11.1 Dumas Method - Pre-Lab Questions

Name: ____ Date: ___________________

Instructor: ____ Section/Group: ____________

Show all work for full credit.

1. If a 275-mL gas container has pressure of 732.6 mm Hg at -28 °C, how many moles of gas are in the container?

2. If the gas is condensed into a liquid, and the liquid weighs 1.95 g, what is the molar mass of the gas?

3. If a balloon has a volume of 0.58 L at 22 °C, find its volume if it is placed in a dry ice/acetone bath at -78 °C.

Downloads

11.2 Dumas Method - Introduction

The Ideal Gas Law (PV = nRT) has many applications. It relates several physical properties of a substance in the gas phase and can be used to determine any one of these properties, if all the others are known. In this experiment, the Dumas Method will be used to determine the mass of a gas using easily measured values of pressure (P), volume (V), and temperature (T), then the molecular weight of an unknown compound will be determined from the number of moles (n).

Relevance

This experiment focuses on the use of gas laws to determine the molar mass of an unknown compound. While this is an important calculation for research, it does not fully impart the value of these laws. Gas laws and the general concept of gas volume and pressure are vital for anyone deciding on a career in chemistry, because many of our models of molecular behavior were developed as a result of early studies of gases. Gas laws are even more important to those studying medicine. For example, oxygen saturation in the body is controlled by both internal and external pressures and raises some important questions:

- Why is it harder for humans to breathe at higher altitudes?
- What is hypoxia?
- What happens to a patient who receives too much oxygen?
- Not enough? And how do you, as the doctor or nurse, control the amount delivered?

None of these questions can be answered without a firm understanding of the gas laws.

Background

The Ideal Gas Law states that PV = nRT, where

P = the pressure of the gas in atmospheres,
V = the volume of the gas in liters,
n = the moles of gas,
T = the temperature of the gas in Kelvins, and
R = the gas constant.

The gas constant R is the same for all gases, or mixtures of gases, and it has been experimentally determined to be 0.0821 atm L/mol K.

A rearrangement of the Ideal Gas Law allows the calculation of the number of moles in a sample.

$$n = \frac{PV}{RT}$$

The *molar mass* of a substance cannot be measured directly, but mass can. The relationship between the mass and the number of moles of a substance is the molecular weight (MW) or molar mass.

MW = mass/n, which can be rearranged to n = mass/MW

To determine the molecular weight, these two relationships can be combined by replacing n in the ideal gas law to get PV = (mass/MW)RT.

This can be rearranged to give the formula:

$$MW = \frac{(mass)RT}{PV}$$

The Experiment

Part I: The Dumas Method

The Dumas Method is used to determine the molar mass of an unknown gas. An unknown liquid in a flask is vaporized by lowering it into boiling water. As the liquid vaporizes, it will push the air out of the flask, so that when all of the liquid has vaporized, the only gas in the flask will be the vapor of the unknown compound. When the flask cools, the unknown compound will re-condense. The amount of compound left in the flask is just enough to fill the flask as a gas.

Knowing the pressure, volume, and temperature of the flask allows you to calculate the moles of gas in the flask. You will measure the pressure in the room and volume of the flask, and assume the temperature of the unknown was 100°C as a gas, because the flask will be in boiling water. Weighing the unknown liquid after it re-condenses will tell you the mass of the unknown gas inside the flask. The molar mass of the unknown can then be calculated by the equation given above. The unknown compound will be one of the substances below.

Compound	Formula	Molar Mass
Acetone	C_3H_6O	58.08 g/mol
Ethanol	C_2H_6O	46.07 g/mol
Hexane	C_6H_{14}	86.18 g/mol
Methanol	CH_4O	32.04 g/mol
Octane	C_8H_{18}	114.23 g/mol
Pentane	C_5H_{12}	72.15 g/mol

Part II: Charles's Law

The Ideal Gas Law can be mathematically rearranged to the following form:

$$\frac{V}{T} = \frac{nR}{P}$$

If the moles of gas and pressure are held constant, then the value of nR/P is a constant number. Therefore, the quantity V/T must be constant as well. Doubling the temperature of a gas will cause the volume to double. This relationship is called Charles’s Law, and can be written as shown below:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where

V_1 = the volume of the gas at initial conditions,
T_1 = the temperature of the gas at initial conditions,
V_2 = the volume of the gas at final conditions,
T_2 = the temperature of the gas at final conditions.

Remember that the temperatures must be in Kelvins! You will test Charles's Law by measuring the volume of a balloon at different temperatures.

11.3 Dumas Method - Procedure

Safety Notes: Avoid skin contact with the unknown chemical. Dispose of the unknown properly. Use caution when using with hot water and the hot plate. The hotplate will be hot for some time after the power is turned off.

Part I: The Dumas Method

1. Obtain a ring stand, clamp, hot plate, 600-mL beaker, 125-mL Erlenmeyer flask, foil, and rubber band.

2. Your instructor will assign an unknown liquid. Record the unknown ID on the data sheet.

3. Place a piece of aluminum foil over the 125-mL Erlenmeyer flask. Cover the top and extend the foil ~1 cm below the rim.

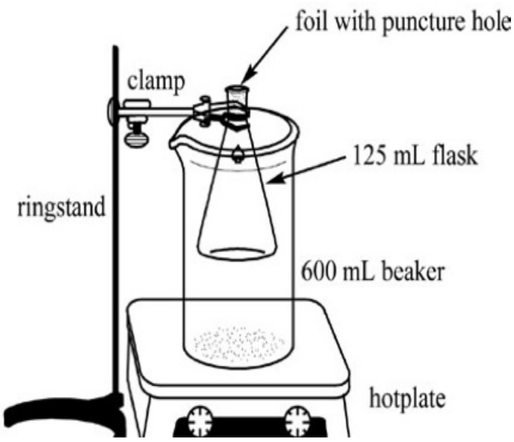
4. Puncture one very small hole in the foil, using a pin or needle. The purpose of the pinhole is to vent the flask, without allowing all the unknown vapor to escape. Secure the foil with a rubber band.

5. Measure the mass of the flask with the foil and rubber band using an analytical balance. Record the mass to the nearest 0.0001 g.

6. Remove the aluminum foil and rubber band.

7. Add 4 mL of your unknown liquid to the flask. Replace the foil and secure it with the rubber band.

8. Build the apparatus shown below:



9. Place the flask in a 600-mL beaker and clamp it to the ring stand. Fill the beaker with tap water and get the level as close to the top as possible without spilling. *It is very important that the level of water in the beaker is as close to the top as possible, otherwise your vaporized unknown will condense on the cooler upper surface of the flask. It is also very*

important that you do not get the foil wet.

10. Turn on the hotplate and bring the water in the beaker to a gentle boil. The unknown liquid will vaporize in the flask. Note: You may have to occasionally add more water to the beaker to keep it full.

11. After all of the liquid has disappeared (tilting the flask a bit makes this easier to see), leave the flask in the boiling water for one more minute. Then remove the flask from the water bath and allow it to cool to room temperature.

12. Leave the foil on the flask! The vapor of the unknown liquid will re-condense in the flask.

13. Wipe the outside of the flask dry and weigh the flask to determine the mass of the condensed liquid. Record this in the data sheet.

14. Dispose of the liquid in the proper waste container.

15. Determine the actual volume of the flask by filling the flask to the brim with tap water, then transfering the water into a large graduated cylinder to determine the volume of the flask. (Note: It will not be exactly 125 mL.)

16. Repeat the steps above for a total of three trials. You may use the same flask for all three trials, but make sure the flask is completely dry before reusing it, and reweigh it before each use.

17. Use a barometer to measure the pressure of the room. Record this value on the data sheet.

Part II: Charles's Law

Note: Be careful when lowering the balloon into the 1000 mL beaker of water, for if your hand is placed into the beaker, it will displace water from the beaker into the trough and could give an inaccurate measurement of the volume of the balloon at the various different temperatures

1. Obtain a trough, 1000-mL beaker, 1000-mL graduated cylinder, balloon, tongs, and hotplate.

2. Blow up a balloon partway so the balloon fits comfortably into a 1000-mL beaker without touching the sides and tie the balloon closed. Note: It may take some trial and error to get the size of the balloon right.

3. *Room Temperature Water Trial.* Place the 1000-mL beaker in a trough and fill the beaker to the brim with room temperature water. Slowly place the balloon in the beaker until it is completely submerged in the water. Water will overflow from the beaker into the trough. Measure the temperature of the water in the beaker and record this temperature in the data

sheet.

4. Remove the beaker from the trough and pour the water in the trough into a 1000-mL graduated cylinder. This will measure the volume of the balloon. Record this volume in the data sheet.

5. _Ice Water Trial._ With the same balloon, repeat the steps above using ice water instead of room temperature water. Lower the balloon very slowly so the air in the balloon has a chance to cool down.

6. Measure the temperature of the ice water.

7. _Hot Water Trial._ Fill the 1000-mL beaker to the top again and heat the water up to approximately 50 °C with a hotplate. With the same balloon, repeat the steps above using hot water. Since the water is hot, it may be easier to use an object such as a small beaker or tongs to push the balloon into the water instead of your hand. Make sure you lower the balloon into the water very slowly, and that you measure the temperature of the water (do not just assume it is 50 °C).

8. _Hotter Water Trial._ Repeat the last step using even hotter water, approximately 80 °C. You should now have four pairs of volume and temperature measurements.

11.4 Dumas Method - Data Sheet

Name: ____ Date: ____________________

Instructor: ____ Section/Group: ____________

Part I: The Dumas Method

Unknown ID ________________

	Trial 1	**Trial 2**	**Trial 3**
Barometric pressure of the room (atm)			
Mass of flask, foil, and rubber band - *initial mass*			
Mass of (dry) flask, foil, rubber band, and liquid - *final mass*			
Mass of unknown (g)			
Volume of flask (L)			

Average mass of unknown liquid from the three trials______________

Part II: Charles's Law

	Room Temperature Water	**Ice Water**	**Hot ~ 50 °C Water**	**Hotter ~ 80 °C Water**
Actual Temperature °C				
Temperature in Kelvin				
Volume of water displaced (mL)				
Volume of the balloon (L)				

Calculations

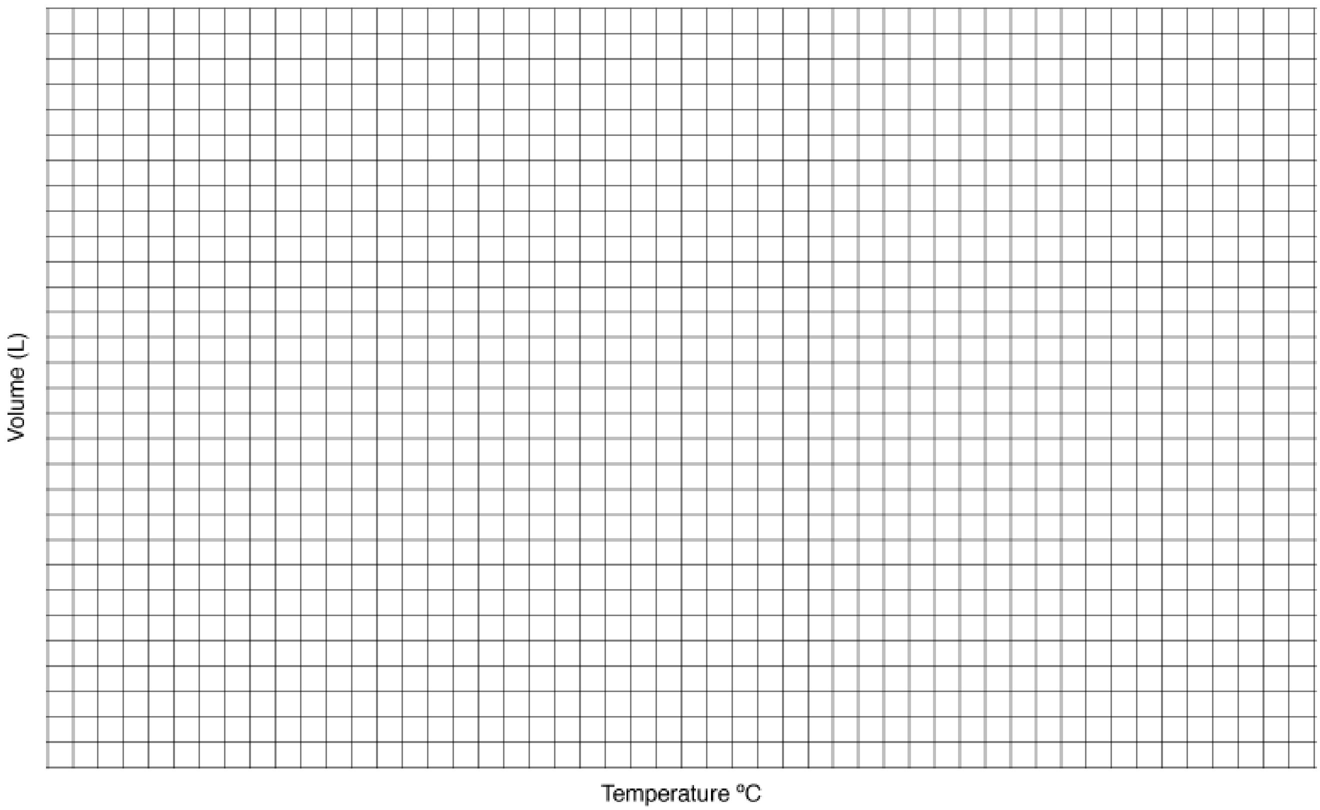
11.5 Dumas Method - Post-Lab Questions

Name: ____ Date: __________________

Instructor: ____ Section/Group: ____________

Show all work for full credit.

1. Graph temperature vs volume for Part II: Charles Law on the graph below.



2. Use the Ideal Gas Law (PV = nRT) to determine the molecular weight of the unknown. If you completed more than one experimental run, calculate the average value of the molecular weight. Show your work.

3. Unknown Identity__________________

4. Comment on sources of error that might have occurred in your experiment.