GAS LAWS

In 1660, Robert Boyle, an English philosopher, performed an experiment in which he showed that the volume of a trapped amount of air varied inversely with the pressure applied to it. However, the relationship between the volume of a trapped amount of air and its temperature was not noted at the same time since the accurate thermometers required to make this observation were not constructed until approximately 1750. It was some time after 1780 that the French scientist Jacques Charles made the observation that the volume and temperature of a gas are directly proportional; or “at a constant pressure, the volume of a fixed mass of gas is directly proportional to its temperature expressed in K.” In today’s lab, you will investigate both of these Gas Laws.

For the Charles’ Law Experiment, you will be given a piece of capillary tubing permanently sealed at one end and containing a moveable plug of mercury at the other end. This plug traps a fixed volume of air and moves up and down as the air expands or contracts with a change in temperature. A plot of the volume of the gas versus the various temperatures, when properly extrapolated, will yield the temperature at which the air should have zero volume.

For the Boyle’s Law Experiment, you will be using a specially designed apparatus, that will allow you to quickly and easily measure volume and gas pressure. The apparatus will be connected to the faucet aspirator, thus lowering the pressure of a trapped air sample. The aspirator will then be turned off and the pressure increased by small increments, and the new volume of the trapped air sample will be successively measured.

PROCEDURE:

<u>Part A: Charles’ Law:</u>

Obtain a capillary tube, thermometer and a ruler from your instructor. The capillary will have a small plug of mercury trapped in the upper end. Be sure to never turn the capillary upside-down since there is a possibility that the mercury may fall out. Mercury is poisonous and may be absorbed through the skin. In case an accident should happen, contact your lab instructor at once.

The capillary and the thermometer should be attached to the metric ruler by means of a rubber band or twist tie. Before making any measurements, and several times during the course of the experiment, check to see that the bottom inside of the capillary is exactly on the “zero line” of the ruler. The same capillary must be used for the entire experiment in order to get consistent results.

Make a mixture of ice and water in a 600 mL beaker. Place the capillary and ruler into the water bath so that the entire capillary up to the mercury plug is immersed. Be careful not to get water into the top of the capillary. Wait several minutes for the tube to reach the temperature of the bath. Record the height of the mercury column to the nearest 0.1 mm and the temperature of the bath to the nearest 0.1°C. Repeat this procedure over the temperature range 0°C to 100°C using water baths at about 10°C intervals. Start with the highest temperature reading then add cold tap water or ice to lower the temperature. After room temperature has been reached, ice can be added to get a lower reading. Record the temperature of the water and the height of the column of air for each determination.

The instructor will provide a bath of dry ice and acetone which will have a temperature well below 0°C. Repeat the same procedure using this bath. **<u>This must be your last reading.</u>** Be sure that the bath is thoroughly stirred and that the mercury plug has stopped moving before you record the height of the air column. Also, be very careful when using this bath because its low temperature can cause severe burns to the skin if the skin should be in contact with it for a long period of time.

At the end of these determinations return the capillary and the ruler to the laboratory instructor.

<u>Part B:</u> **<u>Boyle's Law:</u>**

Use an appropriate spreadsheet or graphing program on a computer and set up the following columns:

1. A data column for the volume reading on the pipette part of the apparatus, in mL.
2. A data column for the vacuum pressure gauge reading in inches of Hg.
3. A calculation column to calculate total volume of the trapped air sample, using the following formula: 10 - Column 1 + dead space volume (This will be provided to you by your instructor)
4. A calculation column to calculate the pressure in torr of the trapped air sample, using the following formula:

   Barometric Pressure in torr - column 2(25.4)

5. A calculation column to calculate the inverse of the volume data, using the following formula:

   1 ÷column 3

Using the special apparatus provided, open the valve to the water aspirator and evacuate the system until the water level in the pipette side of the system reads approximately 10.00 mL. Close the valve to the aspirator. Accurately read the volume of the trapped air sample in the pipette and the pressure gauge reading, in inches.

Open the needle valve to the room slowly, allowing the pressure to in crease in the system, slightly, so that the water level in the pipette rises approximately 1.00 mL. Again accurately read the volume of the trapped air sample in the pipette and the pressure gauge reading, in inches. Repeat this step until the pressure gauge reads 0. Try to get as many data points as possible. You should be able to get at least 5 data points.

Enter your data in columns 1 and 2 of your spreadsheet. Prepare graphs of Corrected Pressure vs. Corrected Volume and Corrected Pressure vs. 1 / Corrected Volume. Which is a better graph to use to illustrate Boyle's Law? Does your data support Boyle's Law? Explain. Using your graph predict what the volume would be for your sample if the pressure were increased to 1000 torr.

Lab #10

GAS LAWS

NAME ____ SECTION _______________

DATA SHEET

READING	***COLUMN HEIGHT(mm)***	***TEMPERATURE(°C)***
1	______________________	_______________________
2	______________________	_______________________
3	______________________	_______________________
4	______________________	_______________________
5	______________________	_______________________
6	______________________	_______________________
7	______________________	_______________________
8	______________________	_______________________
9	______________________	_______________________
10	______________________	_______________________
11	______________________	_______________________
12	______________________	_______________________

Plot your data on a graph, with temperature in °C as the x-axis and height in cm or mm as the y-axis. (Start your axes at -300°C and 0.0 mm). Draw the best straight line through your data points and extrapolate to the x-axis.

<u>FROM YOUR GRAPH:</u>

1. Estimate the temperature at which the volume (height) is zero. ______ °C

2. For this line, the equation is V = mt + b, where V = volume, t = temperature in °C, m = slope, and b = y-intercept.

   (a) Determine the slope (m) of your line, (including units) ___________

   (b) Determine the y-intercept (b) of your line, (including units) __________

Absolute zero, (0.0 K) in °C, can be calculated by dividing (-b/ m). Calculate your experimental value for absolute zero in °C, using this equation.

_________°C

3. **Discussion Question:**
   What advantage is there in using the absolute temperature, in K, rather than the Celsius temperature, in °C, when doing calculations involving gases?

   ____

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   ____

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   ____

4. Which graph in Part B better illustrates Boyle's Law?

5. Does your data support Boyle's Law? Explain.

6. From your graph, determine the volume of your sample of air at 1000 torr.

Lab #10

Boyle's Law Data

NAME ________________________________ **Section #** ______________

Dead Space Volume ___________________ Atmospheric Pressure ___________________

Volume (mL)	Pressure (in)	Corrected Volume (mL)	Corrected Pressure (torr)	1/Corrected Volume (1/mL)

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.