Lab 6: Vapor Pressure & Heat of Vaporization — Unit 6
AP Chemistry 2024-2025

In this lab, you will…
- *Measure the pressure inside a sealed vessel containing a volatile liquid over a range of temperatures*
- *Determine the relationship between pressure and temperature of the volatile liquid*
- *Calculate the heat of vaporization of the liquid*

Background
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. In mathematical terms, the relationship between the vapor pressure of a liquid and temperature is described in the Clausius-Clapeyron equation:

$$lnP = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T}\right) + C$$

where $ln\ P$ is the natural logarithm of the vapor pressure, ΔH_{vap} is the heat of vaporization, R is the universal gas constant (8.314 J/mol•K), T is the absolute, or Kelvin, temperature, and C is a constant (not related to heat capacity). Thus, the Clausius-Clapeyron equation not only describes how vapor pressure is affected by temperature, but it relates these factors to the heat of vaporization of a liquid. ΔH_{vap} is the amount of energy required to cause the evaporation of one mole of liquid at constant pressure. In this experiment, you will introduce a specific volume of a volatile liquid into a closed vessel, and measure the pressure in the vessel at several different temperatures. By analyzing your measurements, you will be able to calculate the ΔH_{vap} of the liquid.

Pre-lab

1. Answer the following in your lab notebook
   a. **Define** each of the following in your own words
      i. Vapor pressure
      ii. Heat of vaporization
      iii. Equilibrium
      iv. Volatile (as it relates to chemistry)
   b. What does it mean to say that vapor pressure is a result of an equilibrium system?
   c. As the temperature of a sample increases, the vapor pressure tends to increase. Why? Be sure to use the terms “kinetic energy” and “intermolecular forces” in your answer.
   d. Why must all gas calculations be done in Kelvin rather than celsius?
   e. What safety precautions must be taken in this lab?

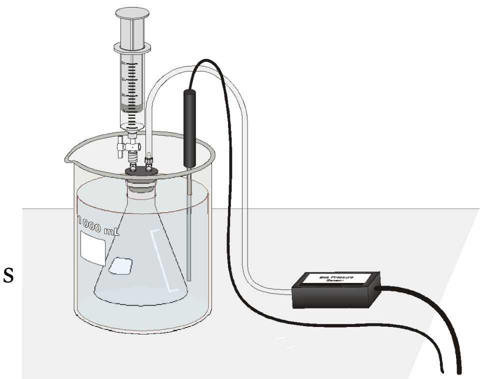
2. After reading the **lab directions,** create a flowchart of the key steps of the procedure. Remember, it doesn’t have to be super artistic, but it should be readable and usable if I took the actual instructions away!

3. Copy the **data table** into your notebook. Leave yourself enough space to record observations!

Materials

- LabQuest
- Gas pressure sensor
- Temperature probe
- Rubber stopper assembly
- Parafilm
- Tubing with connectors
- 20 mL syringe
- 125mL Erlenmeyer flask
- Ethanol, CH_3CH_2OH
- 400 mL beaker
- 600 mL beaker
- Hot plate
- Spoon or dipper

Lab Procedure



1. Prepare a room temperature water bath in a 600 mL beaker. The bath should be deep enough to completely cover the gas level in the 125 mL Erlenmeyer flask.

1. Obtain and wear goggles. **CAUTION**: The alcohol used in this experiment is flammable and poisonous. Avoid inhaling the vapors. Avoid contact with your skin or clothing. Be sure that there are no open flames in the room during the experiment. Notify your teacher immediately if an accident occurs.

2. Use a hot plate to heat ~200 mL of water in a 400 mL beaker. Monitor the hot plate throughout your experiment to ensure the water does not boil.

3. Connect the Gas Pressure Sensor and Temperature Probe to LabQuest.

4. Use the clear tubing to connect the white rubber stopper to the Gas Pressure Sensor. (About one ½ turn of the fittings will secure the tubing). Twist the white stopper snugly into the neck of the Erlenmeyer flask and use parafilm to seal it to avoid losing any of the gas that will be produced as the liquid evaporates (see figure). **Important**: Open the valve on the white stopper.

5. Change the data-collection mode to Selected Events.

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, record these values in the first column (Initial) of your data table.

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

8. Obtain a small amount of ethanol. Draw 3 mL of ethanol into the 20 mL syringe. Thread the syringe onto the valve on the white stopper (see figure).

9. Add ethanol to the flask.
   a. Open the valve below the syringe containing the 3 mL of ethanol.
   b. Push down on the plunger of the syringe to inject the ethanol.
   c. Quickly pull the plunger back to the 3 mL mark. Close the valve below the syringe.
   d. Carefully remove the syringe from the stopper so that the stopper is not moved.

10. Gently rotate the flask in the water bath for a few seconds, using a motion similar to slowly stirring a cup of coffee or tea, to accelerate the evaporation of the ethanol.

11. Monitor and collect temperature and pressure data.
    a. Start data collection.
    b. Hold the flask steady once again.
    c. Monitor the pressure and temperature readings.
    d. When the readings stabilize, select Keep.

12. Add a small amount of hot water, from the beaker on the hot plate, to warm the water bath by 3–5°C. Use a spoon or a dipper to transfer the hot water. Stir the water bath slowly with the Temperature Probe. Monitor the pressure and temperature readings. When the readings stabilize, select Keep.

13. Repeat Step 13 until you have completed five total trials. Add enough hot water for each trial so that the temperature of the water bath increases by 3–5°C, but do not warm the water bath beyond 40°C because the pressure increase may pop the stopper out of the flask. If you must remove some of the water in the bath, do it carefully so as not to disturb the flask.

14. After you have recorded the fifth set of readings, open the valve to release the pressure in the flask. Remove the flask from the water bath and take the stopper off the flask. Dispose of the ethanol as directed.

15. Stop data collection. Tap Table to see the temperature and pressure measurements. Record the pressure readings, as P_{total}, and the temperature readings in your data table.

Data Table

	Initial	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
P_{total} (kPa)		Copy and complete in your lab notebook				
P_{air} (kPa)						
P_{vap} (kPa)						
Temperature (℃)						

Data Analysis

1. The P_{air} for trials 2-6 must be calculated because the temperatures were increased. As you warmed the flask, the air in the flask exerted pressure that you must calculate. Use the gas law relationship below to complete the calculations. Remember that all gas law calculations require temperature to be in Kelvin. Use the P_{air} from trial 1 as P_1 and the Kelvin temperature of Trial 1 as T_1.

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

2. Calculate and record P_{vap} for each trial by subtracting P_{air} from P_{total}.

3. In Google Sheets or Excel, prepare a graph of P_{vap} (y-axis) vs. Celsius temperature (x-axis).
    a. Sketch (or print and tape) the graph into your lab notebook.
    b. Does the plot follow the expected trend of the effect of temperature on vapor pressure? Explain.

4. In Google Sheets or Excel, prepare a second graph. The y-axis for this graph will be the natural logarithm of P_{vap} (lnP) and the x-axis will be the reciprocal of Kelvin temperature (1/T).
    a. Sketch (or print and tape) the graph into your notebook.

b. Calculate the linear regression (best-fit line) equation for this graph.
c. Calculate ΔH_{vap} from the slope of the linear regression (***hint**: refer to the Clausius-Clapeyron equation (in the background) and match it to the $y = mx + b$ form of your regression line)*.

5. The accepted value for ΔH_{vap} for ethanol is 42.32 kJ/mol. Calculate your percent error.

Conclusion

1. Sketch two particle level drawings of a sample of liquid ethanol demonstrating the change in vapor pressure due to temperature. The first should represent a room temperature sample and the second should represent a higher temperature sample.
2. In step 10 of the procedure, why did you need to pull the syringe back to the 3mL mark before sealing and removing it?
3. Based on your answer to analysis question #5, propose sources of error for your experiment.
4. If you were to do this experiment again, what is one specific change you would make to the procedure in order to get more accurate or reliable results?
5. In 3-5 sentences, summarize the key points of this lab.