

Boyle's Law: Pressure-Volume Relationship in Gases

The primary objective of this experiment is to determine the relationship between the pressure and volume of a confined gas. The gas we will use is air, and it will be confined in a syringe connected to a Gas Pressure Sensor (see Figure 1). When the volume of the syringe is changed by moving the piston, a change occurs in the pressure exerted by the confined gas. This pressure change will be monitored using the Gas Pressure Sensor. It is assumed that temperature will be constant throughout the experiment. Pressure and volume data pairs will be collected during this experiment and then analyzed. From the data and graphs, you should be able to determine what kind of mathematical relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's Law.

OBJECTIVES

In this experiment, you will

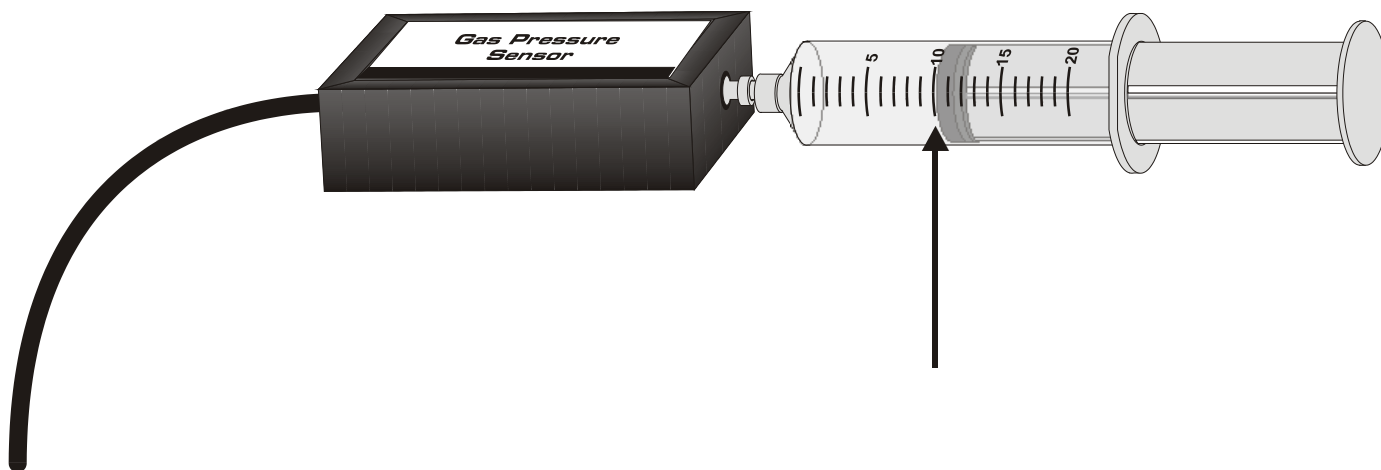
- Use a Gas Pressure Sensor and a gas syringe to measure the pressure of an air sample at several different volumes.
- Determine the relationship between pressure and volume of a gas and describe that relationship with a mathematical equation
- Use LoggerPro software to collect data, analyze the data, and create useful graphs to interpret the data.

MATERIALS

Computer	Vernier Gas Pressure Sensor
Vernier computer interface (Lab Pro)	20 mL gas syringe
Vernier Logger Pro software	

PROCEDURE

1. Log in to the laptop computers using your normal MEID username and password. Make sure that the computer is logging in to the "MCCCD-ORG" network.
2. Open the Logger Pro software. Open the Boyle's Law Lab file: File → Open → _Chemistry with Vernier → "06Boyle's Law"
3. Change the pressure units from kPa to atm.
4. Position the piston of a plastic 20 mL syringe so that there will be a measured volume of air trapped in the barrel of the syringe (5.0 mL is a good place to start). Attach the syringe to the valve of the Gas Pressure Sensor, as shown below. A gentle half turn should connect the syringe to the sensor securely. **Note:** Read the volume at the front edge of the inside black ring on the piston of the syringe, as indicated by the arrow below.



5. With the syringe connected to the Gas Pressure Sensor press the green button.
6. Allow the air in the syringe to equilibrate with the Gas Pressure Sensor for a minute, then press the blue button. A window will pop up, type in the volume in the syringe as 5.0 mL, then click "OK".
7. Move the piston in the syringe by 2mL to a larger volume (do not move to smaller volumes). When the pressure reading is stable press the blue button. In the pop-up window, type in the volume in the syringe to the nearest 0.5mL, then click "OK".
 - a. The syringe may have a leak that allows air to enter while you are recording the data. If the pressure does not stabilize, but slowly goes up, the lowest pressure possible.
8. Measure the pressure of the air in the syringe at various volumes. The best results are achieved by collecting at least seven data points. Move the piston of the syringe about 2mL, when the pressure stabilizes at the new volume, press the blue button again and type in the new volume. Continue in this manner, moving the piston an additional 2mL each time.
9. When all of your data points have been collected, then press the red button.

PROCESSING THE DATA

1. One way to determine if a relationship is inverse or direct is to find a proportionality constant, k , from the data. If this relationship is inverse, $k = P * V$. If it is direct, $k = P / V$. Insert two new calculated columns into your data table: Pressure * Volume and Pressure / Volume.
2. The graph that was created during data collection is a curve. A more helpful type of graph is a straight line. In order to create a graph with a straight line plot, a new calculated column for $1/\text{Volume}$ will need to be created.
3. Insert a new graph of Pressure vs $1/\text{Volume}$. Make sure that the new graph has an appropriate title, and that $1/V$ is being plotted along the x-axis and Pressure is being plotted along the y-axis.
4. Determine the slope of the line in the new graph. The slope of the line will be equal to the value of the proportionality constant, k .
 - a. The equation for a line is : $y = (m*x) + b$. For the graph you have created: $y = \text{Pressure}$, $x = 1/\text{Volume}$, m (the slope) = k , and b (the y-intercept) = the value in the box on the graph.

Boyle's Law: Pressure-Volume Relationship in Gases

Name: Answer Key

Section: _____

QUESTIONS

1. What experimental factors are assumed to be constant in this experiment?

Temperature and moles of gas are assumed to be constant

2. What is the most significant source of error in this experiment?

Human error. Holding the syringe in exactly the same place during data collection, reading the syringe accurately

3. Look at the data in the calculated columns of $P * V$ and P / V . One of these relationships should show a constant value for the proportionality constant, k . Good data may show some variation, but the values for k should be relatively constant. Which relationship shows constant values for k ? How constant are the values for k ?

*The $P * V$ relationship should show similar values. Depending on the accuracy of holding and reading the syringe the values for k may vary. Smaller volumes have the most variation.*

4. Based on the relationship between pressure and volume, what should the gas pressure be at infinite volume ($1/V = 0$)?

At $1/V = 0$ the pressure should be zero

5. Based on your graph, what is the gas pressure at infinite volume, according to your data? Why is this value different from ideal value in question 4?

They should report the y-intercept value from their graph. The y-intercept is not zero because we do not have an ideal gas nor is the data collected under ideal conditions.

6. Using P , V , and k , write an equation representing Boyle's Law. Refer to the slope and intercept data from your graph. Write a verbal statement that correctly expresses Boyle's Law.

*Pressure = (slope from the graph) * (1/Volume) + (y-intercept from the graph)*

7. Based on your data, what would be the pressure if the volume of the syringe was increased to 40.0mL. Show work to support your answer.

Should use their own equation to solve this. Work must be shown.

8. Based on your data, what would be the pressure if the volume of the syringe was decreased to 2.50mL. Show work to support your answer.

Should use their own equation to solve this. Work must be shown.

9. **BONUS** Create a new calculated column for 1/Pressure. Insert a new graph with 1/Pressure on the x-axis and Volume on the y-axis. Give this graph an appropriate title.
- a. Does this graph look the way you expected? Why or why not?

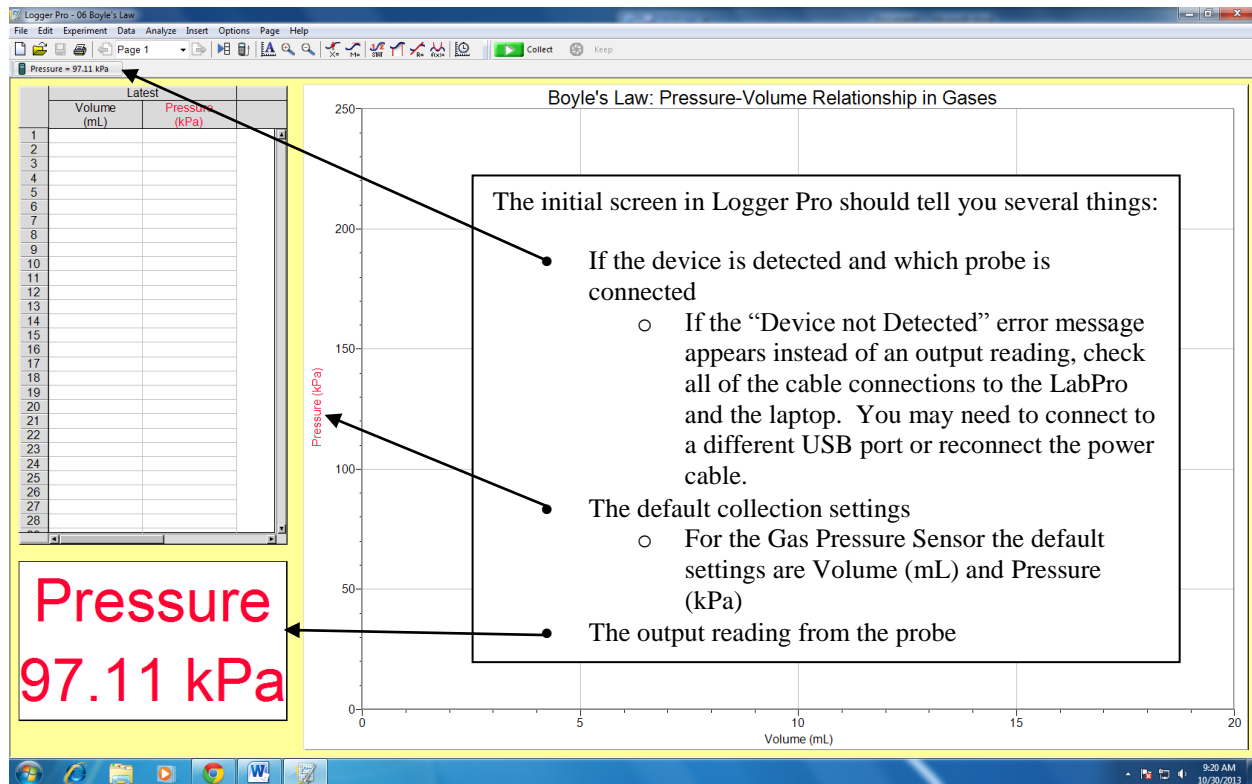
The graph should look similar to the original graph with a similar slope value. k should give approximately the same value regardless of which variable is chosen for y and x (P vs 1/V or V vs 1/P).

10. Attach a printed copy of the data table and graphs to your lab.

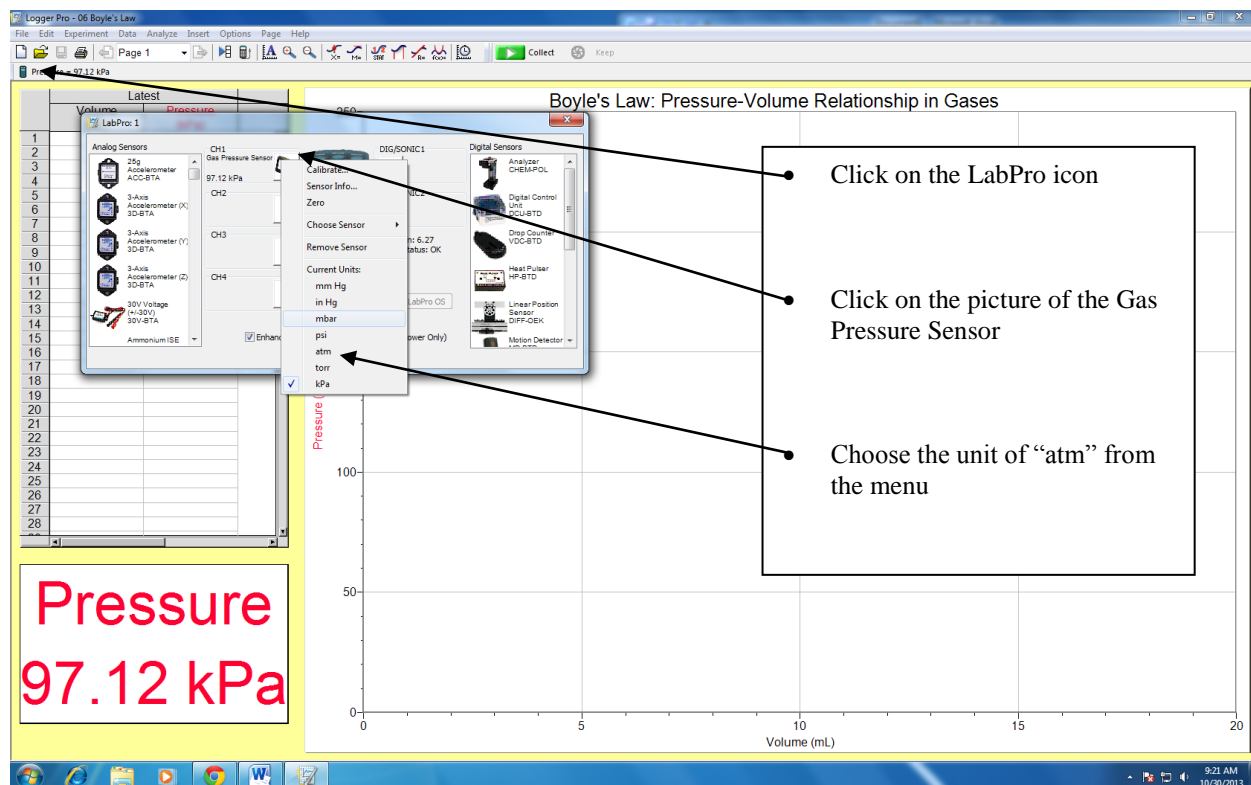
All graphs should be stapled to the report

Logger-Pro User Guide: CHM130LL Boyle's Law Lab

Procedure - Step 2: Initial Start-Up Screen

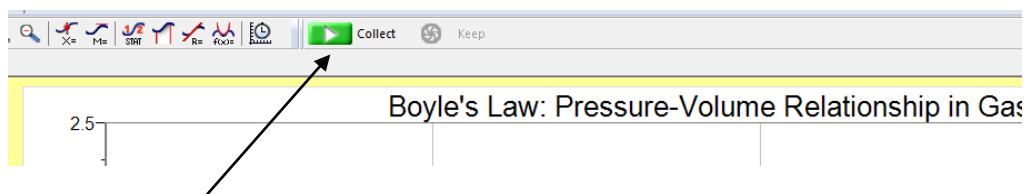


Procedure - Step 3: Changing the Displayed Units from the Sensor

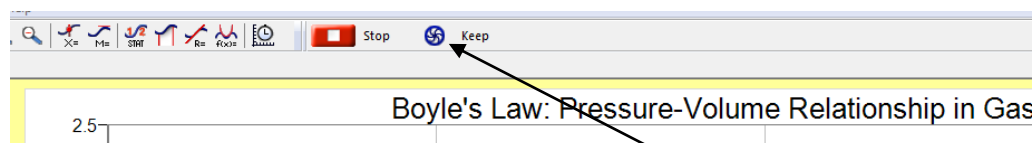


Data Collection

Procedure - Step 5: Before data collection begins, the “Collect” button is highlighted in green



Procedure - Steps 6-8: Collecting data points using Events with Entry mode



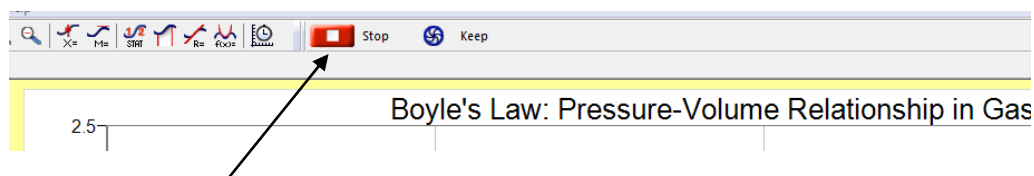
The 'Events With Entry' dialog box is open. It contains the text: 'Sensor value(s) recorded. Type corresponding entry or entries.' Below this, there is a text input field labeled 'Volume' followed by 'mL'. At the bottom, there are three buttons: 'Help', 'OK', and 'Cancel'.

Click on the blue “Keep” button when the pressure stabilizes

Type in the volume of gas in the syringe into the text box (to the nearest 0.5mL)

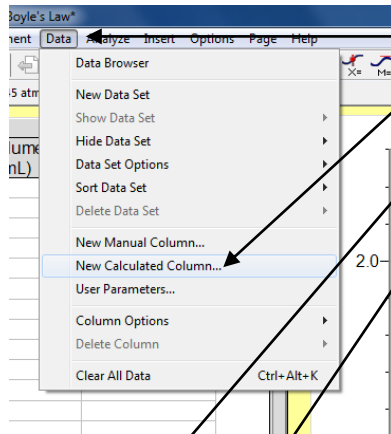
Click “OK”

Procedure - Step 9: To end data collection, press the red “Stop” button



Creating a New Calculated Column in the Data Table

Processing the Data - Step 1:



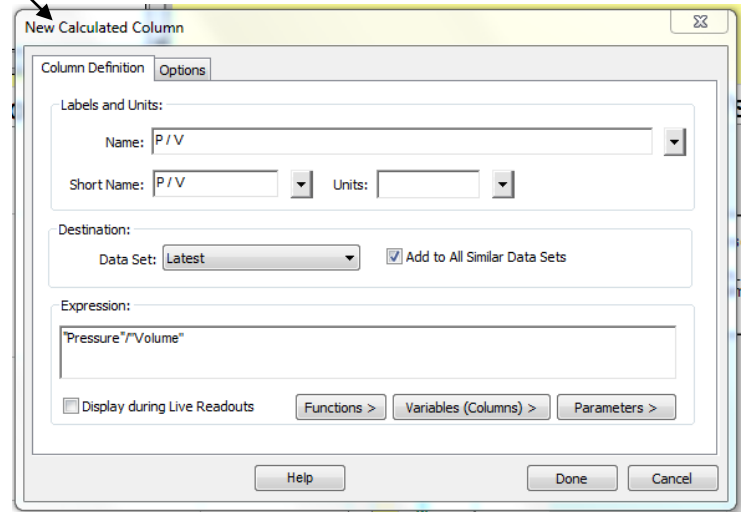
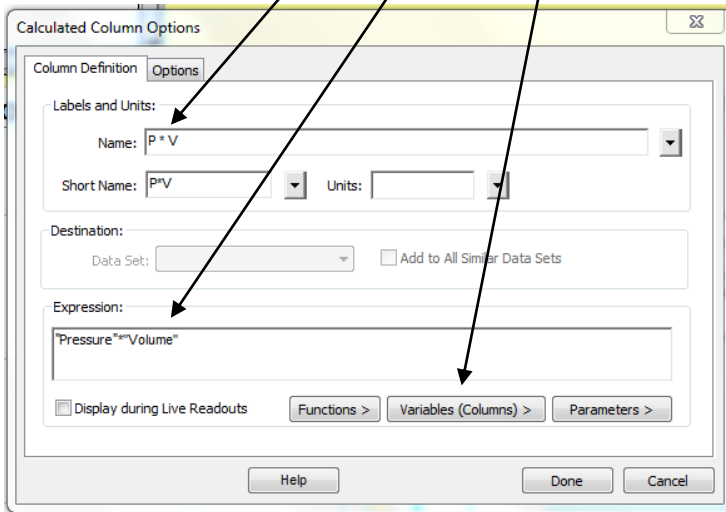
From the Data menu, choose "New Calculated Column"

In the pop-up box, Type in the "Name" and "Short Name" for the calculation

In the "Expression" box, type in your equation.

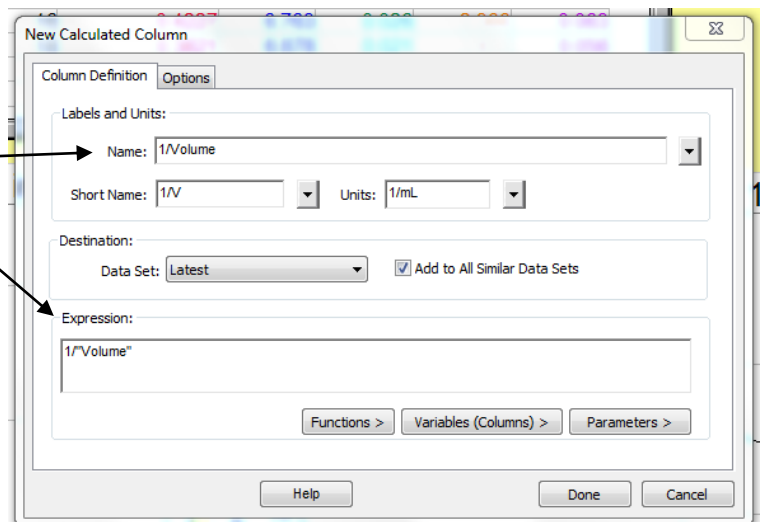
You must click on the "Variables (Columns)" button in order to choose the variables in your expression

Repeat the entire process for the second calculated column



Processing the Data - Step 2:

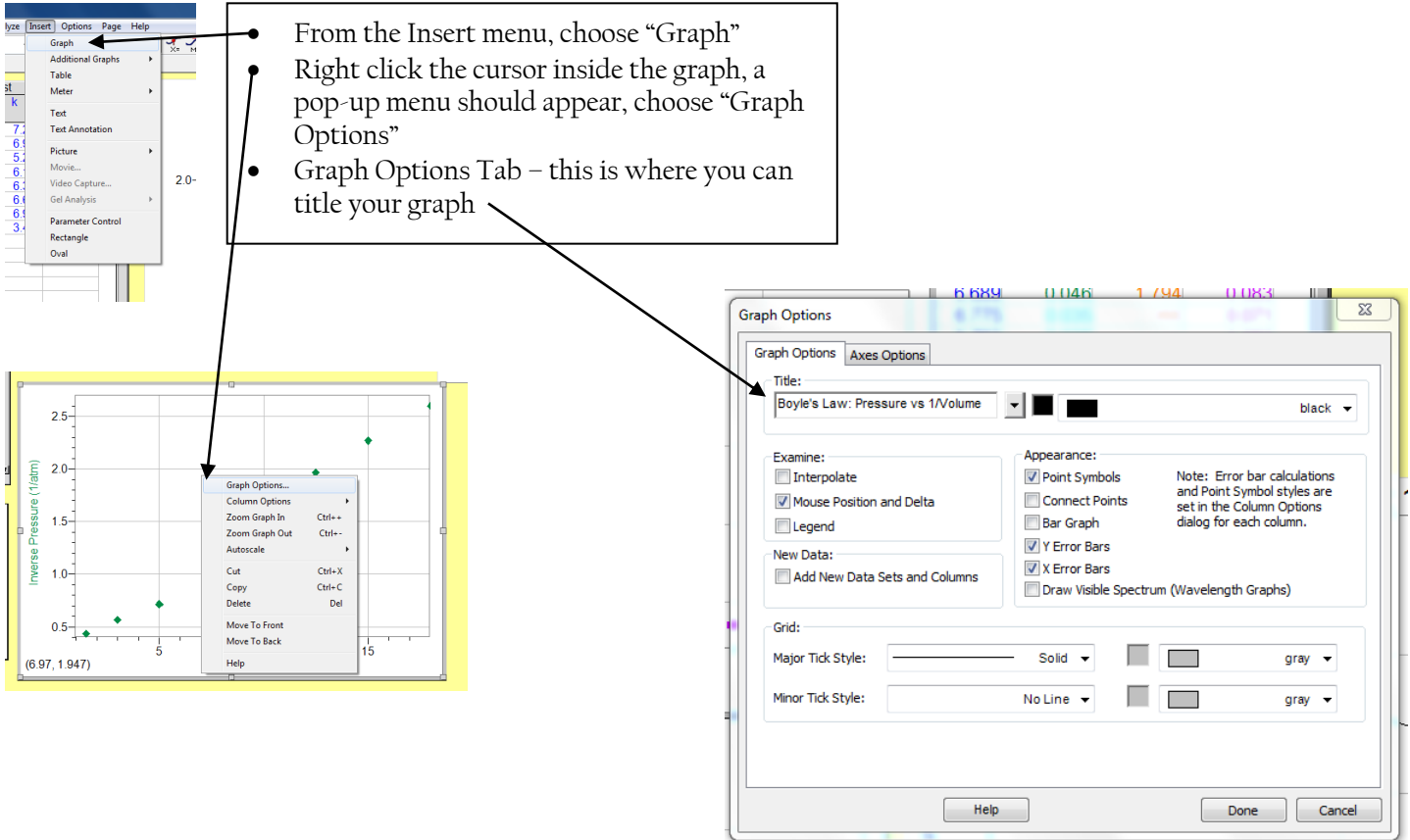
- Follow the above procedure, to create another calculated column for "Inverse Volume"
- Be sure to include the units



Inserting a Graph

Processing the Data - Step 3:

When a new graph is inserted, use the “Graph Options” menu to make changes to the graph



From the Insert menu, choose “Graph”

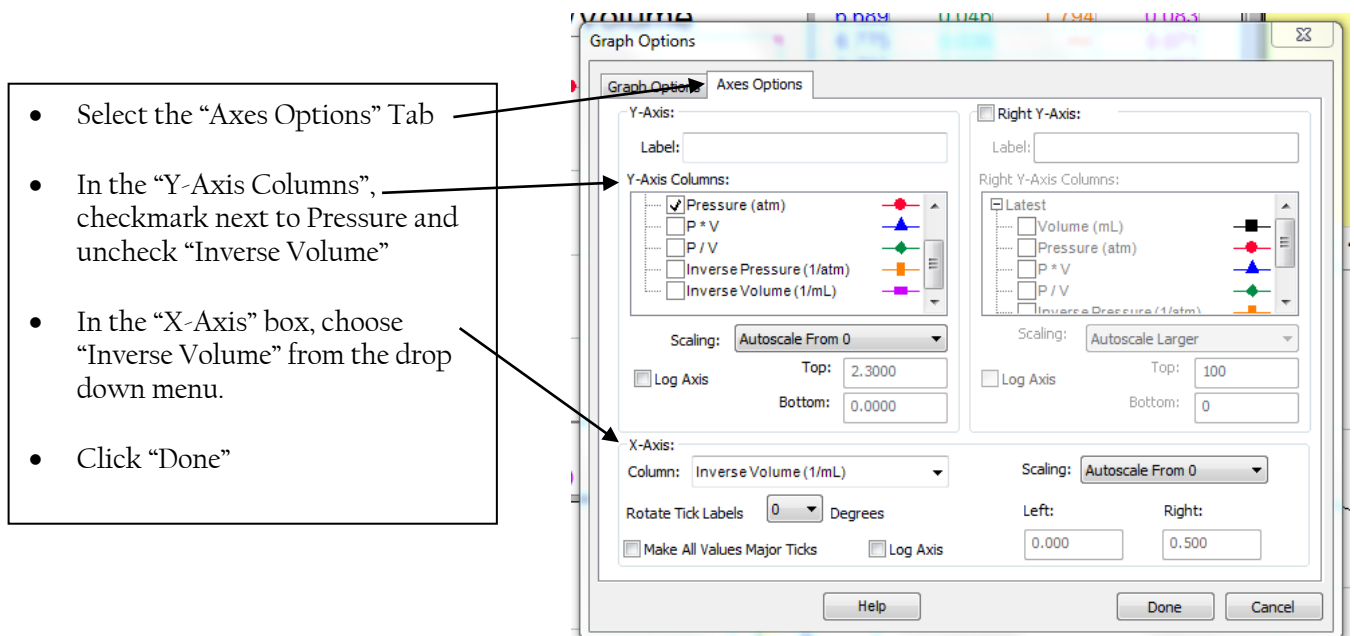
Right click the cursor inside the graph, a pop-up menu should appear, choose “Graph Options”

Graph Options Tab – this is where you can title your graph

The 'Graph Options' dialog box shows the following settings:

- Title: Boyle's Law: Pressure vs 1/Volume
- Examine: Interpolate, Mouse Position and Delta
- Appearance: Point Symbols, Connect Points, Bar Graph, Y Error Bars, X Error Bars, Draw Visible Spectrum (Wavelength Graphs)
- Grid: Major Tick Style: Solid, Minor Tick Style: No Line

When a new graph is inserted, LoggerPro will automatically choose the last column in the data table. You will need to change both the data set being plotted on the y-axis, and the data set being plotted on the x-axis.



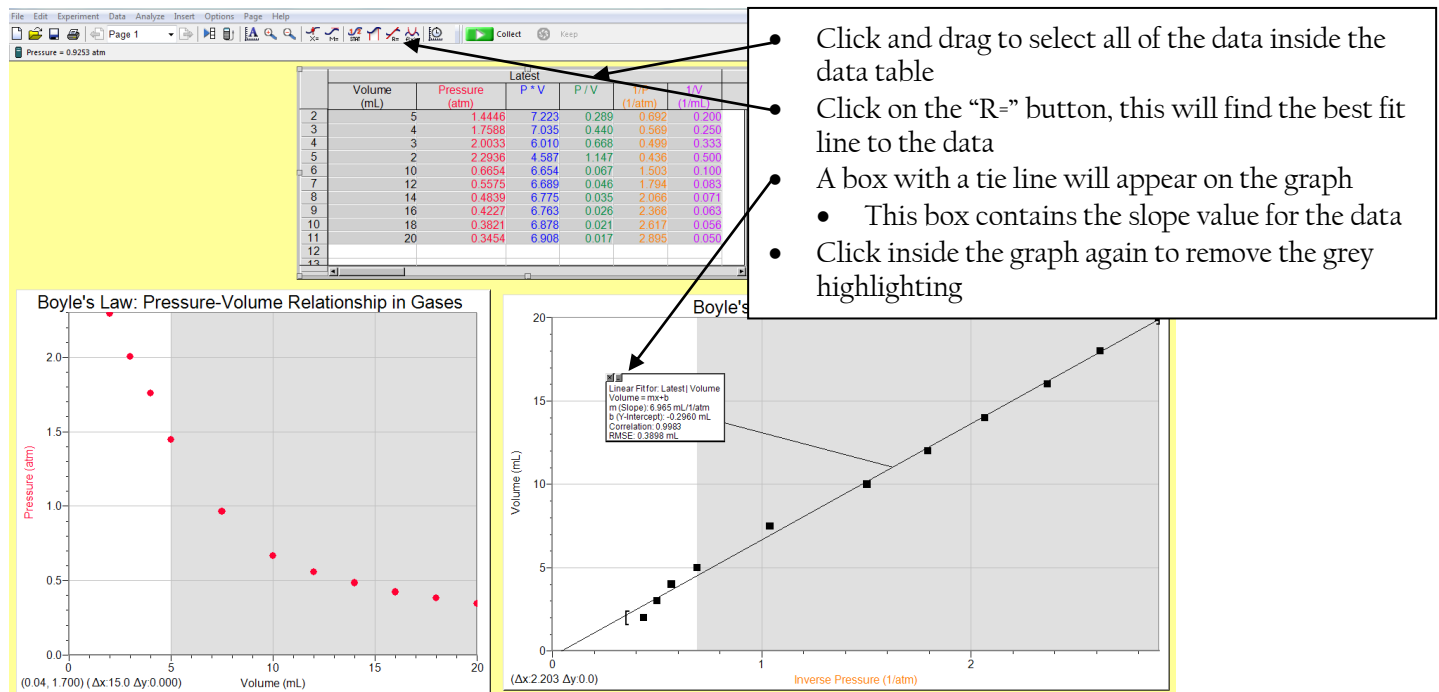
- Select the “Axes Options” Tab
- In the “Y-Axis Columns”, checkmark next to Pressure and uncheck “Inverse Volume”
- In the “X-Axis” box, choose “Inverse Volume” from the drop down menu.
- Click “Done”

The 'Graph Options' dialog box shows the following settings:

- Y-Axis: Column: Pressure (atm), Scaling: Autoscale From 0, Top: 2.3000, Bottom: 0.0000
- X-Axis: Column: Inverse Volume (1/mL), Scaling: Autoscale From 0, Left: 0.000, Right: 0.500

Determining Slope and Intercept

Processing the Data - Step 4:



- Click and drag to select all of the data inside the data table
- Click on the “R=” button, this will find the best fit line to the data
- A box with a tie line will appear on the graph
 - This box contains the slope value for the data
 - Click inside the graph again to remove the grey highlighting

Printing the Data Table and Graphs

1. Select the data output window in the lower left corner of the Logger Pro screen and delete the box.
2. Using the corners of each graph and the data table, re-size the graphs and table and move them around so that the data table and all graphs can be seen on the screen at the same time.
3. Under the File menu, choose “Page Set-Up” and change to Landscape.
4. Under the File menu, choose “Print”. Enter the names of each member of your lab group into the Footer. Make sure that the printer selected is “scc-print/NS316”. Print enough copies of the graph for each member of your group.
5. Staple the printed graph to the lab report and submit to your instructor.

In “Page Set-Up” change to Landscape

- In Printing Options, type the names of all members of the lab group.
 - This will print your names at the bottom of your graph
- Print enough copies for each member of your group

This is a sample of what the printed data table and graphs might look like

		Latest		
Volume (mL)	Pressure (atm)	P * V	P / V	1/P
2	1.4446	7.223	0.289	0.692
3	1.7568	7.035	0.440	0.569
4	2.0033	6.010	0.668	0.499
5	2.2936	4.587	1.147	0.436
6	0.6654	6.654	0.067	1.503
7	0.5575	6.689	0.046	1.794
8	0.4839	6.775	0.035	2.066
9	0.4227	6.763	0.026	2.366
10	0.3821	6.878	0.021	2.617
11	0.3454	6.908	0.017	2.895
12				

