform their own analysis of the sample data using our free Graphical Analysis™ 4 app (GA4) and answer questions based on their results. More information about this free resource can be found at the [Free Sample Data Library](https://www.vernier.com/remote-learning/sample-data-library/). While we strongly advocate for hands-on science when possible, we understand that many schools are in a situation where it is not possible at this time. Additional experiments will be made available soon.

## **Instructions for Teachers**

1. Download and peruse the library of available experiments. Note that each experiment consists of two or more files. These files include
	* **Student handout**
	Each experiment has one Word file. This file includes the experiment instructions and is meant to be distributed to students. The file can be opened in Word or uploaded into Google Drive and converted to a Google Doc. You can edit the instructions before sending the file to your students if you wish, or distribute as is.
	* **Sample data files**
	Each experiment has one or more Graphical Analysis 4 files (file extension of .ambl or .gambl). To open and use these files, you and your students will need to install our free data-collection and analysis app, Graphical Analysis 4, on your devices. Download Vernier’s Graphical Analysis 4 App at <https://www.vernier.com/product/graphical-analysis-4/> for your particular device.
2. Send your students the files for the experiment(s) of your choice. Ask them to read the written instructions as if they were conducting the experiment themselves but complete the data analysis and questions using the sample data provided.

## **Tips for Teaching with Vernier Sample Data Files**

* Note that the student handouts, as written, are designed for an in-person classroom or laboratory environment. We encourage you to read through the Word files prior to sending them to your students, as you may wish to edit to improve their online-learning experience.
* Some experiments require multiple sample data files. The file naming convention will make this clear (e.g., “PEP 23 Magnetic Field – Current Data” and “PEP 23 Magnetic Field – Distance Data”). If you choose to use one of these experiments, make sure the students are given access to all necessary files.
* The [Vernier Video Training Library](https://docs.google.com/spreadsheets/d/e/2PACX-1vQUGzkycEPNVlcZ1zbbG5322eyDIaKkOXI7MWk8fiphb9eszJXOwtR__6IMH8rlDeyjV89wVVw2umrz/pubhtml) has quite a few videos, some of which might be useful to you or your students to visualize how an experiment is set up or how a sensor works.
* Answers to the analysis questions are not being provided in an effort to keep them from circulating freely and being found by students. If you need assistance with an answer, email support@vernier.com using your school email address so we can verify your identity.

## Click on the links below to download experiments and sample data files.

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[General Science](https://www.vernier.com/wp-content/uploads/2020/03/vernier-elementary-and-middle-school-science.zip?utm_campaign=remote-learning-library-gen-science&utm_source=landingpage&utm_medium=&utm_content=)                                          [Biology](https://www.vernier.com/wp-content/uploads/2020/03/vernier-biology.zip?utm_campaign=remote-learning-library-biology&utm_source=landingpage&utm_medium=&utm_content=)            [Chemistry](https://www.vernier.com/wp-content/uploads/2020/03/vernier-chemistry.zip?utm_campaign=remote-learning-library-chem&utm_source=landingpage&utm_medium=&utm_content=)          [Physics](https://www.vernier.com/wp-content/uploads/2020/03/vernier-physics.zip?utm_campaign=remote-learning-library-physics&utm_source=landingpage&utm_medium=&utm_content=)