MOLECULAR WEIGHT DETERMINATION OF AN ORGANIC LIQUID

I. OBJECTIVES

In this experiment the molecular weight of a volatile, unknown organic liquid will be determined. From this information and quantitative analysis data, the molecular formula of the compound may be determined.

II. INTRODUCTION

New or unknown chemical substances are discovered or encountered every day. These compounds are often identified or characterized through qualitative and quantitative methods of chemical analysis. Often, the compound is first analyzed qualitatively to identify all constituent elements, followed by quantitative analysis to determine the relative percentages of each element in the compound. With this information the empirical formula of the compound is then determined. Once the molecular weight is determined, the molecular formula of the compound is then derived.

Many organic (carbon-containing) compounds which exist as liquids at normal (room) temperature are volatile; that is, they easily vaporize near, or not far above, room temperature. Gasoline, benzene, and many ethers and alcohols are examples of such liquids. At sufficiently high temperatures the behavior of these organic vapors conforms (approximately) to the ideal gas law

$$PV = nRT \qquad \text{(Equation 1)}$$

where P, T, V, and n represent the pressure, temperature, volume, and number of moles of vapor, respectively. By definition the number of moles of a substance is equal to its mass (m) divided by its molecular weight (MW).

$$n = \frac{m}{MW} \qquad \text{(Equation 2)}$$

Substituting this expression for n into Equation 1, we get

$$PV = \frac{m\,RT}{MW} \qquad \text{(Equation 3)}$$

Rearranging Equation 3 to isolate the one unknown variable, MW, we get

$$MW = \frac{mRT}{PV} \qquad \text{(Equation 4)}$$

where R is the gas constant and equals 0.08206 L•atm/mole•K.

Thus, given m, T, P, and V for any ideal gas (or vapor), its molecular weight can be calculated.

In this experiment you will determine the molecular weight of an organic liquid by converting it to the gaseous state, measuring P, V, T, and m, and substituting these values into Equation 4. This molecular weight, along with the quantitative elemental analysis data provided by the instructor, will be used in determining the molecular formula.

III. PROCEDURE

Required Apparatus:

800 or 1000 mL Beaker
250 mL Erlenmeyer Flask
Ring Stand
Wire Gauze
Utility Clamp
Thermometer (°C)
Aneroid Barometer
Mass Balance (± .0001 g.)

Required Materials:

Aluminum Foil
Organic Liquids (supplied by instructor)
Boiling Chips (optional)

CAUTION

Inhalation of the organic vapors must be avoided since they are toxic.

CAUTION

The organic liquids and vapors are flammable and must be kept away from any source of ignition.

1. Fill a clean 800 mL beaker about two-thirds full with tap water, mount on a hot plate, and begin boiling.

2. Weigh a clean, dry 250 mL Erlenmeyer flask and 3 in. x 3 in. aluminum foil square, together, to the nearest 0.0001 g. and record.

3. Place the aluminum square over the mouth of the flask, crimp the edges tightly around the mouth so as to make a cap, and carefully punch a <u>small</u> pinhole in the center of the cap, using a needle or small wire.

4. Remove the cap and place a 5 ml. portion of isopropyl alcohol in the flask.

5. Tap a very tiny amount of methyl red indicator from a spatula into the flask, swirl, and immediately reclose with the cap tightly. The indicator is added to enhance the visibility of the liquid in the flask, but its mass is so small that it can be neglected.

6. Clamp the flask to a ring stand. Lower the flask into the boiling water as much as possible and tilt at an angle to prevent entrapment of bubbles.

   Be careful not to allow the water to get under the foil cap.

7. As the liquid in the flask is heated and vaporized, air (and excess vapor) will be forced out through the pinhole.

   Do not add water to the boiling water bath.

8. After the last trace of liquid has evaporated, continue heating for an additional 30 seconds.

9. At this point the vapor will occupy the flask at the prevailing atmospheric pressure. Record the temperature of the boiling water and the barometric pressure.

10. Remove the flask from the boiling water, wipe dry, and cool to room temperature. As the flask cools, the vapor will begin to condense inside the flask. As the vapor condenses, air is drawn back into the flask.

11. Carefully weigh the cooled flask to the nearest .0001 g. and record. The final weight is the weight of the flask, aluminum cap, and liquid.

12. Remove the cap from the flask and discard the liquid into the proper container.

13. Measure the exact volume of the flask by filling it level to the top with water and pouring into a graduated cylinder. Record the volume to the nearest mL.

14. Calculate the molecular weight of the liquid from your data, using Equation 4.

15. Dry the flask completely (or obtain a clean, dry flask) and repeat the procedure (steps 1-14) with another portion of the organic liquid.

16. Conduct the above procedure twice on your unknown organic liquid to determine its molecular weight. (Your instructor may recommend a different color indicator to use with your unknown.)

17. Obtain the quantitative elemental analysis data for your unknown from the instructor.

DATA FORM

	Known Liquid		Unknown Liquid	
Mass of flask and foil (g)	________	________	________	________
Mass of flask, foil, and liquid (g)	________	________	________	________
Mass of liquid (g)	________	________	________	________
Barometric pressure (mmHg)	________	________	________	________
Temperature (^{o}C)	________	________	________	________
Volume of flask (mL)	________	________	________	________
Molecular Weight of Liquid (g/mole)	________	________	________	________
Average Molecular Weight of Liquid (g/mole)	________		________	
Elemental Composition			________	________

Write-Up for Molecular Weight Experiment

I. Purpose

(Omit procedure for this experiment.)

II. Results

(a) Data Table (See table at end of handout)

(b) Calculations (Show for only one trial)

- Mass of liquid
- Molecular weight of liquid
- Average molecular weight of liquid
- % error of your experimentally determined MW of the isopropyl alcohol from the theoretical value of 60.0 g/mole.
- Empirical formula of unknown liquid
- Molecular formula of unknown liquid

III. Discussion

Discuss why your experimentally-determined molecular weight of isopropyl alcohol deviates from the theoretical value for this compound. Consider not only the possible sources of error in the experiment, but also the assumptions made about the gas behavior.