10.10 Gas Pressure Sensor: Vapor Pressure of a liquid and Temperature Relationship

Subjects: Properties of gases, temperature effect on vapor pressure

Description: The relationship between vapor pressure of a volatile liquid and temperature is explored using the pressure sensor. Data is displayed using the Logger Pro program.

Materials:
Faculty laptop
Gas pressure sensor*
Stainless steel temperature probe*
LabQuest interface with USB cable
Logger Pro software
Sensor accessories:*
- Rubber stopper assembly
- Plastic tubing with connectors
- 20 mL syringe

125 mL Erlenmeyer flask
1-liter beaker
400 mL beaker
Ethanol
Hot plate*

*Items located in the drawers opposite the demo bin storage shelves. The hot plates are located in drawers opposite the chemical storage cabinets.

Procedure:

1. Prepare a room temperature bath in the 1 liter beaker.

2. Prepare a hot water bath in the 400 mL beaker using the hot plate.

3. Connect the Gas Pressure Sensor to Channel 1 of the Labquest interface. Connect a Temperature Probe to Channel 2 of the interface. Connect the interface to the computer.

4. Start the Logger *Pro* program on your computer. Open the file "34 Vapor" from the *Advanced Chemistry with Vernier* folder.

5. Connect the white rubber stopper to the Gas Pressure Sensor with the clear tubing. (About one-half turn of the fittings will secure the tubing tightly.) Twist the white stopper snugly into the neck of the Erlenmeyer flask to avoid losing any of the gas that will be produced as the liquid evaporates. **Important**: Open the valve on the white stopper.

6. Your first measurement will be of the pressure of the air in the flask and the room temperature. Place the Temperature Probe near the flask. When the pressure and temperature readings stabilize, note these values.

7. Place the Temperature Probe and the flask in the room temperature water bath. Hold the flask down into the water bath to the bottom of the white stopper. After 30 seconds, close the valve on the white stopper.

8. Draw ~3 mL of ethanol into the 20 mL syringe. Thread the syringe onto the valve on the white stopper.

9. Open the valve below the syringe containing the 3 mL of ethanol.

10. Push down on the plunger of the syringe to inject the ethanol.

11. Quickly pull the plunger back to the 3-mL mark. Close the valve below the syringe.

12. Carefully remove the syringe from the stopper so that the stopper is not moved.

13. Gently swirl the flask in the water bath for a few seconds.

14. Click [Collect] to begin data collection, and hold the flask steady once again.

15. When the readings stabilize, click [Keep].

16. Add a small amount of hot water, from the beaker on the hot plate, to warm the water bath by 3–5°C. Stir the water bath slowly with the Temperature Probe. When the readings stabilize, click [Keep].

17. Repeat step 13 if desired to increase the water temperature more and to get more data points.

17. Click [Stop] to end data collection.

18. Compare the pressure readings of the flask in the room temperature bath to those in the hot water bath.

Discussion:

When a liquid is placed in a container, and the container is sealed tightly, a portion of the liquid will evaporate. The newly formed gas molecules exert pressure in the container, while some of the gas condenses back into the liquid state. If the temperature inside the container is held constant, then at some point equilibrium will be reached. At equilibrium, the rate of condensation is equal to the rate of evaporation. The pressure at equilibrium is called *vapor pressure*, and will remain constant as long as the temperature in the container does not change.

This demonstration illustrates the relationship between vapor pressure and temperature. As the temperature is increased, the vapor pressure also increases.

The relationship between the vapor pressure of a liquid and temperature is described in the Clausius-Clayperon equation,

$$\ln P = -\Delta H_{vap}/R\ (1/T) + C$$

where ln P is the natural logarithm of the vapor pressure, $\Delta Hvap$ is the heat of vaporization, R is the universal gas constant (8.31 J/mol•K), T is the absolute temperature in Kelvin, and C is a constant not related to heat capacity. Thus, the Clausius Clayperon equation not only describes how vapor pressure is affected by temperature, but it relates these factors to the heat of vaporization of a liquid. $\Delta Hvap$ is the amount of energy required to cause the evaporation of one mole of liquid at constant pressure

Safety: The alcohol used in this experiment is flammable. Be sure there are no open flames in the lab during this experiment.

Disposal: None

References:

1. Demo adapted from:
Randall, J. et al. *Advanced Chemistry with Vernier*. 2nd Ed. 2007. Vernier Software and Technology. Experiment 34.
http://www.vernier.com/files/sample_labs/CHEM-A-34-COMP-vapor.pdf