

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

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### LEARNING OBJECTIVES

The objectives of this experiment are

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

### INTRODUCTION

Around 1801-1802, a French scientist and balloonist named Joseph Louis Gay-Lussac began studying the effect of increasing temperature on gases. He observed that the rate of expansion of gases with increasing temperature was constant and was the same for all gases as long as the pressure was constant and water was absent.

In 1848, Lord Kelvin, a British physicist, noted that when studying gases at different initial but constant pressures, extending the temperature-volume lines back to zero volume always produced a common intercept. We will explore these two relationships next.

#### Qualitative:

1. Your instructor will use a special apparatus to demonstrate the qualitative relationship between pressure and temperature. This consists of a hollow steel sphere with a handle and an outlet to which is attached a semi-rigid plastic tube which is attached to a pressure gauge mounted on a plastic plate that can be placed on an overhead projector.
2. The pressure will initially be set to atmospheric and the steel sphere will then be immersed in ice water. **What do you think will happen to the pressure when the cylinder is immersed in ice water? Record your response in your lab notes.** Observe carefully what happens to the pressure indicator of the gauge and compare this to your response to the above question. Also record this in your lab notes.
3. The steel ball will next be immersed in a beaker of hot water. **What do you think will happen to the pressure when the cylinder is immersed in hot water? Record your response on your lab notes.** Again observe carefully what happens to the pressure indicator of the gauge, compare this to your response to the above question and also record this in your lab notes.

**CAUTION:** If your instructor is allowing you to perform the immersion of the steel sphere in the hot water,

be extremely careful here not to burn yourself in the hot water.

### Quantitative:

#### EQUIPMENT SET-UP:

1. **Calibrate the IC Temperature probe** at a minimum of three temperatures between 0 °C and about 60 °C. Be sure the ice bath and hot water baths are **well stirred** to insure an even temperature and the temperature probe and thermometer are side by side and **NOT** touching the bottom of the beaker. **DO NOT** bring the temperature probe and thermometer out of the water baths to make the readings, and keep the thermometer bulb and temperature probe tip submerged in the water baths while making the readings. The temperature probe should now be calibrated to read in °C.
2. **Calibrate the pressure sensor:** You will need to recalibrate the pressure sensor for this part of the experiment in order to increase the sensitivity of the system. Since we are only looking at a small pressure change in the system as the temperature increases, in this calibration you will only change the volume by ± 5 ml with the syringe as follows:

$$P_{25} = \frac{BP(V_1+1)}{(V_2+1)} = \qquad P_{35} = \frac{BP(V_1+1)}{(V_2+1)} =$$

Where BP equals barometric pressure (in mm Hg), V1 equals the original volume of the plunger (30 ml), V2 equals the final volume of the plunger, and 1 equals the volume of the connecting system of the syringe to the pressure sensor. These pressures will be entered into the calibration procedure as you calibrate the pressure sensor.

3. **Assemble the apparatus** as follows:

- a. Fill an 800 ml beaker to about half an inch from the top, add a stirring bar, place on the hot plate, stir vigorously, but **don't splash** and make a 50/50 mixture of ice and water.
- b. Obtain a wide mouth 50 ml Erlenmeyer flask and a two hole rubber stopper which fits the flask very tightly containing a short piece of 4 mm glass tubing in one hole and the temperature probe in the other hole. The glass tubing should have a 12 inch length of 1/8 inch Tygon tubing to connect to the pressure sensor.
- c. Tightly insert the rubber stopper into the flask. Suspend the flask and your temperature probe into the beaker so that the flask is **completely immersed** in the hot water to a depth of at least 2 cm, **but also** so that the bottom of the flask does not interfere with the stir bar spinning. Support the flask by hanging the Tygon tubing over the utility clamp supporting the temperature probe. See Figure 1.

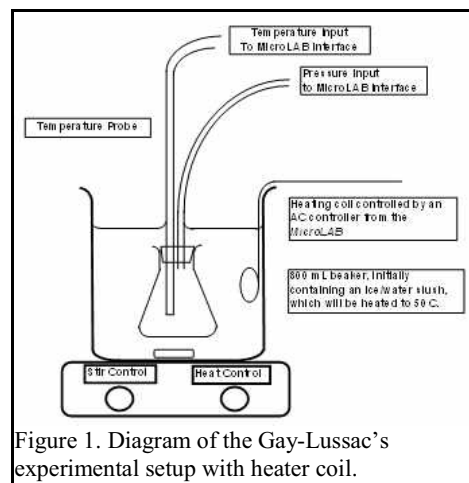


Figure 1. Diagram of the Gay-Lussac's experimental setup with heater coil.

- d. Insert the Temperature probe connector into the proper CAT-5 jack.
- e. Ensure that the screw clamp on one arm of the Y connector is open, then attach the Tygon tubing with the Luer connector to the pressure sensor input, and then attach the Tygon tubing from the flask to other leg of the Y connector. **Now tighten** the screw clamp on the Y tube.

(**Note:** This experiment used the programming ability of the *MicroLAB* to control the water bath in the beaker in 5 °C increments starting in an ice/water slush up to about 50 °C by using an AC Controller to turn the heater in the water bath on and off. Your instructor will provide the program for you or an alternative way of performing the experiment.)

### Collect the data:

1. As soon as the equipment is set up, start the data collection so you can monitor the temperature and pressure for equilibration. When the pressure levels out with the temperature remaining approximately constant, it is time to begin the next step.
2. Remove most of the ice from the beaker and **start the program**. Make sure your program is monitoring time and reading temperature and pressure. The heater should turn on as soon as you click **Start**, the pressure and temperature will be recorded, and the temperature should begin to rise.
3. The temperature should rise to 5 °C and the heater should then turn off, waiting for the pressure to equilibrate. If the temperature begins to rise above 5 °C, add one or two pieces of ice to help maintain it at that temperature. Continue to do this until the pressure levels out and the heater turns on to raise the temperature to 10 °C.
4. Continue step 3 until the temperature of the water bath reaches room temperature, then it will not be necessary to add ice any longer.
5. Continue the heating and equilibration process until the water has reached a temperature of 60 °C.
6. Repeat this experiment a total of three times and compare the results with each other. Be sure to monitor the water level so that it does not rise above the top of the beaker.

### YOUR WRITTEN REPORT

Although this lab is to give you experience in empirically determining the relationships between pressure and temperature, it also is an exercise in communication. Be sure you review the supplemental material provided by your lab instructor entitled "Making Oral Presentations" and "Organizing the Research and its Report." Each student is to **type or word process your own** separate, brief report in the following format:

PROPER COVER PAGE

OVERALL PURPOSE: A brief statement describing the overall purpose of the experiment.

PRESSURE - TEMPERATURE RELATIONSHIP:

QUALITATIVE: Briefly describe your preliminary observations with the qualitative experiments.

QUANTITATIVE: In brief outline form describe what was done for each section of the experiment. Try to achieve clarity of communication of what was done with conciseness. Don't just reiterate the details of the experimental handout. Assume the reader has the same scientific background as you do, but does not necessarily know anything about the experiment you are reporting. However, the reader does not need to know ALL the details, just those necessary to understand what was done.

RESULTS AND CONCLUSIONS: Summarize and tabulate the results you obtained for each section of the experiment, e.g., T1 for pressure vs. temperature, and discuss how these results compare with the introductory discussion and the information contained in your text. (Your Sample Report Sheet is an example of such tabulations.) Reference should here be made in your discussion to your *MicroLab* data tables and graphs by table and graph number. Include in your tabulation the means and standard deviations for the values obtained, where appropriate. The conclusion should logically follow from the structure and organization of your results. Most students do not adequately tie the data together to show how they arrived at the conclusion. Be sure to explain any differences or unexpected deviations. Try to explain the source of any errors. It is not sufficient to just say a result was bad due to "experimental error." You should try to identify specifically "what error" caused the bad data. Was it an error in following directions, an error taking a reading, an error caused by faulty equipment, poor calibration, etc.? Be specific, and justify!

OVERALL CONCLUSION: Briefly describe how this experiment has brought a deeper understanding of the gas laws, and how it relates to the ideal gas law.

ANSWERS TO QUESTIONS: Each question or response should be "keyed" to the original question by its identifier in the Data Treatment section, e.g., R1, R2, etc. Enough of the question should be repeated that the reader understands what question was asked, then a good, concise but complete answer should be given for each of the questions posed in the Data Treatment section. There are 16 questions (responses) to be answered and discussed.

*MicroLab* DATA TABLES AND GRAPHS: These should be properly identified in the title, beginning with T1, or G1, etc., followed by an appropriately descriptive title, including your initials, then ordered according to their discussion in the RESULTS AND CONCLUSIONS discussion. There should be 3 graphs (1 for each run) and 3 *MicroLab* tables (T1 - T3 for the three runs) in your report. It should be remembered that the independent variable should be plotted on the X axis, and the dependent on the Y axis.

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. **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)