Gases: Boyle's Law

INSTRUCTOR RESOURCES

The CCLI Initiative

Learning Objectives

- introduce the concepts and units of pressure, volume and temperature.
- experimentally determine the relationship between pressure and volume, using the ***MicroLAB*** interface system to collect and analyze the data.

Procedure Overview

- interface and syringe assembly set up and calibrated.
- pressure/volume data pairs taken at three different central volume settings.
- data analyzed and graphed, and questions answered.

GASES: BOYLE'S LAW

A. PRESSURE VS VOLUME DATA WORK UP:

The pressure-volume data are stored on your disc under the file names you gave them.

Data Manipulations

1. For each different PV set of measurements, open the file in the spreadsheet, and using the **Add Formula** function, calculate the product of P times V and drag it to **column C**. Using the **Statistical** function by **right** clicking on **Column C**, determine the mean and standard deviation (the standard deviations represents the "standard error" on the mean value) of the data in column C and record these in your lab book and in T1 in your lab report. Calculate a percent error value on the standard deviation for each of the data sets and add this to the table. Insert this table, T1, containing the data for each of the three PV data sets, within the body of the Results and Conclusions section of your written report. The P vs. V table on your experiment write up is an example of how this should be set up.

2. Ensure that you have graphed your dependent variable on Y, and your independent variable on X for each PV data set. Print these graphs with the spreadsheet data and the appropriate title as described above. (**Graphs G1.1, G2 and G1.3 set**)

3. Compare your graphs against the attached series of graphs to determine what mathematical transformation could be used to linearize your data. (**HINT**: To decide on the transformation to use, think about what you physically "felt" in the qualitative pressure/volume experiments as you adjusted the syringe plunger. **CAUTION**: Going for the highest correlation coefficient is not always the best approach if the transform necessary to achieve it is not realistic or does not conform to the experimentally observed conditions. It is possible to find a transform that will give a perfect correlation, but may not correspond to the physics or chemistry of the experiment.) Using the **Add Formula** function, calculate this transformation, drag it to **Column D** and the X-axis and using the **Analysis** function, add a **Linear Curve fit** to the data, then drag the curve fit to the **Y2** axis. Print each of these as **Graphs G2.1, G2.2 and G2.3** (**Remember** to do the transform on the independent variable and then graph the transform on the X axis.)

4. Add the value of the "slope" from each linear graph (G21 - G2.3) to table **T1** for each of the three PV data sets?

5. Calculate the percent difference between the slope and the P*V product for each data set in table **T1**, and add this value to table **T1**.

6. Using PV = nRT, calculate "**n**" for each PV data point set of the three gas volume series, determine the mean, standard deviation and % error on the mean for each, and add that data to your table of data.

GASES: BOYLE'S LAW

Boyle's Law Questions

1. What is the name of the type of curves that are produced by the pressure / volume data? If you don't know this, then go to your algebra books, other students, a math major etc. to find out.

2. Discuss the relationship between the slope for each PV data set and the mean P*V product for that data set, including whether they should be the same and why or why or not.

3. Can you explain the change in the difference between the slope and P*V product from the small volume set to the large volume set? (**HINT**: Think about the defining conditions and the units for the Ideal Gas Law constant!)

4. Which variable, pressure or volume, is measured with the least number of significant digits, i.e., what is the limiting precision in this experiment? Look up Boyle's Law in your text book. (**Cite your reference!**) Are your data consistent with Boyle's Law within the precision of this experiment? Support this with data in your answer

Name ______________________________ Section _________ Date ___________________

GASES: BOYLE'S LAW

Boyle's Law Questions (page 2)

5. The graphs of 1/X and 1/logX appear similar. Why is 1/logX not a good choice for modeling in this experiment?

(**T1** Include an expanded table like this in your Results and Conclusions section.)

Experimen t	P*V mean	Std. Dev.	%err. on P*V mean	Lin. Reg. Slope	% Diff. (P*V vs slope)	"n" mean value	Std. Dev. on "n"	% err. on "n" mean
Small Vol.								
Med. Vol.								
Large Vol.								

GASES: BOYLE'S LAW

Tips and Traps

Boyle's Law

1. It is imperative that an absolute pressure transducer be used in this experiment, rather than a differential transducer. This is due to the fact that a range of approximately 1.5 times atmospheric pressure to less than half atmospheric pressure is covered. Experience has shown that differential transducers do not calibrate well across the positive to negative pressure range.

2. It is also imperative that the connecting tubing fit tightly at all connections, especially for the positive pressure measurements. Very poor results will be obtained without this, and very good results will be obtained with it.

3. Students should get very close to the values tabulated above with careful work.

GASES: BOYLE'S LAW

Suggested Answers to Questions

Boyle's Law Questions

1. What is the name of the type of curves that are produced by the Pressure / Volume data? If you don't know this, then go to your algebra books, other students, a math major etc. to find out.

   This type of curve, where one decreases while the other increases, is termed an "inverse" relationship.

2. Discuss the relationship between the slope for each PV data set and the mean P*V product for that data set, including whether they should be the same and why or why or not.

   The slope of the linear data represents the best estimate of the product of pressure times volume. Ideally, they should be identical, but experimental error, especially in defining precisely the volume and holding it constant while taking the instrumental measurement, causes the deviations.

3. Can you explain the change in the difference between the slope and P*V product from the small volume set to the large volume set? (**HINT**: Think about the defining conditions and the units for the Ideal Gas Law constant!)

   The difference between the slope and the P*V product for each of the three different central volume experiments is due to the increase in the number of mols of gas in the syringe. For example, the PV product increased 1.47 times from a 20 ml central volume to a 30 ml central volume, which is approximately how the number of moles increased.

4. Which variable, pressure or volume, is measured with the least number of significant digits, i.e., what is the limiting precision in this experiment? Look up Boyle's Law in your text book. (**Cite your reference!**) Are your data consistent with Boyle's Law within the precision of this experiment? Support this with data in your answer

   The volume measurement is the least precise in this experiment. The syringe allows reading to two digits, and estimating to a third, where as the *MicroLAB* interface collects data to at least five significant digits.

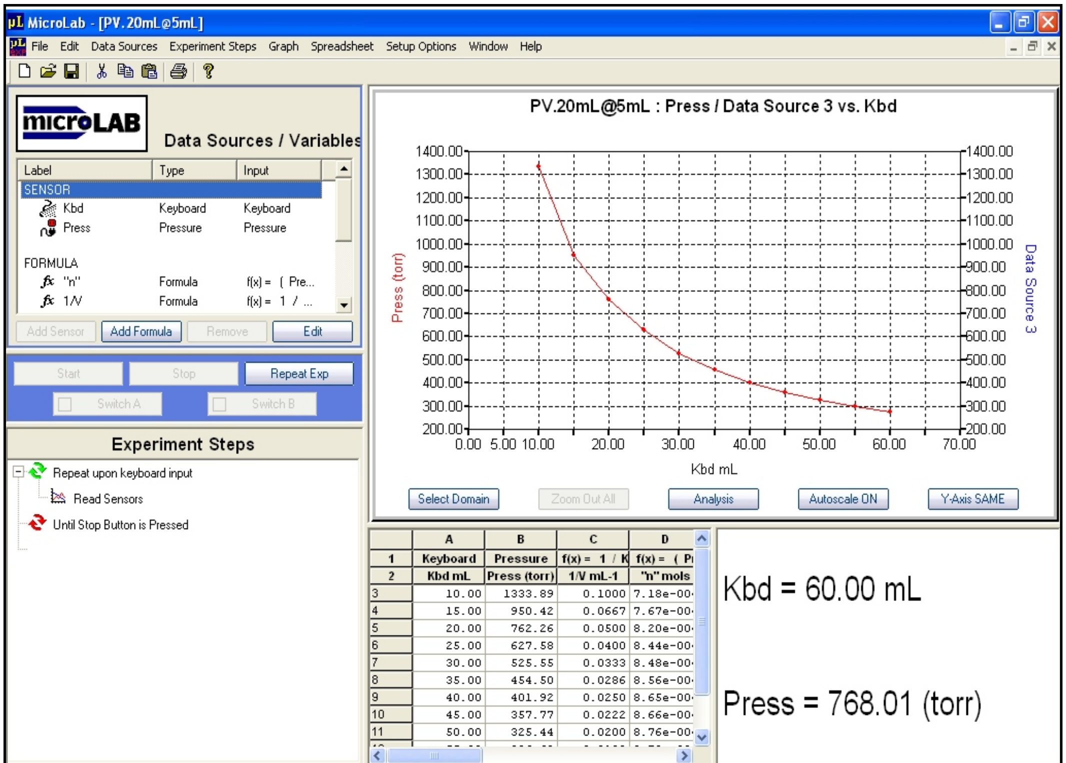
   The data obtained in these experiments is consistent with Boyle's Law within the precision of this experiment, as shown by the linear graph of the pressure versus volume formed by graphing pressure versus the inverse of volume. Boyle's law states that pressure is inversely related to volume.

5. The graphs of 1/X and 1/logX appear similar. Why is 1/logX not a good choice for modeling in this experiment?

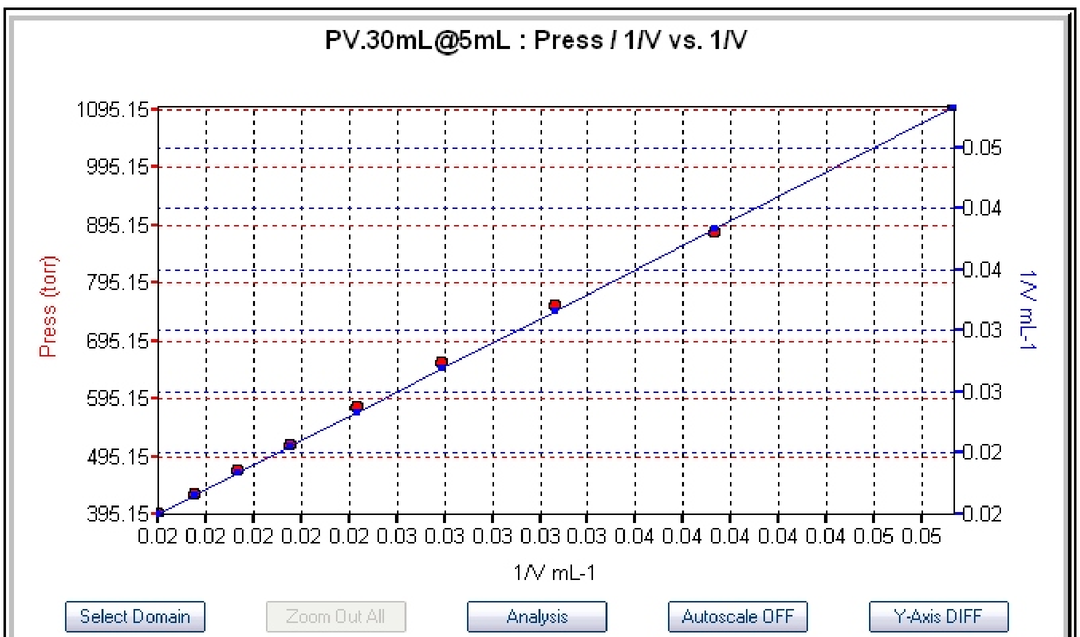
   The logarithm function is based on powers of ten, and we do not have variations in the data in orders of 10, so 1/logX would not be an appropriate function to make the data linear. In addition, if that function is tried on the current data, the resultant data is not linear.

GASES: BOYLE'S LAW

Sample Data



Sample ***MicroLAB*** Main Screen for Boyle's Law data. Note that the pressure decreases and the volume increases, implying an inverse relationship



The original Boyle's law data is made linear by plotting pressure versus 1/ volume, confirming Boyle's law.

GASES: BOYLE'S LAW

Laboratory Preparation (per student station)

Boyle's Law

- Y tube with short rubber tubing attachments (see Figure 2)
- screw clamp (attached to tubing on one leg of the Y tube)
- 60 ml syringe
- ***MicroLAB*** interface pressure sensor
- ***MicroLAB*** program which will accept volume inputs from the keyboard and read pressure values from the pressure sensor.