NAME_____ **SECTION**_____

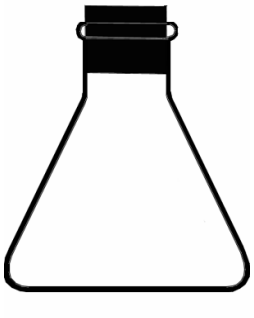
PARTNERS _____ **DATE**_____

THE BEHAVIOR OF GASES

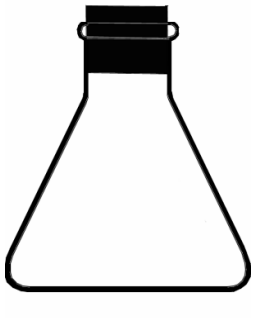
This activity explores the interactions of gas pressure, temperature, volume, and amount of gas by looking at the behavior of gases under changing conditions.

PRE-LAB QUERIES

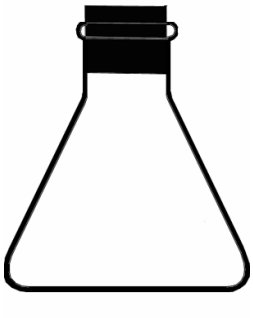
1. Each of the flasks below has a volume of 2 liters. Draw what 1 liter of air, 1 liter of water, and 1 liter brick would look like if they were in the flasks. This is the **macroscopic** view (the way we see it).



1 liter air

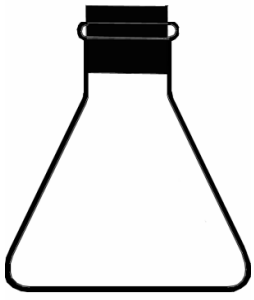


1 liter water

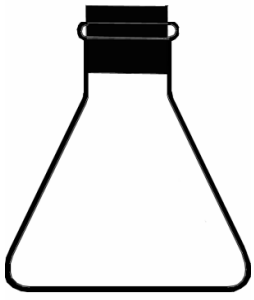


1 liter brick

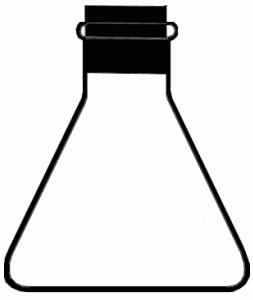
In the next set of 2 liter flasks imagine that you could see the particles (atoms or molecules) in air, water, and brick, and use little circles to draw what they would look like in the jar. This is the **microscopic** view or the view at the molecular or atomic level.



1 liter air



1 liter water



1 liter brick

2. What is a major difference between the gas state and the solid or liquid state?

PROCEDURE

1. If you take a sealed balloon filled with air and gently squeeze it in the middle what happens? What changes? What remains the same?

   If the balloon was filled with water instead of with air, would it behave the same way? Explain.

   If the balloon was filled with water and then frozen solid, what would happen when you squeezed it?

2. Obtain a large, plastic syringe and draw 25 mL of water into it. Eliminate any bubbles of air. Place the opening of the syringe securely against a rubber stopper or cork. Push down on the plunger of the syringe without allowing water to leak from the syringe. Describe how the volume of the water changes with an increase in pressure.

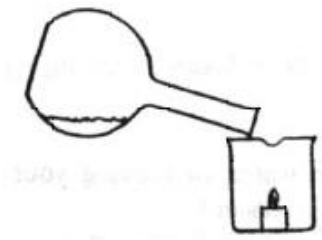
   Repeat the above procedure using 25 mL or air. How does the volume of air change with an increase in pressure? Try to explain the reason for any differences you may have observed.

   The properly you have just investigated is called **compressibility**. What must be happening to particles when a material is compressed?

   How do you think the compressibility of a solid compares to a liquid or gas? Why?

3. Liquids are fluids, that is, they have the ability to flow or pour. Are gases fluids?

You are going to verify your response by trying to pour a gas. The problem that arises is that you cannot see a clear, colorless gas and therefore how can you tell whether or not it is pouring out of a container! We could use a gas that has a color, but many colored gases such as chlorine (green) and fluorine (yellow) are toxic. The simple solution utilizes an observation you made in the *Investigation of Chemical Reactions* laboratory. What happens to a burning splint when it comes into contact with carbon dioxide?



First you have to produce some CO_2. Place about 1 gram of sodium bicarbonate (sodium hydrogen carbonate or baking soda) into the bottom of a Florence flask. Add 25 mL of dilute acetic acid (vinegar). Quickly cover the mouth of the flask with a glass plate so the gas can accumulate before you attempt to pour it. Light a small candle, remove the glass plate and carefully pour the gas onto the flame. **Do not allow any liquid to leave the flask!** If you get no result try adding a small amount of additional reactants into the flask and try again.

Based on your observations are gases fluids? Explain.

4. Obtain a room deodorizer, place it on one end of the lab bench, and open it carefully. Record how long it takes for you to detect the odor.

What state of matter is the deodorizer material?

Explain how the vaporized molecules (causing the odor) from the deodorizer reached your nose.

5. When bubbles of a gas form in a liquid, what do they do? (Visualize a carbonated drink) Why?

Think about walking in knee deep water, or moving your legs while lying in a bath tub filled with water. Now think about walking in air. Which is easier and why?

Water has a density of about 1g/mL at room conditions. Estimate the density of air at room conditions.

Why does a helium balloon rise when it is released?

What would a balloon full of carbon dioxide do if you released it in a room full or air? Why?

The **density** of a gas depends on its molar mass. Under the same conditions, gases with molar masses less than air will float, while those with molar masses greater than the molar mass of air will sink in air. Air has the equivalent of a molar mass of 29 g/mole. How do you think that value was obtained?

Helium behaves just like carbon dioxide towards burning objects. Suppose you were to repeat procedure 3 with a flask of helium instead of carbon dioxide, what would happen? Why?

6. Place a 400 mL beaker with 300 mL of tap water onto a hot plate. Suspend a thermometer from a clamp into the beaker such that it does not touch the bottom. Start to warm the water to between 60-80^{o}C. Do not stir or disturb the water as it warms up.

Describe the beaker before, during, and after warming. Look at the bottom and sides of the beaker. Devise an explanation for any phenomenon you observe.

Gently tap the beaker. What happens and why?

Heat the beaker of water to boiling. Describe what is happening as the water boils. What are some differences when compared to warming?

Keep the beaker of water for later in this lab activity.

7. Inflate a balloon with air to a diameter of about 10 cm and seal it. Why did the balloon expand in size when you inflated it?

How could you determine the volume of air in the balloon? (Describe at least 2 ways.)

Place the balloon in a bell jar. If available also add some shaving cream and fresh marshmallows. Ask the instructor for help if you are unfamiliar with this apparatus. The motor of the vacuum pump will remove air from the bell jar when it is turned on.

Make a prediction about what you think will happen to the balloon as air is removed from the bell jar.

Why did you make that prediction?

Turn on the vacuum pump and observe. What happens to the balloon?

Did the amount of gas in the balloon change?

Formulate an explanation for what you observed.

Keep the balloon for #9.

8. Let's explore this relationship between pressure and volume quantitatively. Locate the station with the CB, TI-83 calculator, and pressure sensor. Be sure that the syringe plunger is pulled out a little past 20 mL (cc) and the blue valve is in line with the clear plastic side opening.

Select [**PRGM**] on the TI-83. When the program are displayed select CHEMBIO and [**ENTER**]. Press [**ENTER**] twice until you reach the MAIN MENU. Select SET-UP PROBES and enter the following information:

Number of probes:	1
Select probe:	3: PRESSURE
Channel number:	1
Calibration:	USE STORED
Pressure units:	ATM

When you get back to the MAIN MENU select 2: COLLECT DATA. For DATA COLLECTION select 3: TRIGGER /PROMPT.

Pick up the syringe and push the plunger to 20 mL (cc). When you have the volume set, press the **TRIGGER** button on the CBL. When you get the ENTER VALUE message on the calculator enter the syringe volume. The menu will ask if you want to enter more data, stop and graph, or quit. Select MORE DATA and repeat the procedure above with a volume that is 4 mL less. Collect data for 3 more volumes that are decreased by 4 mL each.

After the 5th value, select STOP & GRAPH. The calculator should display a graph. If it does not, check with the instructor. Sketch the graph below labeling the axes with the appropriate variable name (x = volume, y = pressure)

What mathematical relationship do you think exists between volume and pressure? Explain.

Write a mathematical expression for pressure and volume based on your data.

What would you estimate the pressure to be for a volume of 30 mL on the syringe?

Before going on, exit the CHEMBIO Program by selecting *NO* when asked if you want to repeat the experiment. Select QUIT when you return to the MAIN MENU.

To test if your prediction is correct we can use the power of the TI-83. The data you collected with the CBL is in lists. Key in [**STAT**] and then [**ENTER**]. L_1 is volume, L_2 is pressure. Transfer the data from the calculator to the table below. Calculate the product of volume and pressure (V x P) for each data pair and enter it in the table. Calculate the average k value.

VOLUME (V)	**PRESSURE (P)**	**k (= V x P)**
		Average k

To determine the equation that best describes the relationship between pressure and volume on the TI-83, go to STAT PLOTS (**[2nd] [Y =]**). Turn off all plots but number 1 and set up to plot L_1 versus L_2. Display the graph by hitting **[ZOOM] [9]** and sketch it here, labeling the axes.

Determine what type of relationship exists between P and V (that is, linear, power, quadratic). Go to **[STAT]** CALC and select the regression equation. When the screen shows the regression, key in **L_1**, **L_2** and press **[ENTER]**. Record the screen information below. If your screen does not show r and r^2 values, ask your instructor to show you how to display these.

Equation form: _____

a = _____ r^2 = _____

b = _____

Fill in the values and place the equation here: _____

How does the average value of k compare to the coefficient "a" in the regression equation?

Now, write the equation in terms of the variables P and V not x and y:

_____

To see how the data fits the regression equation go to **[Y =]** and clear all functions. Press **[VARS]**, arrow down to 5:STATISTICS and **[ENTER]**. Arrow over to EQ and select RegEQ. This will "paste" the regression equation into the Y = function. Hit **[GRAPH]** and the data points will appear and the regression equation will be plotted with the points.

Using the regression equation, calculate the pressure for a volume of 30 mL. How good was your prediction?

9. Place a 400 mL beaker, half-filled with water, on a hot plate and let it reach boiling. Set the hot plate on low. Place a pinch clamp on the knot end of the balloon and place the balloon on the top of the beaker so that the pinch clamp sits inside the beaker but does not touch the water.

What happens to the balloon after it has been on the beaker for 5 minutes? Explain your observation.

Predict what would happen if you heated the balloon to an even higher temperature.

What do you think is happening on the microscopic scale (atomic level)?

After heating the gas, did the density of the gas in the balloon change? Explain your answer.

Remove the balloon from the beaker and place it in an ice bath. Explain what happens.

10. Based on the activities you have just performed, make statements about the relationship between the following sets of variables (as the first increases what will happen to be second?). In each case assume that those two variables are the only ones changing and all other properties are being held constant.

a. temperature – volume

b. pressure – volume

c. amount of gas – volume

d. amount of gas – pressure

e. temperature – pressure

POST-LAB QUESTIONS

1. Let's test out the mathematical relationship between temperature and volume with a set of data gathered on a 2.00 liter balloon that starts out at 25°C.

   What was the pressure in the balloon in the lab activity?

   How do you know?

   Was pressure a variable? Explain.

Temperature (Kelvin)	Volume of balloon (L)
298	2.00
303	2.03
308	2.07
313	2.10
318	2.13
323	2.17

Take the data above and enter it in Lists 1 and 2 (**[STAT]** EDIT). Once the data is entered, go to STAT PLOTS (**[2nd] [Y =]**). Turn off all plots but number 1 and plot L_1 versus L_2. Display the graph by hitting **[ZOOM] [9]** and sketch it here, labeling the axes.

Determine the form of the equation from **[STAT]** CALC and selecting the best regression equation as you did in number 8 and enter the information below:

Equation form: _____

a = _____ r^2 = _____

b = _____

Write the equation in terms of the variables studied: _____

To see how the data fits the regression equation go to **[Y =]** and clear all functions. Press **[VARS],** arrow down to STATISTICS and **[ENTER]**. Arrow over to EQ and select RegEQ. This will "paste" the regression equation into the Y = function. Press **[GRAPH]** and the data points will appear and the regression equation will be plotted with the points.

How good is the fit?

Using the graph or regression equation, determine the temperature required to achieve the following volumes:

V = 2.08 L T = _____ V = 2.25 L T = _____

V = 0.00 L T = _____

2. Suppose you wanted to use the volume-temperature model (mathematical relationship) you developed in question #1 to predict the temperature needed to obtain a volume of 20 L. What are you assuming about the model?