Introduction to Natural Science (2006/07)

Spring 2007 Quarter

Chemistry Lab II: Exploring Gas Laws

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Experiment 1: Exploring the Relationship between Pressure and Volume

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

1. Go to the workstation that is set up for determining the relationship between pressure and volume of gases. You will be shown how to acquire data at this workstation using Vernier software. Draw in a volume of gas sample into the syringe. Seal off the syringe (using the 3-way valve) so that no more gas can move in or out of it (this means that the number of moles of gas is kept constant). Notice that we are using atmospheric air as our "gas sample" and we are doing this experiment at constant room temperature. Using the Vernier software, determine the pressure of the gas sample. Now change the volume of the gas by moving the syringe and determine the pressure of the new volume. Repeat the process 4 times and obtain volume/pressure data. Now 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.

2. Save all your data and leave the workstation. Export this data into a spreadsheet (Microsoft Excel).

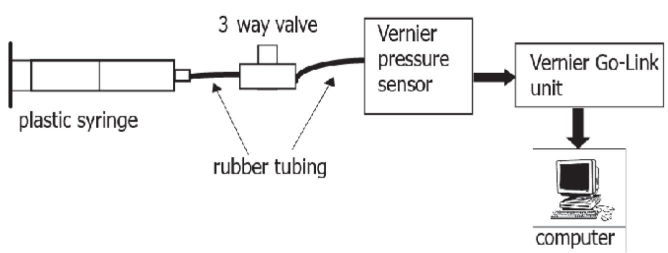
Post Lab Work:

1. Plot a graph of pressure versus volume using Excel (scatter plot with a **smooth curve** through the points). Print your graph and put in the lab notebook.

2. Plot a graph of pressure versus 1/volume. Draw the line of best fit (trend line) that runs through the points. Determine the slope and the intercept of this graph. Put this graph in your lab notebook.

3. Organize your spreadsheet by giving it a suitable title. Add your name and date to the spreadsheet. Put your data into titled columns, print out the spreadsheet and put in your lab notebook.

4. Relate the data you obtained to the gas laws you learned in class. Discuss in detail any special characteristics of the graphs you obtained and any deviations from the expected behavior.



Experiment 2: Exploring the Relationship between Pressure and Temperature

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

Two workstations are set up for this experiment. Each workstation has two different gas samples. The four gases are He, CO_2, N_2 and CH_4.

1. Go to a workstation that is set up for determining the relationship between pressure and temperature of gases. You will be shown how to acquire data at this workstation using Vernier software. You will be provided with two separate 250 ml Erlenmeyer flasks. Each flask is filled with one of the gases from the above set (He, CO_2, N_2 and CH_4) and connected to a pressure transducer. 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. Prepare an ice bath (constant temperature bath at 0°C). Immerse the two Erlenmeyer flasks in this bath and wait for the system to reach thermal equilibrium. **You know that the gas samples have reached thermal equilibrium when the pressures of the gas samples do not change with time. This will take a few minutes so be patient**. Once the system has reached thermal equilibrium, record the temperature and the pressures of the two gas samples. Tabulate your data as follows.

Temperature (°C)	Pressure of gas A (units)	Pressure of gas B (units)

2. Prepare a constant temperature bath at 10°C. Immerse the two Erlenmeyer flasks in this bath and wait for the system to reach thermal equilibrium. **You know that the gas samples have reached thermal equilibrium when the pressures of the gas samples do not change with time. This will take a few minutes so be patient**. Once the system has reached thermal equilibrium, record the temperature and the pressures of the two gas samples using Vernier software. Tabulate your data as shown above.

3. Repeat step 2 above at 6 different temperatures (15°C, 30°C, 45°C, 60°C, 75°C and 90°C are suggested temperatures). When you are done you should have a total of 8 data points for each gas sample.

4. Save your data and export your data to a Microsoft Excel spreadsheet.

5. There will be another station that is set up to do this experiment but this station will have two different gas samples. You do not need to repeat the experiment at this station, but copy the data your colleagues have collected. When you are done you should have data for four different gases at 8 different temperatures (in other words, 8 data points per gas sample).

6. Input all these data points into an Excel spreadsheet. Organize your spreadsheet by giving it a suitable title. Add your name and date to the spreadsheet at some appropriate place. Put your data into titled columns. Print out the spreadsheet and put in your lab notebook. Save your data.

7. Plot a graph of pressure versus temperature (in Kelvin) using Excel so that graphs for all four gases are on the same plot (scatter plot with a line running through the points). Print this graph and put in your lab notebook.

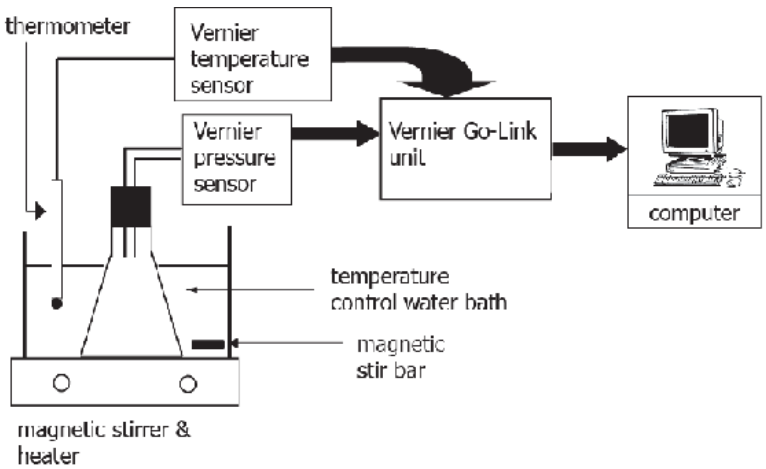
8. Re-do the same graph above using Excel except now plot your x-axis (temperature axis) starting at 0 Kelvin. Use Excel to extrapolate the lines to absolute zero. Print this graph and put in your lab notebook.

Post-lab Exercises:

1. Relate the data you obtained to the gas laws you learned about in class. Discuss in detail any special characteristics of the graphs you obtained and any deviations from the expected behavior.

2. Compare the plots you obtained in step 7 above for the different gases and comment on your observations.

3. Compare the plots you obtained in 7 above with the appropriate graph in your chemistry textbook. Comment on the similarities and differences between these graphs.



Experiment 3: Exploring the Relationship between Volume and Temperature

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

1. Go to a workstation that is set up for determining the relationship between volume and temperature of gases. Make sure that you have a 1.00 mL syringe to do this experiment. You will be shown how to acquire data at this workstation using Vernier software. Draw in a specific amount of gas sample into the syringe. Seal off the syringe so that no more gas can move in or out of it (this means that the number of moles of gas is kept constant). Notice that we are using atmospheric air as our "gas sample". You will also keep the pressure at constant atmospheric pressure.

2. Prepare an ice bath (constant temperature bath at 0°C). Immerse the syringe carefully into the ice bath making sure that the **plunger of the syringe** is not immersed in the bath. Wait for the system to reach thermal equilibrium. **You know that the gas sample has reached thermal equilibrium when the volume of the gas sample does not change with time. This will take a few minutes so be patient**. Once the system has reached thermal equilibrium, record the temperature and the volume of the gas sample. **Always read the volume of the syringe with it vertical (i.e. plunger up) and interpolate to the nearest 0.1 ml)**

Tabulate your data as follows.

Temperature (°C)	volume of the gas sample (units)

3. Prepare a constant temperature bath at 10°C. Immerse the syringe in this bath and wait for the system to reach thermal equilibrium. **You know that the gas sample has reached thermal equilibrium when the volume of the gas sample does not change with time. This will take a few minutes so be patient**. Once the system has reached thermal equilibrium, record the temperature and the volume of the gas sample using Vernier software. Tabulate your data as shown above.

4. Repeat step 3 above at 6 different temperatures (15°C, 30°C, 45°C, 60°C, 75°C and 90°C are suggested temperatures). When you are done you should have a total of 8 data points.

5. Save your data and export it into a Microsoft Excel worksheet.

6. Input all these data points into an Excel spreadsheet. Organize your spreadsheet by giving it a suitable title. Add your name and date also to the spreadsheet at some appropriate place. Put your data into titled columns. Print out the spreadsheet and put in your lab notebook. Save your data to a floppy disk.

7. Plot a graph of volume versus temperature (in Kelvin) using Excel (scatter plot with a line running through the points). Determine the slope and the intercept of the graphs using Excel. Print this graph and put in your lab notebook.
8. Re-do the same graph above using Excel except now plot your x-axis (temperature axis) starting at 0 Kelvin. Use Excel to extrapolate the lines to absolute zero. Print this graph and put in your lab notebook.

Post-lab Exercises:

1. Relate the data you obtained to gas laws you learned about in class. Discuss in detail any special characteristics of the graphs you obtained and any deviations from the expected behavior.

Experiment 4: Determining the Value of the Universal Gas Constant

BE SURE TO USE THE **SAME** ANALYTICAL BALANCE FOR THIS ENTIRE EXPERIMENT. WRITE DOWN THE IDENTIFICATION NUMBER OF THE BALANCE IN YOUR LAB NOTEBOOK.

1. Go to the gas-handling manifold that is set up for this experiment and identify each of the following components of the manifold. Draw a picture of the manifold in your lab notebook and label these components on your picture. This picture need not be drawn to scale but should be neatly done. Use a pencil if you wish. Be prepared to describe to the best of your knowledge 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 at all times.

   - Pump
   - Gas cell
   - CO_2 gas cylinder
   - Pressure gauge
   - Pressure readout
   - All the valves (and their individual functions)

2. You will be provided with a clean glass cell that will be used to contain your gas sample for this experiment. Following directions provided in the lab, carefully evacuate this gas cell. Go to an analytical balance and record 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 gas cell to the gas-handling manifold as directed in the lab. Be sure that the CO_2 gas cylinder is closed. Evacuate the gas-handling manifold. Disconnect the pump by shutting 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 of the gas cell so that CO_2 gas bleeds into the gas cell. Wait for a couple of minutes for the system to equilibriate. You can determine that the system has reached equilibrium when the pressure gauge reads a constant value. Record the pressure in your lab notebook.

4. Close off the valve that connects the gas cell to the manifold. Close the CO_2 gas cylinder. Close the valve that connects the CO_2 gas cylinder to the manifold. Close the valve that connects the pump to the manifold. Open the valve that opens the manifold to the atmosphere. The pressure gauge should now read atmospheric pressure. Carefully disconnect the gas cell from the manifold. Go to an analytical balance and weigh the gas cell with CO_2 gas in it (to the nearest 0.0001 g). Record the weight in your lab notebook.

5. Connect the gas 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. Open the gas cell and evacuate the gas cell. Now close the valve that connects the manifold to the pump. Close the valve that connects the gas 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. Be sure that the pressure reading on the pressure gauge is at least 150 torr different than your previous pressure reading. Open the valve of the gas cell so that CO_2 gas bleeds into the cell. Wait for a couple of minutes for the system to reach equilibrium. You can determine that the system has reached equilibrium when the pressure gauge reads a constant value. Again make sure that your new pressure reading is different (by at least 100 torr) from the previous reading. Record this pressure in your lab notebook.

6. Follow step 4 above and record the weight of the gas cell in your lab notebook.

7. Repeat Step 5 (above) followed by Step 4 (above) to obtain at least 5 more readings of pressure and corresponding weight of the gas cell (a total of at least 7 data points). Make sure that your pressure values are at least 100 torr different from each other. **Do not use pressures above 1000 torr**. Tabulate your data as follows in your lab notebook.

   Identification number of the analytical balance used: ______________________

   Mass of the evacuated, empty gas cell: _______________

   Room temperature: ________________

   Density of water at this temperature: _________________ (cite reference correctly)

Pressure (units)	Weight of cell + CO_2 gas (units)	Weight of CO_2 gas (units)

8. When **everyone in the class has finished working with the gas cell**, first rinse and then fill the cell with de-ionized water. Dry the outside of the cell **<u>completely</u>** and weigh the cell to the nearest 0.0001 g using the analytical balance.

All the data collected by students in your lab group will be available to you through the Masu share for INS. Look for the following file.
Masu/Programs/INS/Workspace/Spring Chem Lab II/Group A data (or Group B data or Group C data)
Download this file (Excel spreadsheet and use it for data analysis.

<u>Post-lab Exercises:</u>

1. From the weight of CO_2 gas data, determine the number of moles of CO_2 gas for each experimental determination. Show all work in your lab notebook.

2. Using the mass of water in the gas cell and the density of water at room temperature (assume it is 1.00 g/ml at room temperature), determine the volume of water in the gas cell. This is equal to the volume of the gas cell. Show all work.

3. Plot a graph of pressure of CO_2 gas versus the number of moles of CO_2 gas using Microsoft Excel. This should be a scatter plot with a line running through the points. Using **<u>the slope of this graph</u>** and the ideal gas equation, determine the value of the universal gas constant. Be sure to pay attention to significant figures and units. Show all work. Attach your graph to the lab notebook.

4. Print out the spreadsheet you used to plot this graph and put it into your lab notebook. Give the spreadsheet an appropriate tile and also give appropriate titles to columns. Add your name and date to the spreadsheet.

5. Compare the values you obtained for the universal gas constant from the above graph with the known value of the universal gas constant (from standard tables). Discuss reasons for any discrepancies. Be very specific.

6. The Following data is provided for you for Ne and SF_6 gases. Use this data and your data for CO_2 and plot graphs of pressure of gas versus the number of moles for each of the three gases on the same graph. Use the data for the three different gases to calculate the value of R. Then use that information to discuss the "universality" of the universal gas constant, R.

Data for Ne gas:

Mass of water in gas cell = 271.603 g
Room Temperature = 21.5 ^{0}C= 294.65 K
Density of water at 21.5 ^{0}C = 0.9979 g/ml
Volume of water = Volume of gas cell = 0.27215 L

Mass of Ne gas (g)	Pressure of Ne (torr)
0.036	119
0.101	334
0.138	461
0.265	887
0.199	667
0.152	510
0.183	611
0.210	703
0.220	734

Data fro SF_6 gas:
Mass of water in gas cell = 271.603 g
Room Temperature = 21.5 ^{0}C= 294.65 K
Density of water at 21.5 ^{0}C = 0.9979 g/ml
Volume of water = Volume of cell = 0.27215 L

Mass of SF_6 gas (g)	**Pressure (torr)**
0.252	118
0.388	180
0.732	339
1.044	482
1.482	681
1.595	731
1.895	869
1.696	773
1.217	555