THE RELATIONSHIP BETWEEN PRESSURE AND TEMPERATURE, i.e., Gay-Lussac's Law

INSTRUCTOR RESOURCES

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Learning Objectives

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

Procedure Overview

- interface and pressure probe assembly set up and calibrated.
- temperature-pressure data pairs taken over wide temperature range.
- data analyzed and graphed, and questions answered.

NOTICE: One program for this experiment requires the use of an AC controller, controlled by a 2.0 voltage output from the *MicroLAB* interface. If you are not equipped with such, then the experiment must be modified. Use the second sample program listed in the Tips and Traps section below.

GASES: Gay-Lussac's LAW

PRESSURE VS TEMPERATURE DATA WORK UP:

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

Gay-Lussac's Law Data Manipulations

1. Graph the dependent variable on Y and the independent variable on X and print this graph with the appropriate title as described above. **Graph G1** Repeat this for each run you made. **G1.1-G3.1**
2. If the points of the scatter graph appear linear, then do a regression line through the data. If the points are **clearly not** linear, then perform the proper transform to make the data linear. Print this graph with the appropriate title as described above. **Graph 1.2 - G3.2**
3. Plot a linear regression graph of °C on Y and Pressure on X. Print this graph with the appropriate title as described above. **G4**
4. Using the **Predict** function under **Analysis**, and for **Graph 4**, predict the value for zero (0) pressure. Enter the predicted value and the Y intercept value in **Table T1** and calculate their percent difference.
5. Using the **Add Formula** function, calculate the corresponding Kelvin temperature and drag to **Column C**.
6. Using the **Add Formula** function, divide the temperature in K by the pressure and drag to **Column D**. (This is the reverse of the normal procedure, but for a purpose.) Determine the mean, standard deviation and percent error on the standard deviation of the data in column D and enter it in **Table T1**.
7. Plot a linear regression graph of Kelvin temperature on Y and pressure on X. Print this graph with the appropriate title as described above. **Graph 5**
8. Calculate the percentage difference between the mean and slope values in the above question and add this value to **Table T1**

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

Y intercept value	Predicted intercept	K/P Mean	Std. Dev.	% error on Std. Dev.	L.R. slope	% Diff. (K/P vs. Slope

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Tips and Traps

1. Where feasible, it is preferable to heat a large amount of water for temperature calibration using a 2 liter Erlenmeyer flask before lab begins so that it is ready when the students need it.

2. The following program requires the use of an AC controller which will accept a 2.0 V signal from the ***MicroLAB*** interface to turn the heater on and off. If your school does not have access to such a controler, you will need to use the program following this one.

Pressure vs Temperature at 5 °C intervals -Gay-Lussac's Law: For this example, both temperature and pressure are recorded automatically by the MicroLAB system every 5 °C from 0 to 60 °C.

Variable control from starting point, changing by increments: Temperature is controlled at a preset value until the pressure attains equilibrium, then the first variable is increased by 5 °C and maintained until the pressure attains equilibrium again. Both variables and time are recorded automatically by the MicroLAB system every 5 °C.

Suggested name: ***gay-lussac's.exp***

Sensors: **Time**: X axis, Col. A, DD on top, units = sec; **Controlled variable**: Y1 axis, Col B, DD in the middle, units = as a function of the variable; **Read any other variable**: Y2 axis (?), Col. C, DD on bottom, units = as function of the variable.

Example Program: (Program for Gay-Lussac's' Law to determine the pressure-temperature relationship.)

Read Sensors (Make an initial sensor reading and store to the data grid)

Start the main repeat loop to attain the initial stabilizing of the temperature to 5.0 °C

Repeat every 0.5 seconds (Pressure changing, maintain a constant temperature)

If Delta Press > +/- 5.00 (pressure changing, maintain constant temp)

If TempIC < 5.00 (Evaluates **truth** of statement.)

Output CAT-5B-ON (Turns Output ON, adjusts the temperature towards a set value.)

Else

Output CAT-5B-OFF (Turns Output OFF, allows temperature to drift down.)

End If (Pressure not changing by +/- 5.00,move on to the actual experiment)

Else

Read Sensors (Read the sensors and store to the data grid)

Output CAT-5B-ON (Turns Output ON, adjusts the temperature towards a set value.)

Wait until Delta TempIC > +/- 5.00 (Output ON to raise temp by 5.0 C)

****Repeat every 0.5 Seconds*** (the beginning of the next data reading loop)

If Delta Press > +/- 5.00 (pressure changing, maintain constant temp)

If Delta TempIC > +/- 0.1 (maintain constant temp)

Output CAT-5B OFF (Turns Output OFF, turning heater OFF)

Else

Output CAT-5B ON (Turns Output ON, turning heater ON)

EndIf

Else (The pressure is not changing by +/- 5.00 so...)

Read Sensors (Read the sensors and store to the data grid)

Output CAT-5B-ON (Turn the output on)

Wait until Delta TempIC > +/- 5.00 (Heat til ∆temp 5.0 C)

EndIf

****Until Stop Button is pressed*** (This will end the entire experiment)

EndIf

Until Stop Button is pressed (Simultaneously ended by the one above)

Comments: The cycles between the two asterisks (*) will continue indefinitely, raising the temperature by 5 °C each cycle until the **Stop** button is clicked.

Temperature probe requires recalibration.

To change the delta value of the controlling (first) variable, double click the **If Delta Temp. . . (first variable)** statement then click on **Delta Function** and enter the new value. To refine the approach to equilibrium, double click the **Delta Press . . . (second variable)** statement then click on **Delta Function** and enter the new value

3. **The following program can be used to collect the Gay-Lussacs' Law data if no AC Controller is available**. Temperature is controlled by an external controller.

Temperature versus pressure (Gay-Lussac's Law): The **Wait until** step allows the observer to monitor the pressure in the Y1 axis and determine when the pressure has equilibrated at a given temperature, then both temperature and volume are recorded automatically by the ***MicroLAB*** system when **Switch A** is clicked.

Suggested name: ***Gay-Lussac's Law***

Sensors: **Pressure**: X axis, Col. A, DD on top, units = ml; **Temperature**: Y1 axis, Col B, DD in middle, units = °C, **Time**: no axis, Col C, DD on bottom, units = seconds.

Example Program: (Program for Gay-Lussac's Law to determine the pressure-temperature relationship.)

Repeat every 0.5 seconds (Starts repeat loop triggered by time.)

Read Sensors (Reads all variables selected in Data Sensors/Variables and stores in a data grid.)

Wait until Switch A is pressed (Allows pressure to equilibrate at an approximately constant temperature.)

(When Switch A is pressed, the program will loop through to the ***Read Sensors*** step, then on to the ***Wait Until*** step and wait there until Switch A is pressed again.)

Until Stop Button is pressed (Ends program.)

Comment: Temperature probe re-calibration required. Pressure and temperature are read at the **Read Sensors** step.

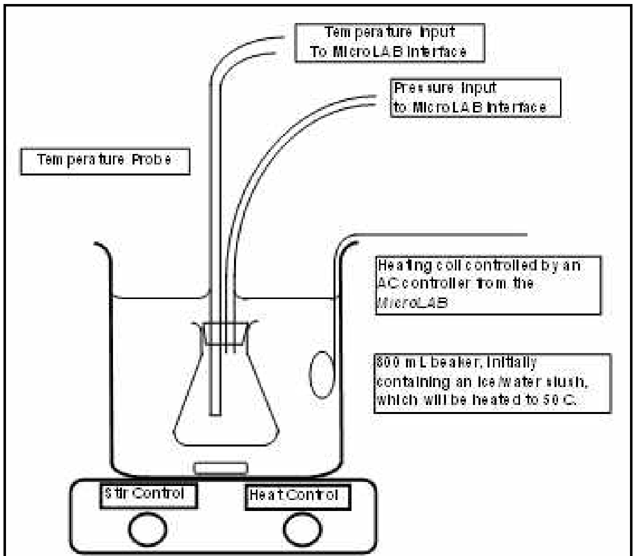


Figure 2: Sample Gay-Lussac's law apparatus setup.

GASES: Gay-Lussac's LAWS

Suggested Answers to Questions

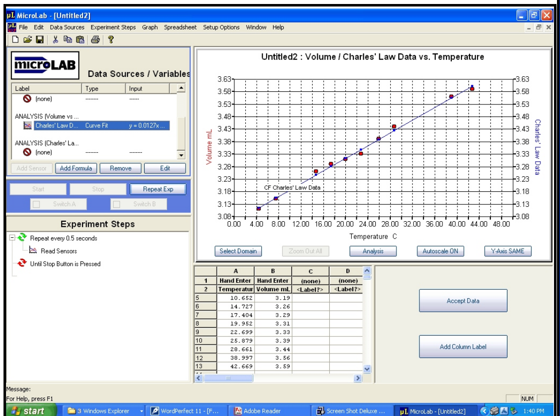
1. What type of curve does the graph of pressure versus temperature appear to produce?
   The data on the graph of pressure versus temperature appears to be linear without any transformation.
2. What type of curve should it produce, and why? (Consider the physical changes that occurred as you performed this experiment.)
   Since Gay-Lussac's law indicates that pressure and temperature are directly related, they should produce a linear relationship without any transformation.
3. In **Data Manipulation** step 4 above, you were to predict the value of the pressure at zero (0) temperature. Is your predicted value the same as the Y intercept in **Graph 4** linear fit equation? Should it be? Why?
   Ideally, the predicted value should be the same as the Y intercept value because they are both based on the same linear fit curve.
4. For the **G5** graph, what is the accepted value for this Y intercept? (Look up the value for absolute 0 in your text, (**Cite your reference !**) this is the "Kelvin" temperature discussed in the introduction.) How does your value compare with the accepted value?
   The accepted value for this relationship is -273.16 °C. (Students should cite a page in their textbook for this reference.) If they have done their work very carefully, they should get close to this value. Experimental results could vary from -250 to -300 or wider.
5. Can you explain any differences? (**HINT**: Think about the precision of the measurements being made, and how they affect the outcome.)
   It is very difficult to insure that the temperature inside of the flask is in equilibrium throughout, and thus that we are really measuring the true pressure and temperature.
6. How do the "mean" value of "T(in K)/P" and the slope value from **Graph 4** compare? Should they be the same? Explain.
   The "mean" value of "T(in K)/P and the slope from graph 4 should be the same. Again, as expressed for the Boyle's Law linearized graph, the linear fit is the best estimate of the "true" value for that parameter.

Y intercept value	Predicted intercept	K/P Mean	Std. Dev.	% error on Std. Dev.	L.R. slope	% Diff. (K/P vs Slope
		60-80	up to 2 or 3	up to 5 %	60 to 80	

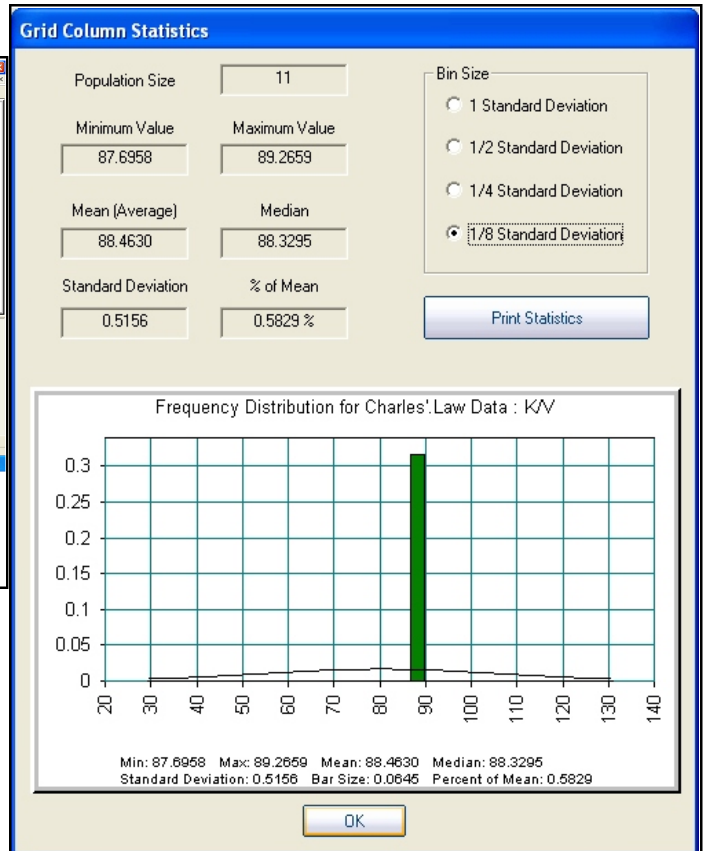
GASES: Gay-Lussac's LAWS
Sample Data

No ***MicroLAB*** data was available at the time of compilation, so data taken on a ***MicroLAB*** interface from several years ago for Charles' Law was hand entered into **MicroLAB**. The data should appear the same, but will have different values.

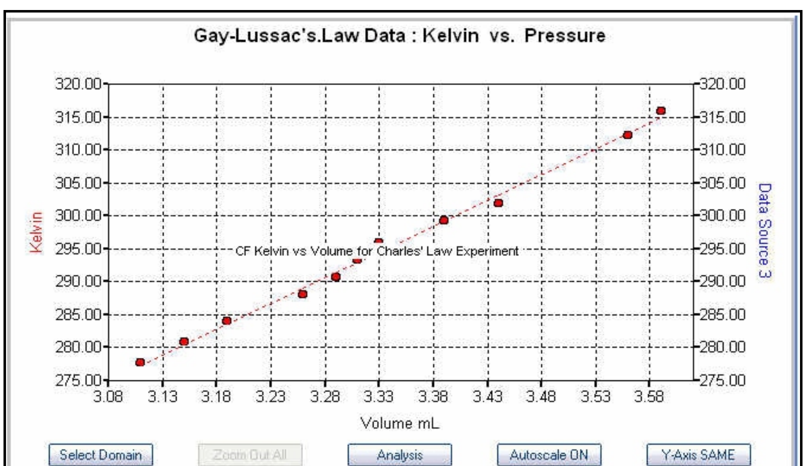
Gay-Lussac's Law data, heating



Main Screen for hand entered data for Gay-Lussac's Law experiment. Data used in this graph was volume temperature, but is analogous to the pressure temperature data, which was not available at the time.



Kelvin /pressure statistics for the Gay-LussacsLaw experiment showing mean of 88.5.



Kelvin temperature vs pressure graph with Y intercep of 34.1 K. Actual value should be 0, but it has been extrapolated over 280 degrees from a range of about 35 degrees. Again, actual data is volume/temperature instead of pressure / temperature.

GASES: Gay-Lussac's LAW

Laboratory Preparation (per student station)

Gay-Lussac's Law

- A ***MicroLAB*** interface and temperature probe
- Wide mouth 50 ml Erlenmeyer flask assembled as per instructions under **Tips and Traps.**
- AC controller system capable of being turned on by a 2.0 signal from the ***MicroLAB*** interface.
- **OR** an external temperature controlled water bath that can be reset 5 °C periodically.
- AC coffee cup heating coil.
- stirring hot plate with stirring bar
- ice