Experiment. Gas Laws.

Goal

To observe gas laws in the laboratory.

Introduction

All ideal gasses, regardless of molar mass or chemical properties, follow the same gas laws under most conditions. Gas Laws are derived from the Kinetic Molecular Theory, which makes the following assumptions:

- Gasses are composed of small particles that are in constant random motion.
- There is a lot of empty space between the particles, and the volume of the particles is negligible compared to this empty space.
- The attraction between the particles is negligible.
- The average kinetic energy of the gas is directly proportional to its Kelvin temperature (basically, the hotter it is, the faster the particles are moving).

If a gas follows these assumptions, the gas is an "ideal gas".

The pressure of a gas results from the gas particles colliding with the sides of the container – the more collisions, the higher the pressure of the gas. Also, a gas expands to fill its container, so the volume of a gas is equal to the volume of its container.

Boyle's Law: Pressure and volume are inversely related at constant temperature – as one increases, the other decreases. For example, as the volume of a sample of gas decreases, the particles collide with the sides of the container more often, leading to increased pressure.

$$P_1V_1 = P_2V_2$$

Charles' Law: Volume is directly related to temperature of a gas, assuming constant pressure. As the temperature increases, the gas particles go faster, so they collide more often with the sides of the container. In order to keep the pressure constant as the temperature rises, the volume must expand to keep the number of collisions the same.

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

Gay-Lussac's Law: Pressure and temperature are directly related, assuming constant volume. As the temperature increases in a system with fixed volume, the molecules move faster and have more collisions with the container, leading to increased pressure.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Avogadro's Law: Volume and moles are directly related, assuming constant temperature and pressure. More moles simply means more gas particles, and more gas particles will occupy more volume (at constant pressure and temperate).

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Combined Gas Law: The above laws joined together become the combined gas law. If more than two properties are changing, this law is used. Any properties that remain constant will drop out of the equation (for example, if temperature and number of moles are constant, they are removed from the equation and it becomes Boyle's Law).

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

Ideal Gas Law: $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ = R or, no properties are changing and PV = nRT. Where R = $0.08206\frac{atm\ L}{mole\ K}$

Laboratory Activity

Equipment	2 x 1000 mL beaker	aluminum can	hot plate	ice
	hot gloves	1 balloon, blown up	beaker tongs	
	250 mL Erlenmeyer flask	side arm flask	rubber stopper	vacuum hose
	small marshmallow	balloon	Vernier LabQuest	
	Vernier Thermometer	Vernier Pressure sensor	Vernier syringe	

Procedure

Part A:

1. Begin heating a half-filled 1000 mL beaker of tap water. Fill another beaker with ice and water to use as an ice water bath.

2. Obtain a small balloon filled with air. Place the balloon in the hot water. Hold the balloon with your fingers, so that you can feel any changes, but do not put your fingers in the water. Record any changes.

3. Transfer the balloon to the ice water bath. Hold the balloon in the ice water with your fingers. Do not put your fingers in the ice water. Record any changes.

4. Save the ice water bath for Part C.

<u>*A note on balloons*</u>: balloons maintain roughly the same pressure as their surroundings – in all balloon experiments the pressure remains approximately constant.

Part B:

1. Obtain a side arm flask. Place a marshmallow inside and plug the top with a rubber stopper. Attach one end of the vacuum hose to the side arm of the flask and the other end to the vacuum line.

2. ***Very slowly*** turn on the vacuum and observe what happens.

3. <u>Turn off the vacuum before disassembling</u>**.**

4. *Do not eat the marshmallow.*

Part C.

1. Pour some tap water into an Erlenmeyer flask.

2. Put an empty balloon over the mouth of the flask.

3. Put the flask onto the hot plate to heat. Observe what happens to the balloon.

Part D:

1. Obtain an empty aluminum can and add approximately 10 mL of water to it.

2. Place the can on a hotplate set to medium and heat until a steady, substantial stream of steam flows out of the can.

3. Using hot gloves, quickly <u>invert</u> the can into an ice-water bath (that is, turn it <u>upside-down</u> as you put it in the ice water). Observe any changes.

4. **The purpose of steps 1 – 3 are to remove most of the gas from the can. As you consider what happened to the can, recognize that the inside of the can has almost no gas in it. Remember that gasses push and never, ever suck!!**

Part E:

1. Obtain a LabQuest and plug in the pressure sensor and digital thermometer probe. Go to Mode and change the mode from time based to Events with Entry.

2. Obtain a syringe and move the plunger so that the inner plunger line is 10.0 mL, then connect the syringe to the LabQuest by turning it on to the pressure sensor. *Do not remove the syringe from the sensor until you are finished with part E.*

3. From the home screen, make sure that the LabQuest is reading pressure. Change units to mmHg.

4. Vary the volume of air in the syringe *without removing it from the sensor*. Pull the syringe out to two volumes larger than 10.0 mL, then push it into two volumes less than 10.0 mL. Record the volume and pressure at each point.

5. Record the air temperature with the probe thermometer.

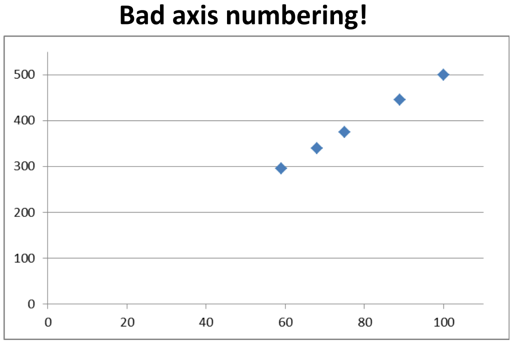
6. Graph 1: Graph the Volume and Pressure results either with the graph provided, or with a graphing program such as Excel if you know how to use one. (Volume in mL on the x axis, Pressure in atm on y axis) Consider the relationship for the first graph. Is the graph linear?

7. Graph 2: Calculate 1/V and replot the data with 1/V on the x-axis and Pressure on the y axis. Is the graph linear?

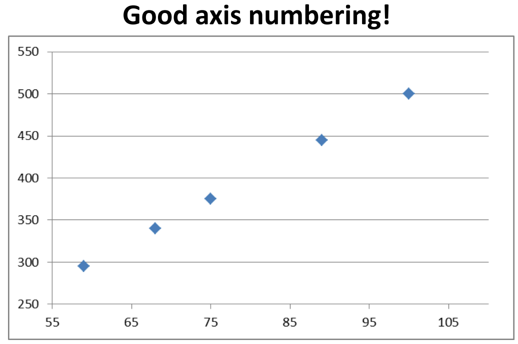
<u>Guidelines for graphing:</u>

- Give the graph a descriptive title. For example "Pressure verses Temperature of Gas in a Weather Balloon", not just "Pressure vs Temperature".
- Label the axis with the type of unit (ex: pressure, temperature, time) and the unit itself (ex: atm, ^{o}C, s)
- Number the axes so that the data takes up most of the graph. <u>For most axes, it is not appropriate to start at zero</u>.

Bad axis numbering!



Good axis numbering!



Name___________________________

Team Name _______________________

CHM111 Lab – Gas Laws – Grading Rubric

Criteria	Points possible	Points earned
Lab Performance		
Lab work performed correctly. Proper safety procedures followed and waste disposed of correctly. Work space and glassware cleaned up. Participated Actively.	2	
Post Lab questions		
All observations recorded and questions answered	8	
Graphs (titled, axes properly labeled, data takes up most of graph)	4	
Questions 1 -6	6	
Total	20	

Subject to additional penalties as per the instructor

Name___________________________

Team Name ________________________

CHM111 Lab – Gas Laws – Lab Report

Part	**Observations** (describe what happened)	**What happened and Why?**
A		Remember that a balloon's pressure inside is about the same as the atmospheric pressure outside.
B		
C		
D		Remember that gasses never suck!! They only push!

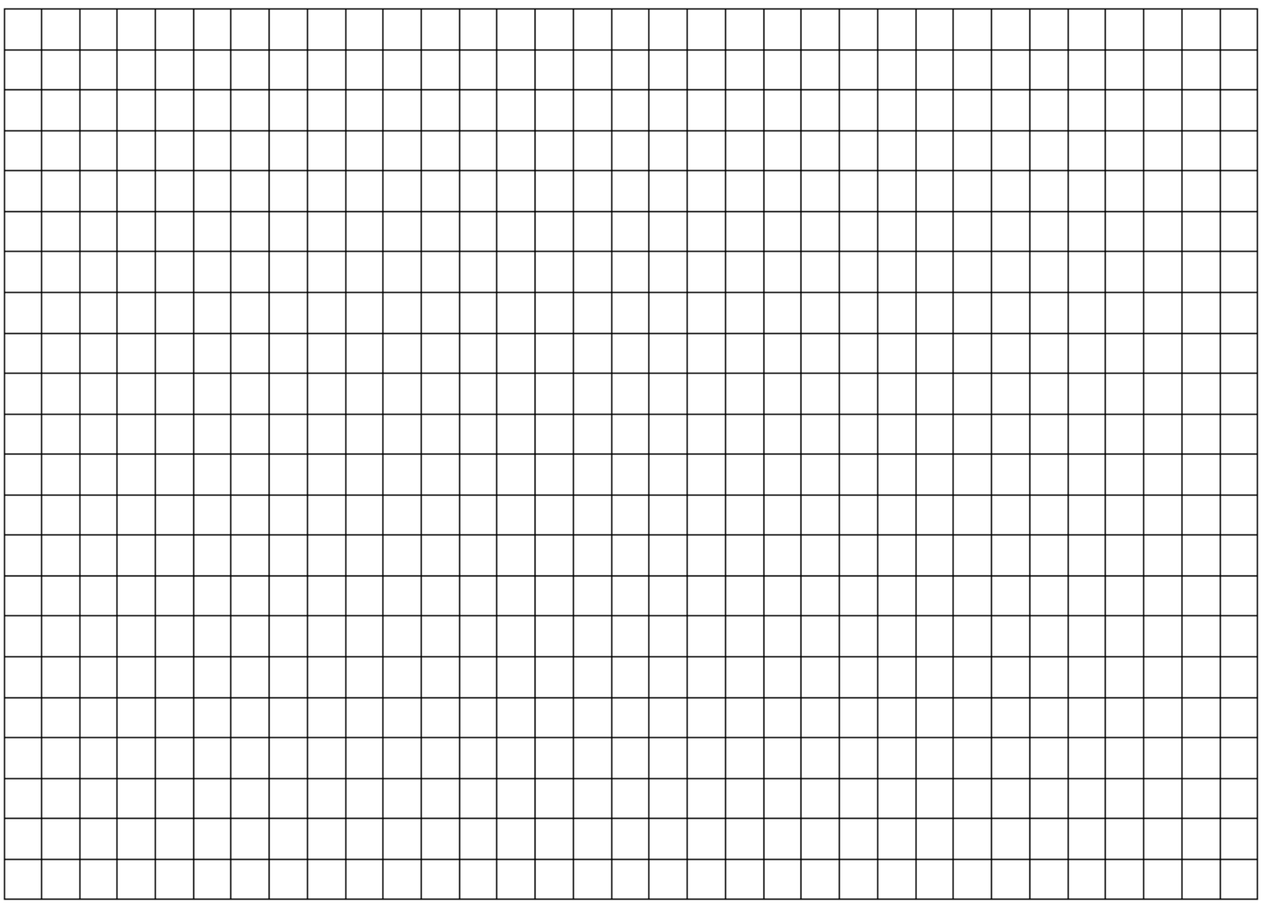
Part E: Record data.

Volume (mL)	**Pressure (atm or torr)**

Temperature of gas ____________________

Graph 1: Graph the Part D data below or with a graphing program. Refer to graphing guidelines in the instructions.
(y axis is P)

Pressure



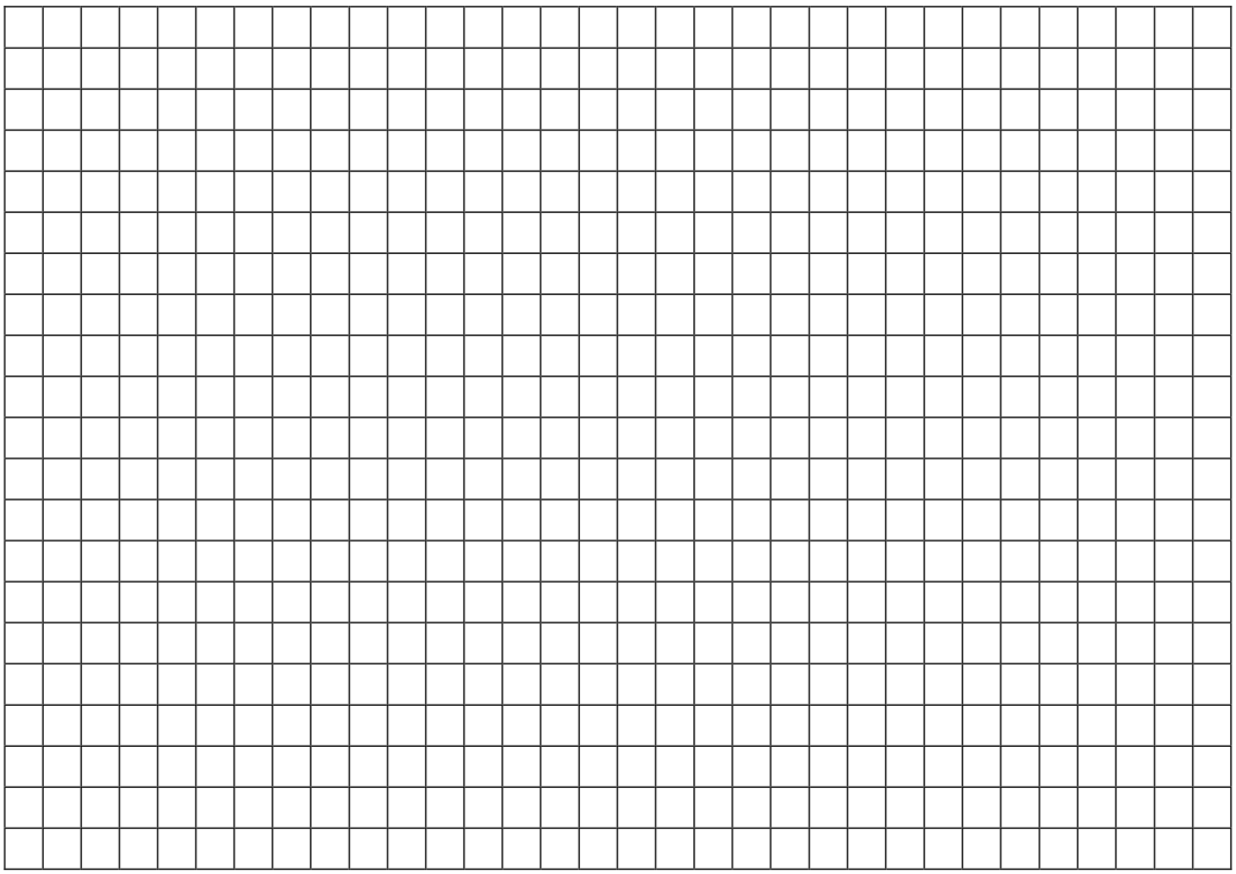
Volume

Calculate 1/V for Graph 2

1/V (1/mL)	Pressure (atm or torr)

Graph 2: x axis is 1/V. y axis is pressure

Pressure



$\frac{1}{V}$

Q1. Looking at Graphs 1 and 2. Which gas law did you observe?

Q2. Based on your graphs, what kind of relationship do pressure and volume have? (directly proportional or inversely proportional?)

Q3. Add a best fit line to Graph 2. (with a graphing program or estimate by hand with a straight edge)

a) Use the best fit line to estimate the pressure of the gas at 25 mL.
b) Use $P_1V_1 = P_2V_2$ and your first set of P,V data to calculate the pressure of the gas at 25 mL.
c) Compare the two values. Use this comparison to discuss if your gas behaves ideally in the experiment.

Q4. Assuming that the temperature of the gas is the same as the temperature of air, use your first set of pressure and volume conditions to calculate the moles of gas in the syringe. (Show all work)

Q5. A weather Balloon with a volume of 100.0 L at a temperature of 22 °C and a pressure of .978 atm is released into the atmosphere where it rises until the pressure is 125 Torr and the temperature is - 15 °C. What is the new volume of the balloon?

Q6. What volume of $NH_3(g)$ can be produced from the complete decomposition of 10.5 grams $(NH_4)_2CO_3$ at a pressure of 1.25 atm and a temperature of 95 °C? The unbalanced equation is: $(NH_4)_2CO_3(s) \rightarrow NH_3(g) + H_2O(g) + CO_2(g)$