Molecular Weight of a Volatile Liquid

Introduction

The Dumas "vapor density" method, one of the earliest and most simple techniques for determining the FORMULA WEIGHT of a volatile liquid, consists of nothing more than determining the WEIGHT of liquid, which, when VAPORIZED, will fill a given flask at a particular temperature and pressure. A simple variation of the ideal gas law is used to calculate the formula weight: If g represents the mass of liquid required, and M its formula weight, then the number of moles of volatile liquid is just g/M, and the ideal gas law can be written as

$$PV = (g)RT/M$$

You can see from this equation how simple it should be to determine the formula weight, M. All you need to know are the easily measurable PHYSICAL PROPERTIES of the gas (P, V, g, T).

A very simple apparatus is constructed for this experiment (see the sample apparatus), consisting merely of an Erlenmeyer flask covered with a small piece of metal foil, in which a small hole is made with a pin. Several milliliters of the liquid whose formula weight is to be determined are placed in the flask, the foil cover (with the pinhole) is attached, and the flask is placed in a BOILING WATER bath until the liquid has JUST EVAPORATED. At the point where the unknown liquid has just evaporated, the flask is FILLED WITH VAPOR of the liquid. Since the flask is OPEN TO THE ATMOSPHERE via the pinhole, many physical properties of the vapor are known. The PRESSURE of the vapor is just the atmospheric pressure (as read from the barometer). The TEMPERATURE of the vapor is just the temperature of the BOILING WATER. The VOLUME of the flask can be measured by seeing how much water is needed to fill it, and the WEIGHT of the vapor contained can be determined on the balance. The pinhole serves one other function also; any liquid beyond that required to fill the entire flask as a vapor can ESCAPE as the liquid is heated.

Some assumptions are made in this experiment that may affect the results to a small degree. When the flask containing vapor is removed from the boiling water bath, the vapor present will condense as the flask cools back to room temperature; the condensed vapor will occupy a small volume, which had been filled by air before heating. The weight of this small amount of air is negligible, however. Also, the assumption is made that the vapor produced from the liquid will behave as an IDEAL gas: Possibly the worst place to expect a gas to behave ideally is near the temperature where it would liquefy. This factor may introduce a small error into the value calculated for the formula weight; this is taken into account when your results are graded, however.

Summary

The molecular weight of an unknown volatile liquid is determined by the Dumas method, using a flask of known volume, with a small pinhole through a foil cover to permit excess vapor to escape and to equilibrate the vapor to atmospheric pressure.

Supplies

Square piece of aluminum foil; small rubber bands; molecular weight unknown (to which a small amount of iodine has been added as coloring agent)—RECORD THE NUMBER OF THE UNKNOWN ON YOUR REPORT SHEET.

CAUTION! THE HOT WATER BATH USED IN THIS EXPERIMENT MAY SPLASH IF NOT HEATED CAREFULLY. USE BOILING STONES. WEAR SAFETY GLASSES AT ALL TIMES!!

Chemicals

Assume all unknowns are toxic and flammable.

Procedure

Inspect the sample apparatus and assemble your apparatus accordingly.

Fasten the aluminum foil snugly to the top of a clean DRY 125 or 250 mL Erlenmeyer flask with a rubber band. The flask must be COMPLETELY DRY, since any water present will vaporize and affect the results adversely.

With a needle (a piece of metal wire pushed into a cork) make a small pinhole in the center of the foil.

Trim the foil around the edges, so that it will NOT DIP INTO THE WATER bath. (Any droplets of water adhering to the foil will affect the weight of the flask.)

Weigh the apparatus CAREFULLY to the nearest 0.001 g.

Remove the aluminum foil carefully (being sure not to tear it), and add about HALF your unknown liquid (approx. 3 mL). The unknown liquid contains a small amount of iodine, which imparts a color, and makes it easier to note when the liquid has evaporated completely.

Reattach the aluminum foil with the rubber bands.

Heat about 300 mL of water in a 600 mL beaker to a GENTLE boil (use 2 or 3 boiling stones to moderate the boiling).

Immerse the flask containing the unknown in the boiling water as illustrated by the sample apparatus. Have as much of the flask immersed in the boiling water as possible. Use a lightly attached utility clamp on top of the flask to weight it down to ensure that the temperature of the vapor is uniform.

Do not permit the foil cover to come in contact with the water; otherwise, water may be trapped under the foil, giving an incorrect weight.

Heat the flask in the gently boiling water until the liquid has completely evaporated. Then continue heating for approximately 30 seconds longer. Complete evaporation of the liquid can be observed by noticing color changes associated with the iodine.

Determine the temperature of the boiling water bath during this period of heating.

Remove the flask from the water bath, wipe the outside completely DRY and allow it to cool to room temperature (a small amount of liquid will reappear in the flask as it cools, as the vapor produced condenses). Reweigh the flask carefully to the nearest 0.001 g.

Repeat the determination with a portion of the remaining unknown liquid. You do not have to clean out the flask; just add the additional liquid, recover with foil and reheat as above.

DISPOSAL

Pour excess unknown back into your sample vial.

The weight of the flask after it has been heated in the boiling water for this second determination must AGREE with the results of the first determination WITHIN 0.l g. If the results do NOT agree, use the remainder of your unknown for a third determination.

Finally, using a graduated cylinder as the measuring device, determine the total volume of the Erlenmeyer flask right up to the very top by adding water.

REMEMBER TO TURN IN THE YELLOW COPY OF YOUR LAB NOTEBOOK TO YOR TA.

Molecular Weight of a Volatile Liquid
Report Sheet (30 Points)

Name ______________________________ Lab Day ______________

Lab Instructor ____________________ Date__________________

Show calculations at the bottom of this page.

Unknown no. _____________

	First Experiment	Second Experiment
Weight of dry apparatus, g	____________________	______________________
Weight of apparatus plus condensed vapor, g	____________________	______________________
Weight of condensed vapor, g	____________________	______________________
Total volume of flask, mL	____________________	______________________
Total volume of flask, liters	____________________	______________________
Barometric pressure, mm Hg	____________________	______________________
Barometric pressure, atm	____________________	______________________
Temperature of vapor, °C	____________________	______________________
Temperature of vapor, K	____________________	______________________
Molecular weight of liquid, g/mole	____________________	______________________

Average molecular weight of unknown ________________________

Molecular Weight of a Volatile Liquid
Post-Lab Questions (40 Points)

Name ______________________________ Lab Day ______________

Lab Instructor ____________________ Date_________________

1. List two reasons why it is necessary to put a pinhole in the aluminum foil.

2. Why was it **NOT** necessary to clean and dry the flask before performing your second determination?

3. A certain liquid has a molecular weight of 100 g/mole. The following data were obtained for a Dumas molecular weight determination:

   P = 1.02 atm V = 0.265 liters T = 372 K and
   g of condensed vapor = 0.58 g

   From this data a molecular weight of 65.5 g/mole was calculated. This value is much less than the expected value of 100 g/mole. What could have accounted for this large error in the molecular weight?

4. Why was the unknown liquid vaporized in a boiling water bath, rather than at room temperature?

5. How would the molecular weight for a volatile liquid be affected if the balance you did your weighing on had an error of 2.3 g? (Choose the best answer.)

A. The molecular weight would be greater than the correct value.

B. The molecular weight would be less than the correct value.

C. The molecular weight would be unaffected by this error and it would be the correct value.

6. It was important that no water gets on the aluminum foil during the heating process. If water does get on the aluminum foil, it must be wiped off before reweighing your flask. A typical drop of water has an approximate volume of 0.05 mL and water has a density of 1.0 g/mL. Calculate the molecular weight of your unknown (using your data from the experiment) if 2 drops of water accidentally remained on the aluminum foil when you reweighed your flask.

Molecular Weight of a Volatile Liquid
Pre-Lab Questions (10 points)

Name ______________________________ Lab Day _____________

Lab Instructor ____________________ Date_________________

(Show calculations on the back of the page.)

1. Define vapor.

2. If 0.80 g of the vapor of an unknown liquid occupied 280 mL at 100°C and 750 mm Hg, calculate the molecular weight of the liquid.