Gas Laws in a Jiffy

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HANDS-ON ACTIVITIES

Exploring the Properties of Gases

- Go Direct Temperature
- Go Direct Pressure

Exploring the Properties of Gases

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. Four properties of gases will be investigated: pressure, volume, temperature, and number of molecules. 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

- 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.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Gas Pressure
Go Direct Temperature
Stir Station
Electrode Support
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 four 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 four possible variables, the other two 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).
Part IV Pressure, P, and number of molecules, n (volume and absolute temperature 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.

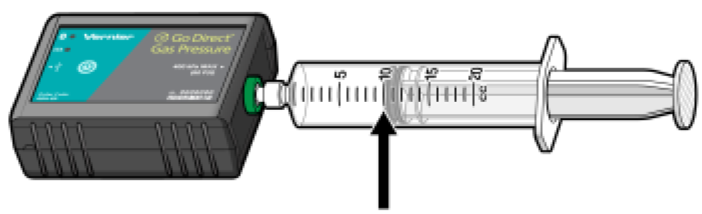

Figure 1

3. Launch Graphical Analysis. Connect the Gas Pressure Sensor to your Chromebook, computer, or mobile device.

4. Set up the data-collection mode.

    a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.

    b. Enter **Volume** as the Event Name and **mL** as the Units. Click or tap Done.

5. The mode you set up in Step 4 allows you to collect pressure data from the Gas Pressure Sensor with different volumes of confined gas in the syringe.

    a. Click or tap Collect to start data collection.

    b. Position the syringe. When the pressure reading has stabilized, click or tap Keep and enter the volume in mL. Click or tap Keep Point to store the data pair. The best results are achieved by collecting at least six data points.

    c. Click or tap Stop to stop data collection when you have finished collecting data and view a graph of pressure *vs*. volume. Export, download, or print a copy of the data and a graph of pressure *vs*. volume.

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 and Temperature Probe to your Chromebook, computer, or mobile device. Click or tap File, 🗋, and choose New Experiment. Click or tap Sensor Data Collection.

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.

Figure 2

8. Set up water baths in large-volume containers as you need them, ranging from ice water to hot water.

9. Change the graph settings to display a graph of pressure *vs*. temperature.

   a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   b. Change Event Mode to Selected Events. Click or tap Done.
   c. Click or tap the Temperature meter and change units to K (Kelvin temperature). Dismiss the meter box.
   d. Tap the x-axis label and choose Temperature (K).

10. Click or tap Collect to start data collection. In Selected Events mode, you will click or tap Keep to collect the pressure and temperature data.

11. Collect pressure data at several different temperatures by switching out the water baths that you prepared in Step 8 and, when you have completed data collection, click or tap Stop to stop data collection

12. Print a copy of the data and a graph of pressure *vs*. absolute temperature.

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 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.

13. Click or tap File, 🗋, and choose New Experiment. Click or tap Sensor Data Collection.

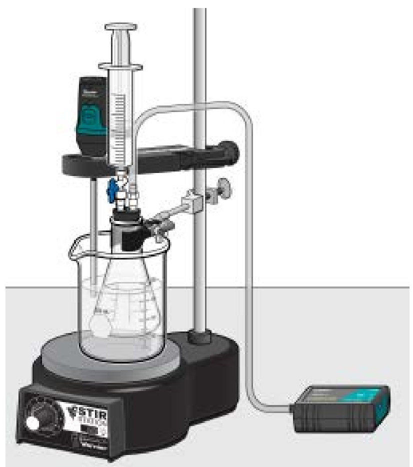

Figure 3

14. 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.

15. Change the graph settings to display a graph of pressure *vs*. temperature.

    a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
    b. Change Event Mode to Selected Events. Enter **Volume** as the Event Name and leave the Units field blank. Click or tap Done.
    c. Click or tap the Temperature meter and change unites to K (Kelvin temperature). Dismiss the meter box.
    d. To display a graph of volume vs temperature, click or tap the x-axis label and choose Temperature (K). Click or tap the y-axis label and choose Volume.

16. Set up water baths in the large-volume container as you need them, ranging from ice water to hot water.

17. Click or tap Collect to start data collection.

18. Collect volume data at several different temperatures and when you have completed data collection, click or tap Stop to stop data collection.

19. Export, download, or print a copy of the data and a graph of pressure *vs*. absolute temperature.

Part IV Pressure and Number of Molecules

In this experiment, you will study the relationship between the number of molecules in a gas sample and the pressure it exerts.

- You can use the same setup as in the previous trial, although the water bath and Temperature Probe are optional. (Temperature must be constant, so choose a convenient temperature to run the experiment.)
- You might be wondering how you are going to count molecules for this section. Here is a hint. Avogadro's hypothesis states that, "Equal volumes of gases, at the same temperature and pressure, contain equal numbers of molecules." Therefore, *if* you keep the temperature and volume constant during the experiment, you can assume that gas volumes are proportional to numbers of molecules. Instead of entering a total number of molecules, you could enter a total *volume* of gas that has been compressed into the flask. For example, 120 mL worth of molecules could be entered as 120 molecules, 140 mL worth of molecules would be entered as 140 molecules.

20. Click or tap File, 🗋, and choose New Experiment. Click or tap Sensor Data Collection.

21. Set up the data collection in Event Based mode, as you did in Step 4, this time enter **Molecules** as the Event Name and leave the Units field blank. Click or tap Done. This mode allows you to collect data from the Gas Pressure Sensor by clicking or tapping Keep and entering a value for the number of molecules.

22. Collect pressure data with several different numbers of molecules introduced into the system. Export, download, or print a copy of the data and a graph of pressure *vs*. number of molecules.

DATA ANALYSIS

1. For each of the four 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 four gas laws that you tested. This value can be an average for each of the data pairs in each part of the experiment.

3. Explain how the results of your experiment can be used to describe the Ideal Gas Law.