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 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.

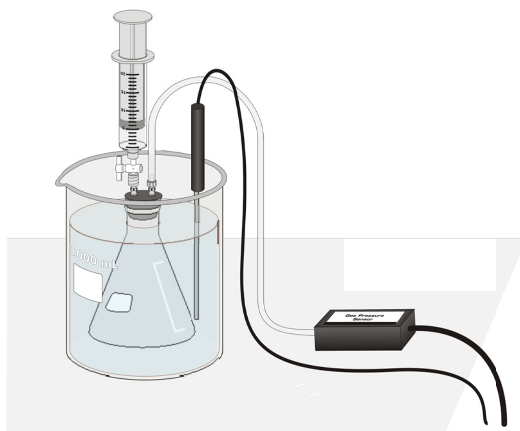


Figure 1

MATERIALS

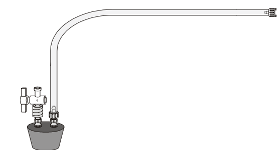
LabQuest Interface
Vernier Gas Pressure Sensor or Pressure Sensor
Vernier Temperature Probe
four 1-liter beakers
20-mL syringe
rubber-stopper assembly
plastic tubing with two connectors
two 125-mL Erlenmeyer flasks
methanol
ethanol
ice

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 Pressure Sensor for data collection.
   a. Plug the Temperature Probe into Channel 1.
   b. Plug the Pressure Sensor into Channel 2.
   c. 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 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 at the right) for now.
   d. 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.



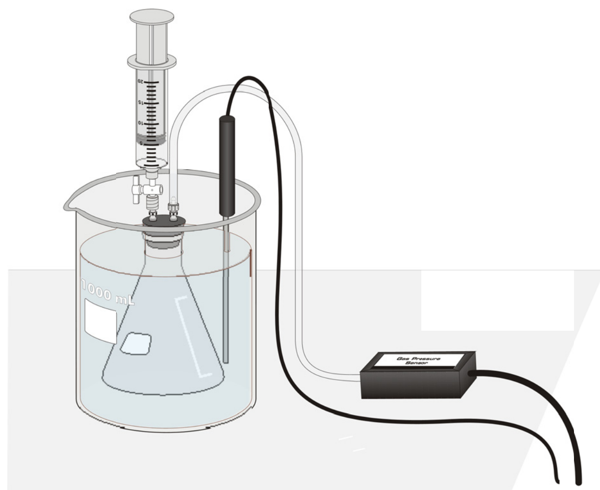
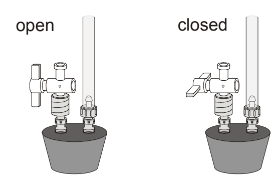


Figure 4

4. Turn on the LabQuest.

5. Make certain that you are collecting temperature in °C and pressure in kPa. The temperature and pressure readings should now be displayed on the calculator screen. 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 4:
   a. Obtain a room-temperature water bath (20-25°C).
   b. Place the Temperature Probe in the water bath.
   c. Hold the flask in the water bath, with the entire flask covered as shown in Figure 4.
   d. After 30 seconds, close the 2-way valve *above the rubber stopper* as shown at the right — do this by turning the white valve handle so it is perpendicular with the valve stem itself.



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 4.

8. Introduce the methanol into the Erlenmeyer flask.
   a. 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 5).
   b. Squirt the methanol into the flask by pushing in the plunger of the syringe.
   c. *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.
   d. Remove the syringe from the 2-way valve with a counter-clockwise turn.
9. When the temperature and pressure readings displayed on the screen have both stabilized, equilibrium between methanol liquid and vapor has been established. Record this first temperature-pressure data pair.
10. Repeat the process for the other three water baths.
11. After you have collected the fourth and last data pair. Remove the flask and the Temperature Probe from the last water bath. Open the side valve of the 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.
12. 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.
13. Collect temperature-pressure data for ethanol at room temperature.
14. Open the 2-way valve of the Pressure Sensor. Remove the stopper assembly from the flask and dispose of the ethanol as directed by your instructor.

PROCESSING THE DATA

1. Convert each of the Celsius temperatures to Kelvin (K). Record the answers.
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):

$$\frac{P_2}{T_2} = \frac{P_1}{T_1}$$

   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.

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.

4. Plot a graph of vapor pressure *vs.* temperature (°C) for the four data pairs you collected for methanol. Temperature is the independent variable and vapor pressure the dependent variable. As directed by your instructor, plot the graph manually or use Graphical Analysis software.

DATA AND CALCULATIONS

Atmospheric pressure	________ kPa

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

Air pressure	no correction kPa	corrected kPa	corrected kPa	corrected kPa	no correction kPa
Vapor pressure	kPa	kPa	kPa	kPa	kPa