Name______________________________ Partner__________________________

Date_______________ Course & Section____________________

PHY230: Relationship Between Pressure and Volume of a Confined Ideal Gas at Constant Temperature – **Boyle's Law: PV=C**

Pressure is the force on a surface divided by the area over which the force is applied. In gases, the force comes from the impact of the moving gas molecules striking the surface. Suppose a sample of gas is sealed in a container that can expand or shrink. The pressure of the gas against the inner surfaces of the container will vary as the container's size is changed. This is because the enclosed gas molecules, each striking the surface with a certain average impulse, will concentrate their impacts over a smaller area if the container shrinks, and spread their impacts over a larger area if it expands. At the same time, in a smaller container, the molecules simply hit the container's surface more often. The combination of these two effects causes the pressure to increase as the volume decreases, and cause the pressure to decrease as the volume increases. The molecules are moving because of kinetic energy from thermal agitation, so a higher temperature would also increase the kinetic energy, and thus increase impact force and pressure, but for now, let's assume that temperature is held constant along with the amount of the gas.

We can construct a quantitative statement about the pressure exerted by a confined gas and the volume occupied by the gas by calculating the pressure in a sealed container of known volume. The mathematical relationship between the pressure and the volume is called Boyle's Law.

You will measure the volume of some air trapped in a capped syringe as you apply various forces to the plunger. Newton's Laws tell us that if the plunger is not accelerating (in fact, it won't be moving at all when you take your data), then the net force on it must by zero. For any particular applied force on the plunger, there will be one position of the plunger where the plunger comes to rest and remains in that position. To find this " equilibrium position", we push or pull gently on the plunger to break static friction and let it rebound. With the piston in that position, the forces exerted downward on the piston must be equal to the upward force on the plunger.

In part one of the experiment, where the syringe is clamped with the cork pointing up, the total downward force comes from the weight of the plunger and any added metal F_{load}, along with the force of the gas F_{gas}. The only upward force is due to the atmosphere of the earth $F_{atmosphere}$.

To summarize in the form of an equation, at equilibrium:

$$F_{gas} + F_{load} = F_{atmosphere} \qquad (1)$$

In part two of the experiment, where the syringe is stood upright on the table top with the cork pointing down, the total downward force comes from the weight of the plunger and any added metal F_{load}, along with the force of the atmosphere $F_{atmosphere}$. The only upward force is due to the gas F_{gas}.

To summarize in the form of an equation, at equilibrium:

$F_{gas} = F_{load} + F_{atmosphere}$ (2)

Since pressure is defined as force divided by area, the force exerted by the confined gas is equal to its pressure multiplied by the "cross sectional" area of the piston, so:

$F_{gas} = P_{gas} \times A_{piston}$ (3)

With the force in newtons and the area in square meters, the pressure is in units of newtons per square meter, N/m^2, also called Pascals (Pa.)

The force on the exterior of the syringe due to atmospheric pressure is similarly

$F_{atmosphere} = P_{atmosphere} \times A_{piston}$ (3)

The atmospheric pressure varies with the weather conditions (lower pressure on rainy days, etc.) The instructor will provide the value for today from a barometer. The force due to the atmospheric pressure is about the same for every data point, so you only need to calculate it once and use the same value for all the trials. (Note that the mass of the outer cylinder of the syringe does NOT contribute to the weight acting on the plunger, so it is irrelevant. Don't measure it!)

Procedure:

1. Report the mass of the unloaded plunger assembly here (written on wooden platform)
   Mass plunger & hanger = __________

2. Obtain the full diameter of the black rubber piston from your instructor. Calculate the radius, cross sectional area, and as always, maintain the proper compliment of significant figures.

   Diameter = _______________ mm, = ________________ m
   Radius = _______________
   Area piston = __________________

3. Based on your measurements of P_{atm} and A_{piston} calculate
   $F_{atmosphere}$ = ____________________

4. Set the initial syringe volume to 40 cubic centimeters. Seal the syringe by twisting in the stopper plug very tightly. Gently pull down on the piston just a little until you feel slight resistance. Release the plunger and let it rebound to an equilibrium position. The weight of the plunger, F_{load} and friction keeps it from returning all the way to 40 mL. Read your trial #1 Volume data point and enter in the data table. Read all volumes as precisely as possible. Gas can sometimes escape around the piston and/or cork and ruin your subsequent trials (especially if it gets dirty). If the plunger returns to this first Volume reading after you finish your trials, then you can be sure that no air escaped. Report whether it does or does not!

5. The total applied force or total F_{load} is equal to the combined weight of the plunger PLUS any slotted metal masses added. Carefully mount the syringe in the holder in a vertical position with the plunger on the bottom. NOTE: The syringe must be held LOOSELY. Don't distort the syringe body or restrict movement of the plunger by tightening clamps. With the hanger empty, give another gentle pull to the plunger and take a volume reading when it reaches equilibrium once again. This is your volume data for trial# 1 where the load is strictly due to the weight of the plunger assembly. Place an additional 0.5 kg on the hanger for each of five trials, and remember to always break static friction by giving the plunger a gentle uniform pull before taking a volume reading. Record all measurements and calculated values in the table. As always, neatly show at least one carefully labeled sample of every type of calculation. (Load Mass is total of plunger & hanger mass plus any added masses!)

TABLE 1:

Trial #	Load Mass	Load Weight, F_{load}	F_{gas}	Volume cm^3	Volume m^3

6. From the forces in the F_{gas} column of table 1, and the cross-sectional area of the syringe, the pressure in the gas can be calculated by rearranging equation (3). Also calculate the product of the pressure and the volume and enter these P and PV values in table 2.

TABLE 2:

Trial #	P_{gas}	$P_{gas} \times V_{gas}$

7. The pressures you calculated should all have been LESS than atmospheric pressure. Why? Now repeat steps 5 & 6 using the same five different masses, but to produce internal syringe pressures that are GREATER than atmospheric pressure. (Set the initial volume of the syringe to 65 cc this time, not 40 cc.)

TABLE 3:

Trial #	Load Mass	Load Weight, F_{load}	F_{gas}	Volume cm^3	Volume m^3

From the forces in the F_{gas} column of table 3, and the cross-sectional area of the syringe, the pressure in the gas can be calculated by rearranging equation (3). Also calculate the product of the pressure and the volume and enter these P and PV values in table 4.

TABLE 4:

Trial #	P_{gas}	$P_{gas} \times V_{gas}$

8. Is a pattern apparent in any of the data? Does the data suggest the presence of any specific systematic errors or flaws in the experimental equipment or procedure? How so? How might the experiment be improved? Report the standard deviation of C.

9. Suppose you put so much weight on the plunger that the volume was reduced to only 1.0 ml. What do you predict the pressure inside the syringe would be then? Show the entire calculation, and explain your reasoning. (Remember PV=C) Comment on the feasibility of performing such a trial.

   V = 1.0 ml
   P = ___________________