Ideal Gas Law

Equipment List

Qty	Item	Part number
1	Ideal Gas Law Apparatus	TD-8596A
1	Pressure Sensor – Absolute	CI-6532A
1	Analog Adaptor	

Introduction

The purpose of this lab is to study the Ideal Gas Law to see how the pressure, volume, temperature, and amount of a gas effect one and another.

Theory

The behavior of a gas depends on a number of variables, namely pressure, P, volume, V, temperature, T, and the amount of gas, n. These variables are related to each other by an equation of state called The Ideal Gas Law.

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

R is called The Universal Gas Constant.

$$R = 8.31\ \frac{J}{moles \cdot K}$$

Most gases, near room temperatures and pressures, can be approximated as an 'Ideal Gas'. An Ideal Gas is a collection of the same type of atoms, or molecules, that move randomly about and exert no long-range forces on each other. Each particle of an Ideal Gas is point like, meaning the particles themselves have no volume. Also, an Ideal Gas must be made up of an extremely large number of particles. So it is convenient to express the amount of gas in a given volume in the term of moles, n.
One mole, of any material, contains 6.02×10^{23} particles of that material. This number is known as Avogadro's number, N_A

$$N_A = 6.02x10^{23}\, \frac{particles}{mol}$$

N_A and the definition of a mole are of great importance to fields such as Chemistry and Physics. The number of moles of a substance is related to its mass m by the expression

$$n = \frac{mass}{molar\ mass} = \frac{m}{M} \qquad \text{eq (2)}$$

The molar mass M is the mass of the particles per mole. The SI units of molar mass is kg/mole, but traditionally they are written as g/mole. One of the reasons Avogadro's number is so useful is that the mass, in grams, of one N_A of any element is numerically the same (approximately) as the mass of one atom of the element expressed in atomic mass units *u*. As an example the molar mass of Hydrogen (H_2) is 2 g/mole, and the atomic mass of Hydrogen (H_2) is 2 *u*.

Since n is the number of moles in a gas and N_A is the number of particles per mole, if we multiply the two we get N, the number of particles in the gas.

$$N = nN_A \qquad \text{eq (3)}$$

Set Up

1. Plug the Pressure Sensor into Analog Ch(A).
2. In the Set Up Window, add the ‘Pressure Sensor, Absolute’ to Analog Ch(A), then at the bottom of the screen set the pressure sensor to 1 Hz.
3. Plug the Ideal Gas Law Apparatus’ cord into the analog adaptor, and then connect the analog adaptor into Analog Ch(B).
4. In the Set up Window add the ‘Thermistor Temperature Sensor’ to Analog Ch(B), then at the bottom of the screen set the pressure sensor to 1 Hz.
5. Close the Set Up Window.
6. Create a Pressure vs Time graph.
7. Create a Temperature vs Time graph. Change the units of Temperature to Kelvins.

Procedure

Part 1: Constant Temperature

1. With the pressure sensor **NOT** connected to the Ideal Gas Law Apparatus set the plunger for a volume of 40 mL. Record this volume as initial volume V_1 in Table 1.
2. Now connect the pressure sensor to the Ideal Gas Law Apparatus. You will need to align the quick-release coupling on the end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling into the port and then turn the coupling clockwise until it clicks. **You will need to uncouple and recouple for each run**.
3. Start collecting data. Let about 5 seconds pass before moving on to the next step.
4. With the base of the Ideal Gas Law Apparatus firmly against the table top with one quick and firm push fully compress the plunger so that the stopper is bottomed out. Hold this position until the temperature and the pressure have stabilized. It should take about 30 seconds for the temperature reading to return to room temperature.
5. While still holding the plungers fully compressed record the volume reading of the Ideal Gas Law Apparatus as the final volume V_2 in Table 1.
6. Release the plunger and allow it to expand back out on its own. (It may not go back to 40 mL) Wait until the temperature and pressure have equalized and are no longer changing. This will take about another 30 seconds.
7. Stop collecting data.
8. Repeat Process for a total of 5 data runs. Then calculate the average values of V_1, P_1, V_2, P_2.

<u>Analysis of Ideal Gas Law Lab</u>

Name____ Group#________

Course/Section_______________________________________

Instructor____

Constant Temp

1. Highlight the area on the pressure graph at the beginning of the run before you compressed the air. Take the mean value of this region and record it as the initial pressure P_1 in Table 1.
2. Highlight an area of the pressure graph at the point just before you released the plunger that corresponds to a time where the temperature has returned to room temperature. Take the mean value of this region and record it as the final pressure P_2 in Table 2.

Table 1 (10 points)

	V_1 (mL)	**P_1 (kPa)**	**V_2(mL)**	**P_2(kPa)**
Run 1				
Run 2				
Run 3				
Run 4				
Run 5				
Avg				

1. For a constant temperature, the Ideal Gas Law $PV = nRT$, gives a constant value for the product of pressure times volume, such that we can write:

$$P_1V_1 = P_2V_2$$

Applying a little algebra and we get;

$$\frac{V_1}{V_2} = \frac{P_2}{P_1} \qquad \text{eq (4)}$$

From you average experimental values calculate the two ratios, $\frac{V_1}{V_2}$, and $\frac{P_2}{P_1}$. Show work in the space provided. (10 points)

2. According to eq (4) those two ratios in question 1 should be equal, but they are not. One of the reason for this is that there is a small consistent error in the volume that Ideal Gas Law Apparatus is calibrated for. The calibration does not include the volume of the air in the tubing. If we call the unknown volume of the tubing V_o, then eq (4) can be rewritten as:

$$\frac{V_1+V_o}{V_2+V_o} = \frac{P_2}{P_1} \quad \text{eq (5)}$$

Now using algebra, and your average values from Table 1 solve eq (5) for V_o. Show work in the space below. (10 points)

3. Calculate the Standard Errors for P_1, and P_2 from Table 1. Show work. (10 points)

Varying Temperature

1. For Run 1, highlight the area on the temperature graph at the beginning of the run before you compressed the air. Take the mean value of this region and record it as the initial temperature T_1 in Table 2.
2. From the temperature graph record the max temperature value as final temperature T_2 in Table 2. Also, note what time this temperature occurred at.
3. Transfer the value of the initial pressure P_1 in Table 1 to in the initial pressure P_1 in Table 2.
4. From the pressure graph find the pressure value that corresponds to the same time value that the peak temperature value occurred at. Record this pressure value at the final pressure P_2 in Table 2.
5. For the volume values, take initial and final volume values from Table 1, and add the calculated correction value, V_o, to both of them. Then record the corrected volume values in Table 2.
6. Then repeat the process for all 5 runs, and then calculate the average values of *V, P*, and *T*.

Table 2 (10 points)

	V_1 (mL)	**P_1 (kPa)**	**T_1 (K)**	**V_2(mL)**	**P_2(kPa)**	**T_2(K)**
Run 1						
Run 2						
Run 3						
Run 4						
Run 5						
Avg						

4. The Ideal Gas Law States that

$$\frac{PV}{T} = nR = constant$$

Because of this we can write

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Using the average values from Table 2 calculate the values of the two ratios $\frac{P_1V_1}{T_1}$, and $\frac{P_2V_2}{T_2}$. Show work in the space provided. (10 points)

5. Calculate the % difference between the two ratios from question 4. Show work in the space provided. (10 points)

6. Since air is about 78% Nitrogen assume that all the gas in our experiment was Nitrogen. From the average values of V_1, P_1, and T_1 from Table 2 calculate the number of moles of Nitrogen inside the Ideal Gas Law Apparatus. Then calculate the number of Nitrogen molecules in that many moles of gas. Show work in the space provided. (10 points)

7. State at least <u>two</u> possible 'physics' reasons for errors in the experiment (*do not include rounding errors, calculation errors, human errors or equipment malfunction*). (10 points)

8. Did our experiment confirm the Ideal Gas Law? Explain your answer. (10 points)