MOLAR MASS OF A VOLATILE LIQUID

Introduction

At any temperature, a liquid has above it a corresponding vapour pressure. As the temperature increases, the vapour pressure increases. If the temperature is increased to the point where the vapour pressure of the liquid becomes equal to the barometric, or atmospheric pressure, then the liquid is said to boil. The temperature at which vapour pressure equals atmospheric pressure is the boiling point.

The vapour is a gas. If we assume the vapour to behave as an ideal gas, we can apply the Ideal Gas Law:

$$PV = nRT \qquad (1)$$

The number of moles, n, can be written as $\frac{m}{M}$ where m is the mass of the gas and M its molar mass.
Substituting in (1) we have:

$$PV = \frac{m}{M}RT \qquad (2)$$

Rearranging the equation we have:

$$\boldsymbol{M = \frac{mRT}{PV}} \qquad \textbf{(3)}$$

Equation 3 will be used to calculate the molar mass of a volatile liquid.

A small amount of liquid is introduced into a weighed flask. The flask is placed in boiling water, where the liquid will vaporize completely, driving out the air and filling the flask with vapour at barometric pressure and the temperature of the boiling water. If we cool the flask so that the vapour condenses, we can measure the mass of the vapour and calculate a value for M.

Procedure

Weigh a clean, dry, 125 mL Erlenmeyer flask and rubber stopper on the analytical balance.

To assemble the heating bath for the flask you will need a hot plate, ring stand, clamp, and 800 mL beaker. Clamp the flask to the ring stand. Position the beaker on the hot plate so the flask can be easily lowered into the beaker. Add enough water to the beaker so that most of the flask will be submerged in water. Remove the flask. Heat the water to boiling.

While waiting for the water bath to boil, obtain a thermometer and an unknown sample from the front bench. Record the identification number of the sample.

Cut a square of aluminum foil large enough so that it covers the mouth of the flask but does not extend far down the neck of the flask. Pour about half of the unknown liquid into the flask. Cover the mouth of the flask with the foil -- crimp the foil around the neck of the flask to make as tight a seal as possible. With a pin or needle, punch a tiny hole in the center of the foil. Clamp the flask into position and lower it into the boiling water bath.

Watch the liquid level in the flask; the level should gradually drop as vapour escapes through the pinhole in the foil. When the last drop of liquid has vaporized, *immediately* remove the flask from the water bath, remove the foil and insert the stopper *without delay*. Measure the temperature of the boiling water. Hold the flask in a beaker of cool water for about two minutes to allow the vapour to condense. Dry the flask with paper towel to remove the surface water. Carefully loosen the stopper, for not more than a second or two, to allow air to enter. (As the flask cools the vapour inside condenses and the pressure drops, which explains why air rushes in when the stopper is removed.) Weigh the flask, stopper, and condensed vapour on the analytical balance.

Carry out a second trial by adding the remainder of the unknown liquid to the flask and repeating the procedure. It is not necessary to empty the residual unknown liquid between trials.

When you have completed the mass measurements for the final trial, dry the inside of the Erlenmeyer flask. Fill the flask with water to its total capacity (to the brim). Weigh the flask (with the stopper along-side) on a top-loading balance. Empty the flask, shake out the excess water, and put the flask in the oven to dry. Determine the volume of the flask. (Density of water at 25 °C = 0.9971 g mL^{-1})

Record the barometric pressure.

QUIZ REVEWI QUESTIONS

1. Know how to convert pressures.

2. Experimental calculations.

3. Know in lab questions:

Would the following actions increase, decrease, or have no effect on the experimental molar mass? Explain.

a. The flask was kept in the hot water bath after all the liquid had vaporized.

b. The flask was removed from the hot water bath before all of the liquid was vaporized.

c. The exterior of the flask was not dried before the final weighing with the condensed vapour inside.

d. The flask was left open to the atmosphere while it was being cooled and the stopper was inserted just before the final weighing.

e. The unknown liquid was impure and left a non-volatile residue on the bottom of the flask.