Matter and Motion
Fall 2015
Chemistry Lab 5: Discovery of Gas Laws
From Dharshi Bopegedera, *J. Chem. Educ.* **2007**, *84*, 465-468.

The purpose of this lab is to explore properties of gases and various relationships between pressure, volume, moles, and temperature. Using the results in this lab, you will be able to derive the Gas Laws and the Gas Constant.

PRELAB QUESTIONS

Read the entire lab carefully (including the Post-lab) then complete the Pre-lab before coming to lab. It should be completed in your chemistry lab notebook and presented for a check as you walk in the door.

1. Some of the words in this lab may be new to you. Make a list of any new vocabulary and their definitions.
2. Describe all of the data/measurements you will take during this lab. Be as specific as possible, i.e, include the units used and the number of times each measurement made.
3. Explain how you will be able to calculate the universal gas constant, R, using the data from this lab.

You will rotate around stations during this experiment. Some stations may take longer than others, so please be patient and use your time wisely. If you find yourself waiting, then work on the calculations from the part you just finished.

Part I: Exploring the relationship between pressure and volume of a gas sample

In this experiment we will keep the temperature and the number of moles of a gas sample constant and explore how the pressure relates to its volume.

To be done in the lab: (work in pairs)

1. Locate the experimental setup for Experiment 1. You will be given directions on how to acquire data at this workstation. Take a few minutes to familiarize yourself with this process. Draw a diagram of the experimental setup in your lab notebook.
2. Draw in a volume of atmospheric air (this is your "gas sample") into the 60 mL plastic syringe. Seal off the syringe using the 3-way valve so that gas cannot move in or out of the syringe (hence the number of moles of gas is constant). This experiment is done at constant room temperature. Record the room temperature in your lab notebook. Read the volume of the gas sample in the syringe and input this information into the computer. The Vernier pressure sensor will read the pressure of the gas sample.
3. Change the volume of the gas sample by moving the plunger of the syringe. Read and input the volume of the gas into the computer. The Vernier pressure sensor will read the pressure.
4. Repeat the above process 2 more times and obtain volume/pressure data. Then let your lab partner repeat the process 4 more times and obtain volume/pressure data. Both of you should have a total of 8 data points when you leave the station.
5. Save all your data and export it into a Microsoft Excel spreadsheet. Save the Excel file.

Part II: Exploring the relationship between pressure and temperature of a gas sample

In this experiment we will keep the volume and the number of moles of a gas sample constant and explore how its pressure relates to the temperature. Two workstations are set up for this experiment. Each workstation has two different gas samples. The gases provided are Ar, He, CO_2, and N_2. **You are required to work at one workstation with two of the above gases only.**

To be done in the lab: (work in pairs)

1. Locate one of the experimental setups for Experiment 2. You will be given directions on how to acquire data at this workstation. Take a few minutes to familiarize yourself with this process. Draw a diagram of the experimental setup in your lab notebook.

2. You will be provided with two separate, sealed, 250 ml Erlenmeyer flasks (these are the sample cells). Each flask is filled with atmospheric air, He, CO_2, or N_2 gas. Write down the gases given to you. The Erlenmeyer flasks are connected to Vernier pressure sensors. Since the gas sample is contained in a fixed volume Erlenmeyer flask, the volume and the number of moles of gas sample remain constant throughout the experiment.
3. Prepare an ice water bath (about 0°C). Immerse the two Erlenmeyer flasks (up to the neck) in this bath and wait for the system to reach thermal equilibrium. The gas samples have reached thermal equilibrium when the pressure readings do not change with time. This will take a few minutes, so be patient. Once the system has reached thermal equilibrium, use the Vernier sensors and software to continuously record the temperature and the pressures of the two gas samples. While continuing data collection, use the magnetic stirrer/heater unit to slowly warm up the ice water bath. When the temperature reading is around 90 °C, the data collection can be discontinued.
4. Your data will be tabulated as follows:

time (s)	temperature (°C)	pressure of gas ___	pressure of gas ___

5. Save your data and export it to a Microsoft Excel spreadsheet. Save the spreadsheet and leave the workstation.
6. There is a second station set up for Experiment 2, with two gases different from the ones you used. Do not repeat the experiment at this station, but find a lab group that worked at this station and copy their data. When you are done you should have data for four different gases (atmospheric air, He, CO_2, and N_2).

Part III: Exploring the relationship between volume and temperature of a gas sample

In this experiment we will keep the pressure and the number of moles of a gas sample constant.

To be done in the lab: (work in pairs)

1. Locate the experimental setups for Experiment 3. You will be given directions on how to acquire data at this workstation using Vernier software and sensors. Take a few minutes to familiarize yourself with this process. Draw a diagram of the experimental setup in your lab notebook.
2. Draw in a sample of atmospheric air into the 5 mL glass syringe. Seal off the syringe with the 3-way valve so that gas cannot move in or out of it (this holds the number of moles of gas constant). During the experiment, pressure of the gas will be held constant at atmospheric pressure by allowing the plunger of the syringe to move freely. Read the atmospheric pressure using the barometer and record this value in your lab notebook.
3. Prepare an ice water bath (about 0°C) and immerse the syringe carefully in it. Do not immerse the plunger of the syringe. Allow the plunger to move freely and wait for the system to reach thermal equilibrium. **The gas sample has reached thermal equilibrium when its volume does not change with time. This will take a few minutes, so be patient**. Once the system has reached thermal equilibrium, record the temperature of the bath and the volume of the gas sample. Always read the volume of the syringe with it vertical (plunger up). Tabulate your data as follows.

temperature (°C)	volume of the gas sample (mL)

4. Prepare a constant temperature water bath at 10°C. Immerse the syringe in this bath, wait for the system to reach thermal equilibrium, record the temperature of the bath, and the volume of the gas sample. Tabulate your data in the above table.
5. Repeat step 4 above at 6 different temperatures (15°C, 30°C, 45°C, 60°C, 75°C and 90°C). When you are done you should have a total of 8 data points.
6. Save your data and export it to a Microsoft Excel spreadsheet. Save the spreadsheet and leave the workstation.

<u>Part IV: Exploring the relationship between the pressure and number of moles of a gas</u>

Be sure to use the <u>same</u> analytical balance for this entire experiment. Write down the identification number of the balance in your lab notebook. The volume of the gas will be held constant and the experiment is done at constant temperature.

<u>To be done in the lab:</u>

1. Locate the experimental setup and identify each of the following components of the gas-handling manifold. Draw a diagram of the experimental setup in your lab notebook and label the important components. Be prepared to describe the functions of each of the components. Then find an instructor to help you with the rest of this experiment. Do not attempt this experiment without the presence of an instructor <u>at all times.</u>

- vacuum pump
- sample cell
- CO_2 gas cylinder
- pressure sensor
- all the valves (and their individual functions)

2. You will be provided with a 250 mL Erlenmeyer flask that will serve as the sample cell. Following directions provided in the lab, carefully evacuate this gas cell. Use an analytical balance to weigh its mass to the nearest 0.1 mg (0.0001 g). Use a piece of tissue to handle the gas cell to avoid getting finger oils on the cell.
3. Connect the sample cell to the gas-handling manifold as directed in the lab. Ensure that the CO_2 gas cylinder is closed. Evacuate the gas-handling manifold. Shut off the valve between the gas handling manifold and the pump. Open the CO_2 gas cylinder and fill the manifold with a small amount (about 100 torr) of CO_2 gas. Open the valve into the sample cell so that CO_2 gas bleeds into it. Wait for a couple of minutes for the system to equilibriate. The system has reached equilibrium when the pressure sensor reads a constant value. Record this pressure in your lab notebook.
4. Close the valve that connects the sample cell to the manifold. Close the CO_2 gas cylinder and the valve that connects the CO_2 cylinder to the manifold. Pump out the rest of the manifold. Carefully open the valve that opens the manifold to the atmosphere. The pressure gauge should now read atmospheric pressure. Carefully disconnect the sample cell from the manifold. Weigh the sample cell using the same analytical balance you used before (to the nearest 0.0001 g). Record this weight in your lab notebook.
5. Connect the sample cell to the manifold. Close the valve that opens the manifold to the atmosphere. Open the valve that connects the pump to the manifold and evacuate the manifold including the sample cell. Close the valve that connects the manifold to the pump. Close the valve that connects the sample cell to the manifold. Open the valve that connects the CO_2 gas cylinder to the manifold and open the CO_2 gas cylinder so that a small amount of CO_2 gas gets into the manifold. Ensure that the reading on the pressure gauge is at least 150 torr different from your previous pressure reading. Open the valve of the sample to allow CO_2 gas to bleed into it. Wait for a couple of minutes for the system to reach equilibrium. Record this pressure in your lab notebook.
6. Follow step 4 above and record the weight of the sample cell in your lab notebook.
7. Repeat Step 5 followed by Step 4 and obtain at least 5 more readings of pressure and the corresponding weight of the sample cell (a total of 7 data points). **Do not let pressures get above 1000 torr**. Tabulate your data as follows in your lab notebook.

Identification number of the analytical balance used: ______________________
Mass of the empty sample cell: _______________
Room temperature: ________________

pressure	weight of cell + CO_2 gas	weight of CO_2 gas

8. When **everyone in the class has finished working with the sample cell**, rinse and then fill it with de-ionized water. Dry the outside of the cell completely and weigh the sample cell to the nearest 0.0001 g.
9. In the computer lab, a "class spreadsheet" is set up for you to record your data from this experiment. Input your data into this spreadsheet. When the entire class has input their data, save this spreadsheet and use it for data analysis.

Part I Calculations:

1. Plot a graph of pressure versus volume using Microsoft Excel (scatter plot). Print your graph and put in the lab notebook.
2. Plot a graph of pressure versus 1/volume using Microsoft Excel (scatter plot. Print your graph and put in the lab notebook.
3. Give your spreadsheet a suitable title. Put your data into titled columns. Add your name and date to the spreadsheet. Print out the spreadsheet and put in your lab notebook.
4. Based on the graphs you plotted, what conclusions can you draw about the relationship between the pressure and volume of a gas sample at constant temperature? Explain your reasoning.

Part II Calculations:

1. Give your Microsoft Excel spreadsheet a suitable title. Put your data into titled columns and add your name and date to the spreadsheet. Save your data electronically.
2. Plot a graph (scatter plot) of pressure versus temperature (in Kelvin) using Microsoft Excel for each gas sample. Print these graphs and put them in your lab notebook.
3. Based on the graphs you plotted, what conclusions can you draw about the relationship between the pressure and temperature of a gas sample at constant volume? Explain your reasoning. Compare the graphs for the four different gases and comment on your observations.

Part III Calculations:

1. Organize your spreadsheet by giving it a suitable title. Put your data into titled columns and add your name and date. Print out the spreadsheet and put in your lab notebook.
2. Plot a graph (scatter plot) of volume versus temperature (in Kelvin) using Microsoft Excel. Print this graph and put in your lab notebook.
3. Based on the graph, comment on the relationship between the volume and temperature of a gas sample at constant pressure.

Part IV Calculations:

1. Convert the weight of CO_2 gas to moles of CO_2 gas. Show all calculations in your lab notebook.
2. Using the mass of water in the sample cell and the density of water at room temperature (look this up and cite your source), determine the volume of water in the cell. This is the volume of the sample cell. Show all calculations in your lab notebook.
3. The instructor will provide you with data collected from a similar experiment for Ne and SF_6 gases. Plot graphs of pressure versus the number of moles for CO_2, Ne and SF_6 gases using Microsoft Excel (scatter plot) on the same figure. What conclusions could be drawn from this graph about the relationship between the pressure and the number of moles of a gas that is held at constant temperature and volume?
4. Plot graphs of PV versus nT using Microsoft Excel (scatter plot) for CO_2, Ne and SF_6 gases on the same figure. Draw a line of best fit (trend lines using Microsoft Excel) through the data points and determine the slope. Pay attention to significant figures and units. Attach your graph to the lab notebook. Print out the spreadsheet and put it into your lab notebook.
5. Compare the slopes you obtained from the PV versus nT graphs for CO_2, Ne and SF_6 gases. What conclusions could you draw from these graphs and slopes?