

Molar Mass Determination of a Volatile Liquid

The experimental determination of the molar mass of gases and vapors is one important application of the Ideal Gas Law. To determine the molar mass of a gas or vapor, we need to determine the mass of the sample of gas under known conditions of temperature and pressure. Assuming the gas obeys the Ideal Gas Law:

$$PV = nRT$$

and if pressure, temperature and volume are determined experimentally and R is a constant, we can solve the equation for moles of gas. The molar mass (grams/mole) of the gas or vapor can be determined based on the mass of the liquid remaining in the flask and the number of moles calculated from the ideal gas law.

In this experiment, the molar mass of a volatile liquid will be determined using the ideal gas law. A small amount of the liquid is introduced into a weighed flask. The flask is then placed in boiling water where the liquid will completely vaporize, driving out any air and filling the flask with vapor at barometric pressure and the temperature of the boiling water. The mass of the vapor can be determined by cooling the flask to condense the vapor.

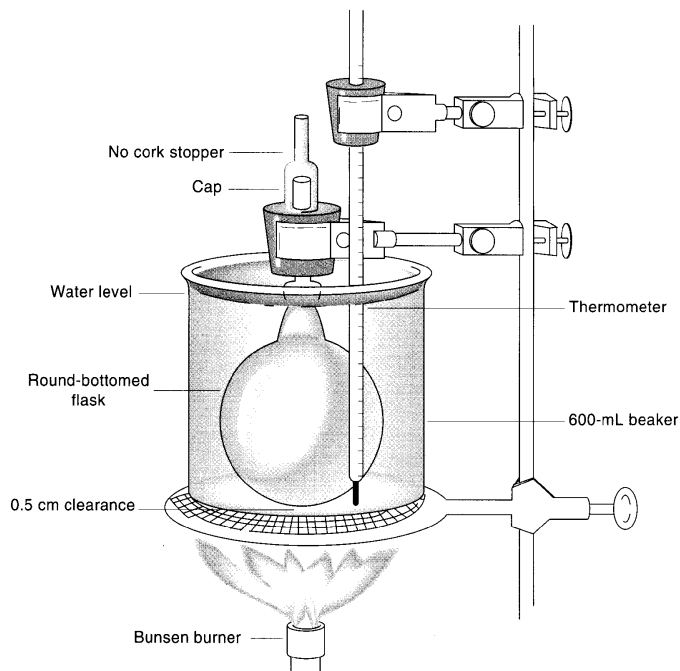


Figure 1

PROCEDURE

Obtain a round bottom flask fitted with a glass cap with a capillary opening, and a cork ring should support the entire apparatus at all times. If necessary, wash the flask with a touch of acetone, then dry the flask and cap and record the mass of the empty, dry flask and cap to the nearest 0.001g using the cork ring for support.

Obtain an unknown liquid and record the identification number. Pour approximately 5 mL of your unknown sample into the flask. (Note: the exact volume is not important; the mass of the final condensed vapor will be determined.) Assemble the apparatus as shown in Figure 1. It is important to have the round bottom flask immersed as deeply as possible in the 1000 mL water bath for uniform heating. Add a few boiling chips to the water in the 1000 mL beaker and heat the water to the boiling point. Watch the liquid level in your flask; the level should gradually disappear as vapor expands and pushes first air from the flask then excess vapor. Once all the liquid has disappeared, continue to heat the flask for 5 minutes to allow the vapor to reach the temperature of the boiling water. Measure and record the temperature of the boiling water. Also record the barometric pressure.

Turn off the burner and wait for the water to stop boiling (about 30 seconds). Remove the flask from the beaker of water and allow the flask to cool to room temperature and the vapor to condense. (You can speed up this process by running tap water over the stoppered flask.) Dry the outside of the flask and weigh the flask with the condensed vapor.

Repeat the procedure using another 5 mL sample of your liquid unknown. **Do not empty or clean the flask between trials**; just pour another 5 mL into the flask

Once the two trials are complete (and not before!), find the volume of the flask. Fill the flask and cap with water. Determine the mass of the flask filled with water, then determine the temperature of the water used to fill the flask. Using the *Handbook of Chemistry and Physics*, determine the density of the water to at least six sig figs. Using the density of water and the mass of water in the flask, calculate the volume of the flask.

Determine the **average molar mass** of your liquid sample and **parts per thousand**. Rinse the flask with a touch of acetone, then blow dry. Return the flask to the cart.

POSTLAB QUESTIONS:

- Determine if each of the following procedural errors would **increase**, **decrease**, or have **no effect** on the molar mass calculations in this experiment. **Explain** your reasoning.
 - The flask was not dried before the final weighing with the condensed vapor inside.
 - The flask was removed from the boiling water before the vapor had reached the temperature of the boiling water. All the liquid had vaporized.
 - The volume of the cap was not measured with the volume of the flask.
 - The student uses 7.5 mL of liquid sample.
- A student performs the experiment described. She determines the mass of an empty flask and stopper to be 55.441 g. She then adds 5 mL of an unknown liquid and heats the flask in a boiling water bath at 100.°C. After all the liquid has vaporized, she removes the flask from the bath and allows it to cool. She determines the mass of the flask, stopper and condensed vapor to be 56.039 g. The volume of the flask was determined to be 215.9 mL. The barometric pressure in the laboratory that day is 752.2 mm Hg. Calculate the **moles** of vapor present as well as the **molar mass** of the vapor using the Ideal Gas Law.
- How might this process be useful to chemists in an industrial setting? Explain.