

Vapor Pressure of Liquids

In this experiment, you will investigate the relationship between the vapor pressure of a liquid and its temperature. When a liquid is added to the Erlenmeyer flask shown in Figure 1, it will evaporate into the air above it in the flask. Eventually, equilibrium is reached between the rate of evaporation and the rate of condensation. At this point, the vapor pressure of the liquid is equal to the partial pressure of its vapor in the flask. Pressure and temperature data will be collected using a Gas Pressure Sensor and a Temperature Probe. The flask will be placed in water baths of different temperatures to determine the effect of temperature on vapor pressure. You will also compare the vapor pressure of two different liquids, ethanol and methanol, at the same temperature.

OBJECTIVES

In this experiment, you will

- Investigate the relationship between the vapor pressure of a liquid and its temperature.
- Compare the vapor pressure of two different liquids at the same temperature.

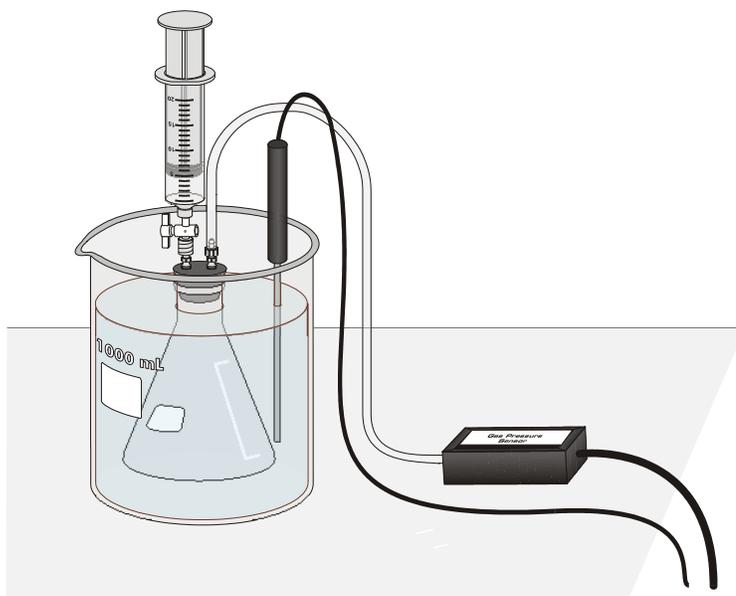


Figure 1

MATERIALS

computer
Vernier computer interface
Logger *Pro*
Vernier Gas Pressure Sensor
Vernier Temperature Probe
rubber-stopper assembly
plastic tubing with two connectors

20 mL syringe
two 125 mL Erlenmeyer flasks
methanol
ethanol
ice
four 1 liter beakers

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** The alcohols 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. Notify your teacher immediately if an accident occurs.
2. Use 1 liter beakers to prepare four water baths, one in each of the following temperature ranges: 0 to 5°C, 10 to 15°C, 20 to 25°C (use room temperature water), and 30 to 35°C. For each water bath, mix varying amounts of warm water, cool water, and ice to obtain a volume of 800 mL in a 1 L beaker. To save time and beakers, several lab groups can use the same set of water baths.
3. Prepare the Temperature Probe and Gas Pressure Sensor for data collection.
 - a. Plug the Gas Pressure Sensor into CH1 and the Temperature Probe into CH2 of the computer interface.
 - b. Obtain a rubber-stopper assembly with a piece of heavy-wall plastic tubing connected to one of its two valves. Attach the connector at the free end of the plastic tubing to the open stem of the Gas Pressure Sensor with a clockwise turn. Leave its two-way valve on the rubber stopper open (lined up with the valve stem as shown in Figure 2) until Step 9.
 - c. Insert the rubber-stopper assembly into a 125 mL Erlenmeyer flask. **Important:** Twist the stopper into the neck of the flask to ensure a tight fit.

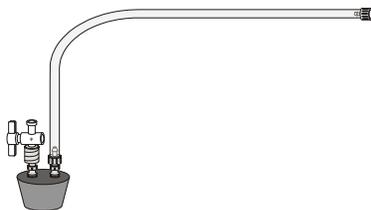


Figure 2

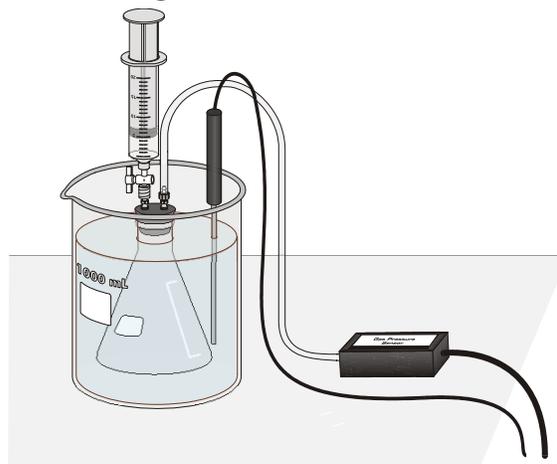


Figure 3

4. Prepare the computer for data collection by opening the file “10 Vapor Pressure” from the *Chemistry with Computers* folder of *Logger Pro*.
5. The temperature and pressure readings should now be displayed in the meter. While the two-way valve above the rubber stopper is still open, record the value for atmospheric pressure in your data table (round to the nearest 0.1 kPa).

6. Finish setting up the apparatus shown in Figure 3:
- Obtain a room-temperature water bath (20-25°C).
 - Place the Temperature Probe in the water bath.
 - Hold the flask in the water bath, with the entire flask covered as shown in Figure 3.
 - After 30 seconds, close the 2-way valve *above the rubber stopper* as shown in Figure 4—do this by turning the white valve handle so it is perpendicular with the valve stem itself.

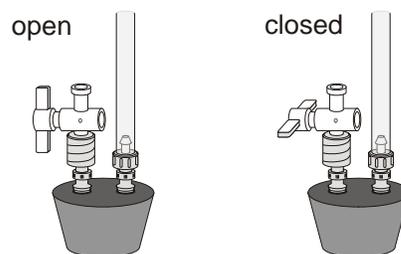


Figure 4

7. Obtain the methanol container and the syringe. Draw 3 mL of the methanol up into the syringe. With the two-way valve still closed, screw the syringe onto the two-way valve, as shown in Figure 3.
8. Introduce the methanol into the Erlenmeyer flask.
- Open the 2-way valve above the rubber stopper—do this by turning the white valve handle so it is aligned with the valve stem (see Figure 4).
 - Squirt the methanol into the flask by pushing in the plunger of the syringe.
 - Quickly* return the plunger of the syringe back to the 3 mL mark of the syringe, then close the 2-way valve by turning the white valve handle so it is perpendicular with the valve stem.
 - Remove the syringe from the 2-way valve with a counter-clockwise turn.
9. To monitor and collect pressure and temperature data:
- Click .
 - When the pressure and temperature readings displayed in the meter stabilize, equilibrium between methanol liquid and vapor has been established. Click . The first pressure-temperature data pair is now stored.
10. To collect another data pair using the 30-35°C water bath:
- Place the Erlenmeyer flask assembly and the temperature probe into the 30-35°C water bath. Make sure the entire flask is covered.
 - When the pressure and temperature readings displayed on the computer monitor stabilize, click . The second data pair has now been stored.
11. For Trial 3, repeat the Step-10 procedure, using the 10-15°C water bath. Then repeat the Step-10 procedure for Trial 4, using the 0-5°C water bath.

Experiment 10

- Click  to end data collection. Record the pressure and temperature values in your data table, or, if directed by your instructor, print a copy of the table.
- Gently loosen and remove the Gas Pressure Sensor so the Erlenmeyer flask is open to the atmosphere. Remove the stopper assembly from the flask and dispose of the methanol as directed by your teacher.
- Obtain another clean, dry 125 mL Erlenmeyer flask. Draw air in and out of the syringe enough times that you are certain that all of the methanol has evaporated from it.
- Repeat Steps 6-8 to do *one* trial only using ethanol in the room temperature water bath. When the pressure stabilizes, record the measured pressure of ethanol displayed in the meter in your data table.
- Gently loosen and remove the stopper assembly from the flask and dispose of the ethanol as directed by your teacher.

EXTRA CREDIT

The Clausius-Clapeyron equation describes the relationship between vapor pressure and absolute temperature:

$$\ln P = \Delta H_{\text{vap}} / RT + B$$

where $\ln P$ is the natural logarithm of the vapor pressure, ΔH_{vap} is the heat of vaporization, T is the absolute temperature, and B is a positive constant. If this equation is rearranged in slope-intercept form ($y = mx + b$):

$$\ln P = \frac{\Delta H_{\text{vap}}}{R} \cdot \frac{1}{T} + B$$

the slope, m , should be equal to $-\Delta H_{\text{vap}} / R$. If a plot of $\ln P$ vs. $1/T$ is made, the heat of vaporization can be determined from the slope of the curve. Plot the graph using *Logger Pro*:

- Go to Page 2 of the experiment file by clicking on the Next Page button, .
- In the table, enter the four vapor pressure-temperature data pairs. To do this:
 - Click on the first cell in the Temperature (K) data column in the table. Type in temperature value (K) for the first data pair, and press the ENTER key.
 - The cursor will now be in the Vapor Pressure (kPa) data column—type in its value and press ENTER.
 - Continue in this manner to enter the last three data pairs values.
 - If necessary, click on the Autoscale button, , to automatically rescale the data points.

3. Create a column 1/Temperature (in units of 1/K). To do this:
 - a. Choose New Calculated Column from the Data menu.
 - b. Enter “1/Temperature” as the Name, “1/Temp” as the Short Name, and “1/K” as the Unit.
 - c. Enter the correct formula for the column (1/Temperature) into the Equation edit box. To do this, type in “1” and “/”. Then select “Temperature Kelvin” from the Variables list. In the Equation edit box, you should now see displayed: 1/“Temperature”.
 - d. Click .

4. Create a column ln Vapor Pressure. To do this:
 - a. Choose New Calculated Column from the Data menu.
 - b. Enter “ln Vapor Pressure” as the Name, “ln V Press” as the Short Name. You do not need to enter a unit.
 - c. Enter the correct formula for the column into the Equation edit box. Choose “ln” from the Function list. Then select “Vapor Pressure” from the Variables list. In the Equation edit box, you should now see displayed: ln(“Vapor Pressure”). Click .
 - d. Click on the vertical axis label and choose ln Vapor Pressure.
 - e. Click on the horizontal axis label and choose 1/Temperature.
 - f. Autoscale the graph by clicking on the Autoscale button, , on the toolbar.
 - g. Click the Linear Fit button, .

5. From the Regression Statistics option, find the slope, m , of the regression line.

6. Use the slope value to calculate the heat of vaporization for methanol

$$m = - \left(\frac{\Delta H_{\text{vaporization}}}{R} \right) \quad \text{or} \quad \Delta H_{\text{vaporization}} = -(m \times R).$$

Remember that R in this equation is 8.31 J/mol K.

Attach this graph and your calculations to your report sheet for extra credit.

REPORT SHEET

NAME _____ DATE _____

Atmospheric pressure _____ kPa

1. Convert each of the Celsius temperatures to Kelvin (K). Write the answer in the space provided.

Substance	Methanol				Ethanol
Trial	1	2	3	4	1
Temperature (°C)	°C	°C	°C	°C	°C
Temperature (K)	K	K	K	K	K
Measured pressure	kPa	kPa	kPa	kPa	kPa

2. To obtain the vapor pressure of methanol and ethanol, the air pressure must be subtracted from each of the measured pressure values. However, for Trials 2-4, even if *no* methanol was present, the pressure in the flask would have increased due to a higher temperature, or decreased due to a lower temperature (remember those gas laws?). Therefore, you must convert the atmospheric pressure at the temperature of the *first* water bath to a *corrected* air pressure at the temperature of the water bath in Trial 2, 3, or 4. To do this, use the gas-law equation (use the Kelvin temperatures):

$$\frac{P_2}{T_2} = \frac{P_1}{T_1} \quad \text{or re-arranged into the format we need, it is } P_2 = \frac{P_1}{T_1} \times T_2$$

where P_1 and T_1 are the atmospheric pressure and the temperature of the Trial 1 (room temperature) water bath. T_2 is the temperature of the water bath in Trial 2, 3, or 4. Solve for P_2 , and record this value as the *corrected* air pressure for Trials 2, 3, and 4. For Trial 1 of methanol and Trial 1 of ethanol, it is not necessary to make a correction; for these two trials, simply record the atmospheric pressure value in the blank designated for air pressure.

Show calculations here:

Substance	Methanol				Ethanol
Trial	1	2	3	4	1
Air pressure	no correction kPa	Corrected (P_2) kPa	Corrected (P_2) kPa	Corrected (P_2) kPa	no correction kPa

3. Obtain the vapor pressure by subtracting the corrected air pressure from the measured pressure in Trials 2-4.

Subtract the uncorrected air pressure in Trial 1 of methanol (and Trial 1 of ethanol) from the measured pressure.

Substance	Methanol				Ethanol
Trial	1	2	3	4	1
Vapor pressure	Show calculation here:				
	kPa	kPa	kPa	kPa	kPa

4. Plot a graph of vapor pressure vs. temperature ($^{\circ}\text{C}$) for the four data pairs you collected for methanol. Temperature is the independent variable (x) and vapor pressure is the dependent variable (y). As directed by your teacher, plot the graph manually, or use MS Excel, or use Logger Pro. Note: Be sure to plot the vapor pressure, not the measured pressure. Attach the graph to this page.
5. How would you describe the relationship between vapor pressure and temperature, as represented in the graph you made in the previous step?
6. Explain this relationship using the concept of kinetic energy of molecules.
7. Which liquid, methanol or ethanol, had the larger vapor pressure value at room temperature?
8. Explain your answer. Take into account various intermolecular forces in these two liquids.