Exploring the Properties of Gases 30

The purpose of this investigation is to conduct a series of experiments, each of which illustrates a different gas law. You will be given a list of equipment and materials and some general guidelines to help you get started with each experiment. Three properties of gases will be investigated: pressure, volume, and temperature. By assembling the equipment, conducting the appropriate tests, and analyzing your data and observations, you will be able to describe the gas laws, both qualitatively and mathematically.

OBJECTIVES

In this experiment, you will

- Conduct a set of experiments, each of which illustrates a gas law.
- Gather data to identify the gas law described by each activity.
- Complete the calculations necessary to evaluate the gas law in each activity.
- From your results, derive a single mathematical relationship that relates pressure, volume, and temperature.

MATERIALS

Vernier computer interface
computer
Vernier Gas Pressure Sensor
Temperature Probe
20 mL gas syringe
plastic tubing with two Luer-lock connectors
rubber stopper assembly with two-way valve

large-volume container for water bath (at least 10 cm in diameter and 25 cm high)
125 mL Erlenmeyer flask
hot-water supply (up to 50°C) or hot plate
ice
100 mL graduated cylinder

PRE-LAB EXERCISE

Review each of the three parts of this experiment before starting your work. You will need to decide the best way to conduct the testing, so it is wise to make some plans before you begin. You may wish to conduct a test run without collecting data, in order to observe how the experiment will proceed.

In each part of the experiment, you will investigate the relationship between two of the three possible variables, the other being constant. In this pre-lab exercise, sketch a graph that describes your hypothesis as to the mathematical relationship between the two variables; e.g., direct relationship or inverse relationship.

Part I   Pressure, P, and volume, V (temperature and number of molecules constant).
Part II   Pressure, P, and absolute temperature, T (volume and number of molecules constant).
Part III Volume, V, and absolute temperature, T (pressure and number of molecules constant).

PROCEDURE

Part I Pressure and Volume

1. Obtain and wear goggles.

2. 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. Attach the syringe to the valve of the Gas Pressure Sensor, as shown in Figure 1. 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 in Figure 1.
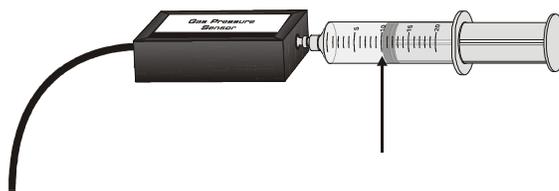
Figure 1

3. Connect the Gas Pressure Sensor to Channel 1 of the Vernier computer interface. Connect the interface to the computer using the proper cable.

4. Double click on the Logger *Pro* program on the desktop of your computer. Click on the open file icon or go to File menu and click on open. Double click *Advanced Chemistry with Vernier* folder. Double click on "30a Gases". This file allows you to collect pressure data from the Gas Pressure Sensor, using Events with Entry mode. Be sure the box in the lower left of the screen is reporting a pressure value above 0 in red. If it is not, call your instructor over to help you make sure the interface probe is connected properly. When you are ready to collect data, click on the green "collect" button on the right side of the Toolbar at the top. The button will change to a red "stop". **<u>DO NOT</u>** click on stop until you have finished collecting data. Click on ⊛ Keep . You will now have a dialog box open asking you to enter the volume. Enter the current volume of gas in the syringe and click OK. When you change volumes in step 5 below, click on ⊛ Keep button each time and enter the volume reading from the syringe each time.

5. Measure the pressure of the air in the syringe at various volumes. When you are finished click on the red Stop button. Print a copy of the graph and data for each member of your team. The best results are achieved by collecting at least six data points.

Part II Pressure and Absolute Temperature

In this experiment, you will study the relationship between the absolute temperature of a gas sample and the pressure it exerts. Using the apparatus shown in Figure 2, you will place an Erlenmeyer flask containing an air sample in a water bath and you will vary the temperature of the water bath.

6. Connect the Gas Pressure Sensor to Channel 1 and a Temperature Probe to Channel 2 of the interface.

7. Assemble the apparatus shown in Figure 2. Be sure all fittings are airtight. Make sure the rubber stopper and flask neck are dry, then twist and push hard on the rubber stopper to ensure a tight fit.

8. Click on the open file icon or go to File menu and click on open. Open the file "30b Gases". **DO NOT** save changes to 30a. This file is set up to collect pressure and temperature data from the attached sensors, using Selected Events mode. When you are ready to collect data, click on the green Collect button and then the ⊛ Keep button. A pressure and temperature value will be automatically reported in the data table and a point plotted on the graph. **DO NOT** click the red stop button until you are finished collecting all the data.
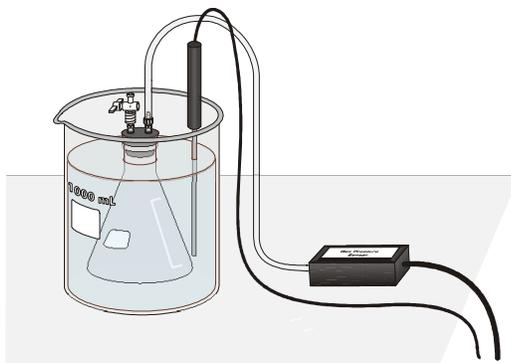
Figure 2

9. Collect pressure data at several different temperatures. Set up water baths in the large-volume container, as you need to. When you are finished click on the red stop button. Print a copy of the graph and data for each member of the team.

Part III Volume and Absolute Temperature

In this experiment, you will study the relationship between the volume of a gas sample and its absolute temperature. Using the apparatus shown in Figure 3, you will place an Erlenmeyer flask containing an air sample in a water bath and you will vary the temperature of the water bath. Keep some of these factors in mind as you plan your procedure.

*   If you are starting with a cold-water bath, set the piston at the 0 mL mark on the syringe. This will allow the gas volume to be increased in warmer water baths.
*   The temperature of the water bath cannot be increased by more than 30-40 degrees from your starting temperature.
*   Even though you are not plotting pressure, it is important to monitor pressure in the Meter to ensure that it remains constant.
*   It is important to know the *total* volume of air in the flask *and* the syringe. The volume of the flask, up to the bottom of rubber stopper, can be accurately measured using a graduated cylinder. For the estimated volume of the tubing (from the rubber stopper to the Gas Pressure Sensor box), as well as in the valve below the bottom of the syringe, use a value of ~4 mL.

10. Ensure that the Gas Pressure Sensor is plugged into to Channel 1 and the Temperature Probe is plugged into Channel 2 of the interface.

11. Assemble the apparatus shown in Figure 3. Be sure all fittings are air-tight. Make sure the rubber stopper and flask neck are dry, then twist and push hard on the rubber stopper to ensure a tight fit. Be sure the water level is at least as high as the confined air in the syringe.
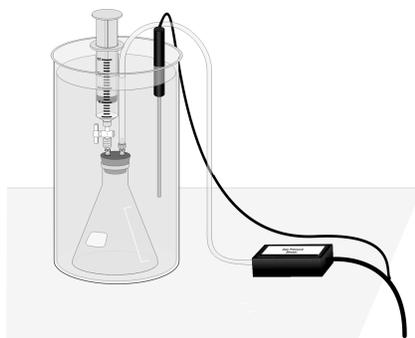
Figure 3

12. Open the file "30c Gases" from the *Advanced Chemistry with Vernier* folder. **DO NOT** save any changes to 30b. This file is set up to collect pressure and temperature data from the attached sensors, using Events with Entry mode. This mode allows you to collect a data pair simultaneously from the Gas Pressure Sensor and Temperature Probe after clicking on the green collect button and then by clicking on the [🔄 Keep] button and entering a value for the volume. **DO** NOT click on the red stop button until all data has been collected. Even though the pressure reading will not be plotted on the graph of volume *vs.* temperature, it is important for pressure to be monitored so that it can be kept constant.

13. Collect volume data at several different temperatures. Set up water baths in the large-volume container as you need them, ranging from ice water to hot water. When you are finished collecting data, click on the red stop button. Print a copy of the graph and data for each member of the team.

14. When you have finished collecting data and have all your graphs, close the Logger Pro program **WITHOUT** saving changes. Then shut down your computer.

DATA ANALYSIS

1. For each of the three parts of the experiment, write an equation using the two variables and a proportionality constant, k (e.g., for Part I, $P = k \times V$ if direct, or $P = k/V$ if inverse).

2. Calculate the constant, k, for each of the three gas laws that you tested. This value can be an average for each of the data pairs in each part of the experiment.

PRESTUDY

Gases: Charles' Law

Name _____ Section _____

1)(2 points) Convert the following temperatures and express the answers to the proper number of significant figures:

    a) 253.0°C to K

    b)23 K to °C

2) (8 points)

Air Column Length (cm)	Temperature (°C)
9.31	100.0
8.74	79.9
8.40	61.0
7.70	39.5
7.45	20.9
6.75	0.1
4.79	-78.5

    Plot air column length vs temperature (°C) and attach the graph to this sheet. Start your axes at 0.00 cm. and -300 °C. Draw the best straight line and extrapolate to 0.00 cm.

Determine the slope (m) of the line. _____

Determine the y-intercept (b) of the line. _____

Absolute 0, (0 K) is equal to *-b / m* . Determine the value of absolute 0 from your graph.