#19350 BOYLE'S LAW APPARATUS, HANGING

Purpose:

To experimentally verify Boyle's and Charles' Laws for gases.

Required Accessories:

One	(1)	Ring stand
Two	(2)	Burette clamps
One	(1)	Beaker (250 ml)
One	(1)	Thermometer
One	(1)	Set of hook weights (100, 200, 300, 1000g)
		Ice

Assembly:

1) Pull the piston all the way out. <u>Lubricate the entire side wall of the rubber plunger with silicone grease.</u> Insert the piston into the syringe.

2) Firmly press one end of tubing with pinchcock onto the tip of the syringe.

To increase the gas pressure:

1) Attach the burette clamp near the top of a ringstand..

2) Adjust the jaws of the clamp so that the flared edges of the syringe rest on the edges of the clamp jaws. Avoid exerting pressure on the walls of the syringe by tightening the clamp too much.

3) Any desired volume of air may be drawn into the syringe by opening the pinchcock and pulling the piston to the desired position on the scale. Close the pinchcock.

4) Attach weights in succession to the weight hanger. Before taking readings on the scale, bump the weights several times to insure the piston has settled properly. When recording your readings, be sure to include the weight of the piston assembly.

To decrease the gas pressure:

1) Invert the apparatus with one burette clamp loosely holding the mid-section of the syringe.

2) Mount the second burette clamp under the first clamp. Let the flared edges of the apparatus rest on the jaws of the second clamp.

3) Attach weights in succession to the weight hanger. Before taking readings on the scale, bump the weights several times to insure the piston has settled properly. When recording your readings, be sure to include the weight of the piston assembly.

You are now ready to perform experiments with Boyle's law. To change the volume of air in the syringe, open the pinchcock at the end of the syringe and push or pull on the piston. Close the pinchcock.

Boyle's Law:

Given any gas in a state of thermal equilibrum we can measure it's pressure *p*, temperature *T*, and volume *V*. Experiment shows that for a constant temperature, the volume of the gas varies with the pressure applied to the gas. Robert Boyle, an english physicist, studied this phenomena in 1662 and found that there was a specific relationship between pressure and volume and that it was the same for all types of gases. To determine what this relationship is, we will look at the compressibility of gas.

With the assembled apparatus, draw approximately 10 cc into the cylinder. Using several equal weights, hang them carefully one at a time on the metal loop of the apparatus and record the volume of the gas as indicated on the scale of the syringe. Before reading the scale on the syringe, tap the table or the side of the apparatus a couple of times to overcome the static friction between the piston and the syringe walls.

Record the weight and corresponding volume for as many values as possible. After all of the weights are hung on the apparatus, remove them one at a time and record the volumes again. Use this data as trial #2. Plot the data on graph paper plotting the number of weights (which is proportional to pressure) on the independent axis and the volume on the dependent axis.
How does the volume depend on the pressure? Is the plot linear? Try making a new plot with 1/(weight) plotted on the independent axis. Is this plot linear? It should be close to linear with the exception of the points that correspond to one or two weights. Can you explain why these points do not fit the curve? Any plot of data that is a straight line says that the two parameters that are plotted are directly proportional.

Therefore, the volume is directly proportional to 1/pressure (since pressure equals force times area and the area of the piston is constant). Mathematically this can be written:

$$V \propto 1/p$$

This is Boyle's law and was determined under conditions of constant temperature. Try repeating this experiment using different gases.

Charles' Law:

You have discovered how equal changes in pressure affect equal volumes of gases. Can you predict how equal changes in temperature affect equal volumes of gases?

Heat approximately 200 ml of water in a 250 ml beaker. A larger beaker may be easier for students to use. Remember it is necessary to have enough water in the beaker to cover the portion of the syringe that holds the trapped volume of air. Bring the water to about 90°C.

Draw 10cc of air into the syringe then close the pinchcock. Place the thermometer in the beaker of hot water. Hold the syringe by its top and push the portion of the syringe containing the trapped volume of air under the hot water. Wait a few minutes for the air in the cylinder to equilibrate, then measure the volume shown on the syringe scale. When measuring the volume of the trapped air it is helpful to quickly push the piston down into the cylinder then release it. This will help overcome the effects of friction between the piston and cylinder walls. Record the volume. Measure the volume again, but this time give the piston a sharp pull outward and release it. The measured volume in this case will be larger. Again, this is due to friction between the piston and cylinder wall. The actual volume will be the average of these two measurements.

Allow the beaker of water to cool by 10°C and make a new volume measurement. Repeat this procedure of cooling by 10°C and measuring the volume until you've covered the range from about 60 or 70°C to 0°C. From 30°C and lower
it may be necessary to add small pieces of ice to help bring the temperature down.

Plot your data points on a graph with volume as a function of temperature. Are the results of your experiment consistent with your prediction? Can you summarize the findings of your experiment in a general statement similar to the method used in Boyle's law? Remember, if the plot is linear, it represents a direct proportionality and can be written as

$$V \alpha T$$

where α means "is proportional to".

Ideal Gas Law:

The concept of "proportional to" can be made "equal to" by including a constant of proportionality that is given by the slope of a linear plot of the data. Therefore, taking a second look at Boyle's and Charles' laws we can first combine the two laws by saying the volume is both proportional to the temperature and to 1/pressure:

$$V \alpha T \bullet 1/p$$

and then replace the proportionality with equality and a constant:

$$V=T \bullet 1/p \bullet \text{constant}$$

or

$$pV=\text{constant} \bullet T$$

The constant in this equation is related to the mass of gas in the cylinder and has been determined to be the number of moles of gas (n) times the universal gas constant (R) found in most physics text books. By making this substitution, we have reconstructed the ideal gas law:

$$pV=nRT$$

Time Allocation:

To prepare this product for an experimental trial should take less than ten minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.