

# PRESSURE-TEMPERATURE RELATIONSHIP IN GASES

## LAB PS 2.CALC

From *Chemistry with Calculators*, Vernier Software & Technology, 2000.

## INTRODUCTION

Gases are made up of molecules that are in constant motion and exert pressure when they collide with the walls of their container. The velocity and the number of collisions of these molecules are affected when the temperature of the gas increases or decreases. In this experiment, you will study the relationship between the temperature of a gas sample and the pressure it exerts. Using the apparatus shown in Figure 1, you will place an Erlenmeyer flask containing an air sample in water baths of varying temperature. Pressure will be monitored with a Pressure Sensor and temperature will be monitored using a Temperature Probe. The volume of the gas sample and the number of molecules it contains will be kept constant. Pressure and temperature data pairs will be collected during the experiment and then analyzed. From the data and graph, you will determine what kind of mathematical relationship exists between the pressure and absolute temperature of a confined gas. You may also do the extension exercise and use your data to find a value for absolute zero on the Celsius temperature scale.

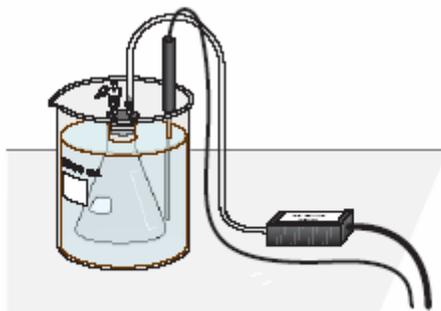


Figure 1

## PURPOSE

The purpose of this experiment is to determine the relationship between pressure and temperature for a gas, keeping the volume of the gas and the number of gas molecules constant.

## EQUIPMENT/MATERIALS

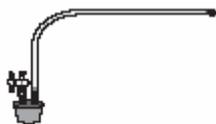
LabPro interface	plastic tubing with two connectors
TI Graphing Calculator	125-mL Erlenmeyer flask
Vernier Gas Pressure Sensor	rubber stopper assembly
Vernier Temperature Probe	ring stand and utility clamp
ice	4, 1-liter beakers
hot plate	glove or cloth

## SAFETY

- Always wear an apron and goggles in the lab.
- Use caution handling the hot plate and boiling-water bath.

## PROCEDURE

1. Prepare a boiling-water bath. Put about 800 mL of hot tap water into a 1-L beaker and place it on a hot plate. Turn the hot plate to a high setting.
2. Prepare an ice-water bath. Put about 700 mL of cold tap water into a second 1-L beaker and add ice.
3. Put about 800 mL of room-temperature water into a third 1-L beaker.
4. Put about 800 mL of hot tap water into a fourth 1-L beaker.
5. Prepare the Temperature Probe and Pressure Sensor for data collection.
  - a. Plug the Temperature Probe into **CH 1** of the LabPro interface.
  - b. Plug the Pressure Sensor into **CH 2** of the interface.



*Figure 2*

- c. Obtain a rubber-stopper assembly with a piece of heavy-wall plastic tubing connected to one of its two valves. Attach the connector at the free end of the plastic tubing to the open stem of the Pressure Sensor with a clockwise turn. Leave its two-way valve on the rubber stopper open (lined up with the valve stem as shown in Figure 2) until Step 5e.
- d. Insert the rubber-stopper assembly into a 125-mL Erlenmeyer flask. Important: Twist the stopper into the neck of the flask to ensure a tight fit.

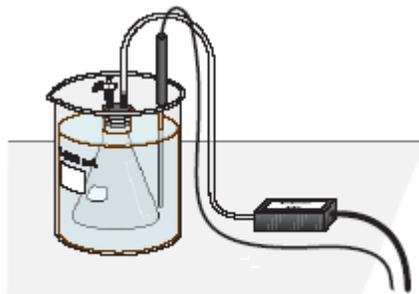


Figure 3

- e. Close the 2-way valve above the rubber stopper—do this by turning the valve handle so it is perpendicular with the valve stem itself (as shown in Figure 3). **The air sample to be studied is now confined in the flask.**
  
6. Turn on the calculator and start the DATAMATE program. Press  to reset the program.
7. Set up the calculator and interface for a Temperature Probe in CH 1 and a Pressure Sensor in CH2.
  - a. Select SETUP from the main screen.
  - b. If the calculator displays a Temperature Probe in CH 1 and a Pressure Sensor in CH2, proceed directly to Step 8. If it does not, continue with this step to set up your sensors manually.
  - c. Press  to select CH 1.
  - d. Select TEMPERATURE from the SELECT SENSOR menu.
  - e. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
  - f. Press  once, then press  to select CH2.
  - g. Select PRESSURE from the SELECT SENSOR menu.
  - h. Select the gas pressure sensor from the PRESSURE menu.
  - i. Select the calibration listing for units of **kPa**.
8. Set up the data-collection mode.
  - a. Advance the cursor to MODE using  the key, then press  to select it.
  - b. Select SELECTED EVENTS from the SELECT MODE menu.
  - c. Select OK to return to the main screen.

9. Select START to begin data collection. Temperature readings (in °C) and pressure readings (in kPa) are displayed on the calculator screen.
10. Collect pressure vs. temperature data for your gas sample.
  - a. Place the flask into beaker containing cold tap water. Make sure the entire flask is covered (see Figure 3). Stir.
  - b. Place the Temperature Probe into the water bath.
  - c. When the temperature and pressure readings displayed on the calculator screen have both stabilized, press ENTER to store the temperature-pressure data pair.
11. Place beaker on hot plate and repeat the Step 10 procedure using the warm water bath.
12. Repeat the Step 11 procedure using the hot-water bath.
13. Use a ring stand, utility clamp, and slit stopper to suspend the Temperature Probe in the boiling-water bath. **CAUTION:** *Do not burn yourself or the probe wires with the hot plate.* To keep from burning your hand, hold the tubing of the flask using a glove or a cloth. After the Temperature Probe has been in the boiling water for a few seconds, place the flask into the boiling-water bath and repeat Step 11. Press  to stop data collection. Remove the flask and the Temperature Probe.
14. Press    to choose **CH2 VS. CH1**.
15. Examine the data points along the displayed graph of pressure vs. temperature (°C). As you move the cursor right or left, the temperature (X) and pressure (Y) values of each data point are displayed below the graph. Record the data pairs in your data table. Round pressure to the nearest 0.1 kPa and temperature to the nearest 0.1°C.
16. Examine your graph of pressure vs. temperature (°C). In order to determine if the relationship between pressure and temperature is direct or inverse, you must use an absolute temperature scale; that is, a temperature scale whose 0° point corresponds to absolute zero. We will use the Kelvin absolute temperature scale. You can manually add 273° to each of the Celsius temperatures to obtain Kelvin values, or if you want the calculator to draw the graph, create a new list for Kelvin temperature, L1 as below:
  - a. Press , then return to the main screen.
  - b. Select QUIT to quit the DATAMATE program.
  - c. Press  to clear the screen.
  - d. Create a list of Kelvin temperature values in L3. Note: The temperature (°C) is currently stored in L2.

1) To view the data lists, press

 displays the EDIT menu

- 1 displays the list editor
- 2) Use the arrow keys to move the cursor until the **L3** heading is highlighted.
- 3) Create a list of Kelvin temperature values in **L3** by pressing

```
2nd
L 2
+
273
ENTER
```

- 4) L1 is pressure (kPa), L2 is temperature (°C), and L3 is temperature (K). Record the Kelvin temperature values in your data table.

17. You will use the TI-83 to graph pressure vs. absolute temperature.

### 18. Making a Graph.

- a. **Selecting a Stat Plot.** Use the following keystrokes to select Plot1.

```
2nd
STAT PLOT   Displays the Stat Plot editor
1           Selects Plot1
```

- b. **Selecting the options for Plot1.** The options for Plot1 are displayed on the calculator screen. You want your calculator screen to look just like the one shown in step c. To select an option, use the arrow keys to move the cursor to it and press ENTER to select it.

Use the following keystrokes to select L3 (absolute temperature) for Xlist:

```
2nd
L3   Selects L3
```

Use the following keystrokes to select L1 (pressure) for Ylist:

```
2nd
L1   Selects L1
```

- c. Your calculator screen should now look just like the **one shown below**.



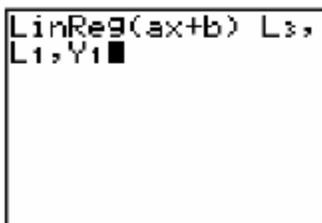
19. **Viewing your graph.** Press GRAPH to view your graph. If you do not see a graph on the calculator screen, press ZOOM then 9. You should now see your graph.

20. If there is a correlation between gas pressure and absolute temperature, you should be able to draw a straight line through the points in your graph. This straight line is called a *line of fit*. The line of fit may not pass through any or all of the points in your line graph, but it will show the overall trend of the data that is graphed.

- a. **Drawing a line of fit.** Use the following keystrokes to draw a *line of fit* through your data points:

2nd	
QUIT	
CLEAR	Returns the calculator to the home screen and clears it
STAT	
>	Displays the CALC menu
4	Displays LinReg(ax+b) on the home screen
2nd	
L3	Selects L3 as the X data
,	
2nd	
L1	Selects L1 as the Y data
,	
VARS	
>	Displays the Y-Vars menu
1	Selects 1:Function
1	Stores the line of fit in Y1

- b. Your calculator screen should now look like the one shown below.



- c. If your calculator screen looks like the one shown above press **ENTER**.  
Otherwise press **CLEAR** and repeat step a.
21. To display the linear-regression curve on the graph of pressure *vs.* temperature (K), press **GRAPH**.
  22. Press **Y=** to view the equation for the line of fit . Write the equation that is stored in **Y1** on your Data Sheet.
  23. (optional) Print a graph pressure *vs.* Kelvin temperature (with a regression line displayed).

## **EXTENSION**

The data that you have collected can also be used to determine the value for absolute zero on the Celsius temperature scale. Since absolute zero is the temperature at which the pressure theoretically becomes equal to zero, the temperature where the regression line (the extension of the temperature-pressure curve) intercepts the x-axis should be the Celsius temperature value for absolute zero. You can use the data you collected in this experiment to determine a value for absolute zero.

1. **Making a Graph.** You will use the TI-83 to graph pressure vs. temperature ( $^{\circ}\text{C}$ ).

a. First clear the equation stored in Y1 by pressing

Y1  
CLEAR

b. **Selecting a Stat Plot.**

2nd  
STAT PLOT            Displays the Stat Plot editor  
1                        Selects Plot1

c. **Selecting the options for Plot1.** The options for Plot1 are displayed on the calculator screen. You want your calculator screen to look just like the one shown in step c. To select an option, use the arrow keys to move the cursor to it and press ENTER to select it.

Use the following keystrokes to select L2 (temperature,  $^{\circ}\text{C}$ ) for Xlist:

2nd  
L3 Selects L2

d. Your calculator screen should now look just like the shown below.



2. **Viewing your graph.** Press **WINDOW** to view the settings for viewing your graph on the calculator screen. You want your calculator screen to look just like the one shown on the next page. To change a setting, use the arrow keys to move the cursor to it and enter the new setting. **Note:** Use (-) for negative numbers.

```
WINDOW
Xmin=-300
Xmax=100
Xscl=1
Ymin=-5
Ymax=140
Yscl=1
Xres=1
```

3. Press **GRAPH** to view your graph. Your data points should appear in the upper right corner of the calculator screen.
4. **Drawing a line of fit.** Use the following keystrokes to draw a *line of fit* through your data points:

2nd	
QUIT	
CLEAR	Returns the calculator to the home screen and clears it
STAT	
>	Displays the CALC menu
4	Displays LinReg(ax+b) on the home screen
2nd	
L2	Selects L2 as the X data
,	
2nd	
L1	Selects L1 as the Y data
,	
VARS	
>	Displays the Y-Vars menu
1	Selects 1:Function
1	Stores the line of fit in Y1

Your calculator screen should now look like the one shown below.

```
LinReg(ax+b) L2,
L1,Y1
```

5. If your calculator screen looks like the one shown above, press **ENTER**. Otherwise press **CLEAR** and repeat step 4.
6. To display the linear-regression curve on the graph of pressure vs. temperature, press **GRAPH**.
7. **Graphical determination of absolute zero.** Press TRACE then to trace along the line of fit. Use < to move cursor until Y value displayed at the bottom of the graph is 0 or as close to 0 as possible. The corresponding X value is your experimental value or absolute zero. Record this value in the **EXTENSION** section on your data sheet.
8. (optional) Print a graph pressure vs. temperature ( $^{\circ}\text{C}$ ) with the regression line displayed.

**DATA SHEET**

Name \_\_\_\_\_  
Name \_\_\_\_\_  
Period \_\_\_\_\_ Class \_\_\_\_\_  
Date \_\_\_\_\_

**PRESSURE-TEMPERATURE RELATIONSHIP IN GASES**

**DATA TABLE**

Pressure (kPa)	Temperature (°C)	Temperature (K)	Constant, k (P / T or P•T)

**GRAPH OF PRESSURE VS. ABSOLUTE TEMPERATURE**

$Y_1 = \text{___} X + \text{___}$  **Equation for line of fit**

The equation for the line of fit is in *slope-intercept form*

$y = mx + b$  where  $m$  is the slope and  $b$  is the y-intercept.

What is the slope? \_\_\_\_\_

What is the y-intercept? \_\_\_\_\_

**PROCESSING THE DATA**

1. In order to perform this experiment, what two experimental factors were kept constant?
  
2. Based on the data and graph that you obtained for this experiment, express in words the relationship between gas pressure and temperature.

3. Explain this relationship using the concepts of molecular velocity and collisions of molecules.
  
  
  
  
  
  
  
  
  
  
4. Write an equation to express the relationship between pressure and temperature (K). Use the symbols P, T, and k.
  
  
  
  
  
  
  
  
  
  
5. 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 direct,  $k = P/T$ . If it is inverse,  $k = P \cdot T$ . Based on your answer to Question 4, choose one of these formulas and calculate k for the four ordered pairs in your data table (divide or multiply the P and T values). Show the answer in the fourth column of the Data and Calculations table.
  - a. How “constant” were your values?
  
  
  
  
  
  
  
  
  
  
  - b. Overall, how do your values compare to the slope of your line of fit?
  
  
  
  
  
  
  
  
  
  
6. According to this experiment, what should happen to the pressure of a gas if the Kelvin temperature is doubled? Check this assumption by finding the pressure at  $-73^{\circ}\text{C}$  (200 K) and at  $127^{\circ}\text{C}$  (400 K) on your graph of pressure versus temperature. How do these two pressure values compare?

**EXTENSION**

7. Experimental value for absolute zero \_\_\_\_\_ .
8. The actual or *theoretical value* of absolute zero is  $-273.15^{\circ}\text{C}$ . Calculate the percent error in your experimental value of absolute zero. The formula for calculating percent error is

$$\% \text{ error} = \frac{|\text{theoretical value} - \text{experimental value}|}{\text{theoretical value}} \times 100$$

9. What do you think are the sources of error in this experiment?