*Determination of the Molar Mass of Volatile Liquids*

Introduction

The molar masses of compounds are used daily in the chemistry profession. The molar mass is defined as the mass, in grams, of 1 mole of any element or compound. How is molar mass determined and how is the molar mass of an unknown found? In this experiment, the molar masses of several volatile liquids will be calculation based on measurements of their vapor density.

Background

The ideal gas law relates the four measureable properties of a gas (P, V, n, T). In this experiment, the ideal gas law will be sued to determine the molar mass of volatile liquids.

PV = nRT *Equation 1*

The number of moles (n) of any pure substance is equal to its mass divided by its molar mass.

n = mass/molar mass *Equation 2*

Substituting for n in Equation 1 and then rearranging produces the equation for the molar mass of a gas.

molar mass (g/mol) = mass x RT *Equation 3*

P x V

The molar masses of several volatile liquids with boiling points well below the boiling point of water are determined. A small sample of the liquid is placed in a tared 15-mL plastic pipet and the pipet is then heated in boiling water to vaporize the liquid. The air and excess vapor escape, leaving the pipet filled only with the volatile liquid vapor at atmospheric pressure and at the temperature of boiling water. The pipet is then removed and cooled to condense the vapor.

Once cooled, the pipet is weighed. By massing the same pipet filled with deionized water, the volume of the pipet is calculated. The molar mass of the volatile liquid is then determined from Equation 3 using the mass of the condensed vapor, the volume of the pipet, the atmospheric pressure, and the temperature of the boiling water.

Pre-Lab Questions

A determination of the molar mass of methyl alcohol (CH3OH) yielded the following data.

temperature of boiling water bath 99.5 oC

barometric pressure 738 mm Hg

temperature of room temp. water bath 24.0 oC

density of water at room temp. 0.9973 g/mL

|  |  |
| --- | --- |
|  | Trial 1 |
| mass of empty pipet | 1.557 g |
| mass of pipet and condensed methyl alcohol | 1.571 g |
| mass of pipet and water | 16.001 g |
| mass of condensed methyl alcohol |  |
| mass of water in filled pipet |  |
| volume of pipet |  |
| molar mass of methyl alcohol (experimental) |  |
| molar mass of methyl alcohol (theoretical) |  |

Using the data, fill in the rest of the table. Calculate the molar mass of methyl alcohol.

(Hint: The volume of the pipet is equal to the volume of water in the pipet. Use the relationship of mass and density to determine this volume. Once the volume of the pipet is determined, equation 3 in the Background section can be used to calculate the molar mass of methyl alcohol.)

Materials

Acetone, CH3COCH3, 2mL beral-type pipets, super jumbo, narrow stem, 15mL, 4

Ethyl alcohol, CH3CH2OH, 2mL balance, milligram

Isopropyl alcohol, (CH3)2CHOH, 2mL barometer

Beakers, 400mL, 2 boiling stones

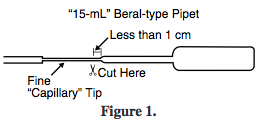
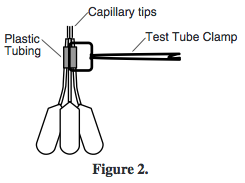
Hot plate thermometer

Plastic tubing hot plate

Test tube clamp scissors

Ring stand marker

Procedure

1. Place a 400mL beaker on the hotplate and add about 300mL of water to the beaker, along with several boiling stones. Turn on the hot plate to boil the water
2. Obtain 3, 15mL jumbo beral-type pipets. Pull the thin stems of each so that a very fine capillary tip is formed where the stem as been pulled (figure 1).
3. Cut the pipet as shown in figure 1 so that the capillary tip is less than 1cm long.
4. Label the pipets #1, #2, #3 with a marker.
5. Mass each pipet to the nearest 0.001g and record this mass in the data table.
6. Draw 2-3mL of the ethyl alcohol from the labeled bottle in the hood into each of the previously prepared and labeled pipets.
7. Insert the tips of the pipets containing the ethyl alcohol into the short piece of plastic tubing, then, secure the tubing with a test tube clamp (figure 2).
8. Lower the pipets into the boiling water bath. Make sure the entire bulb of each pipet is below the water line.
9. Heat for at least 5 minutes.
10. Carefully remove the pipets from the water. Inspect each pipet. If any liquid remains in a pipet bulb, heat the entire assembly for another minute.
11. Cool pipets by lowering the pipet assembly into a bath of room temperature water in a 400mL beaker
12. Record the temperature of the boiling water bath and the barometric pressure of the room in the data table.
13. Dry the pipets with paper towels and mass each pipet, which now contains only the condensed vapor, to the nearest 0.001g. Record these values in the data table.
14. Fill a 250mL beaker with room temperature deionized water.
15. Fill pipet #1 with the deionized water, then expel the water into the sink to flush the remaining ethyl alcohol from the pipet. Repeat this process several times.
16. To determine the volume of pipet #1: fill the pipet completely with deionized water, dry the outside, and mass the pipet and water; record the mass in the data table.
17. Repeat step 16 for pipets #2 & #3.
18. Repeat steps 2 thru 13 for acetone and isopropyl alcohol.

Data Table

Temperature of boiling water bath \_\_\_\_\_\_\_\_\_\_\_\_ oC

Barometric pressure \_\_\_\_\_\_\_\_\_\_\_\_ mm Hg

Temperature of room temp. water bath \_\_\_\_\_\_\_\_\_\_\_\_ oC

Density of water at room temperature \_\_\_\_\_\_\_\_\_\_\_\_ g/mL

Pipets

|  |  |  |  |
| --- | --- | --- | --- |
|  | Pipet #1 | Pipet #2 | Pipet #3 |
| Mass of empty pipet |  |  |  |
| Mass of pipet and water |  |  |  |
| Mass of water in filled pipet |  |  |  |
| Volume of pipet |  |  |  |

Volatile liquids

|  |  |  |  |
| --- | --- | --- | --- |
|  | Trial #1 | Trial #2 | Trial #3 |
| Ethyl Alcohol |  |  |  |
| Mass of pipet and condensed liquid |  |  |  |
| Mass of condensed liquid |  |  |  |
| Acetone |  |  |  |
| Mass of pipet and condensed liquid |  |  |  |
| Mass of condensed liquid |  |  |  |
| Isopropyl Alcohol |  |  |  |
| Mass of pipet and condensed liquid |  |  |  |
| Mass of condensed liquid |  |  |  |

\* Use the CRC Handbook to determine the density of water at the temperature of the room temperature water bath used in this experiment. Enter this density value in the data table and use this value, and the mass of water in each filled pipet, to calculate the volume of each pipet.

Results

Calculate the molar mass of the liquid used in each run and the average of the three runs for each volatile liquid.

Volatile liquids

|  |  |  |  |
| --- | --- | --- | --- |
|  | Trial #1 | Trial #2 | Trial #3 |
| Ethyl Alcohol |  |  |  |
| Molar mass |  |  |  |
| Acetone |  |  |  |
| Molar mass |  |  |  |
| Isopropyl Alcohol |  |  |  |
| Molar mass |  |  |  |

Post-Lab Questions

1. Volatile liquids with lower boiling points often give better results than those with higher boiling points. Suggest a reason for this.
2. What effect would vapor condensation in the neck of the jumbo pipets have on the reported molar mass? How large an error might this be?
3. Some liquids have enough attractions between molecules to form dimers. (Dimers are molecules formed from the combination of the identical molecules, A + A 🡪 A2.) What effect would this have on the experimental molar mass?