Serrata Gas Law Apparatus Cat. No 1011006

Include:

Syringe
Plug Stopper
Wood, with 2 holes
Wood, with 15/16 hole
Wood, with 2 holes
Instructions

Additional Materials Needed:

Uniform weights.
Vernier callipers (preferred) or ruler.
Large beaker.
Thermometer

About Gas Laws:

This apparatus is designed to allow the student verify the Ideal Gas Law:

$$PV = nRT$$

It consists of a syringe held between two wooden blocks. The experiment has two parts:

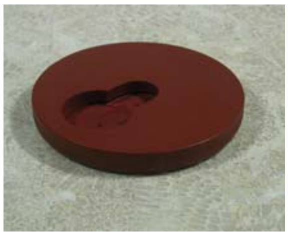
1) Verifying change in volume of a gas with changes in pressure at constant temperature (**Boyles' Law**)
2) Verify change of volume of a gas with changes in temperature at constant pressure (**Charles' Law**) By combining the two relationships, we arrive at the ideal gas law,

Assembly Procedures:

Syringe Assembly:

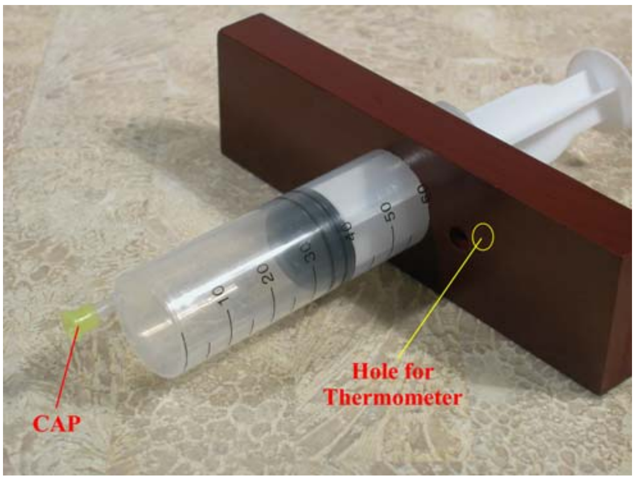
1. With the plunger out, insert tip of syringe into stepped round wood block. See pictures:

2. Insert plunger head into larger slot on the wood cap block and slide it over to the centre of the wood cap block. See pictures



3. Insert the plunger into the syringe thus capturing a volume of air (at least 20 ml) - See the picture on the left.
4. From the bottom of the stepped wooden block attach the cap to the end of the syringe. See picture.

5. For CHARLES' Law use the following assembly:



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Verification of Boyles' Law:

Robert Boyle in 1662 first studied the relationship between pressure and volume of a gas at constant temperature. He found that the pressure P of the gas was inversely proportional to its volume V. In other words, if you double the pressure on a given amount of gas, its volume will halve.

1. Draw 35 cc of air into the syringe and place the cap on the end.
2. Place the syringe into the two wooden blocks as shown.
3. Place uniform weights (identical books work well) on the top block. After placing each weight, record the volume of air in the syringe and the number of weights added. Tapping the syringe lightly will help to reduce errors due to friction.
4. After all the weights have been added and the data recorded, remove them one by one, recording the volume and number of weights as before.
5. Weigh each of the weights and record the average weight.
6. Disassemble the apparatus and remove the plunger from the syringe. Using. vernier callipers (preferred) :or ruler, measure the inside diameter of the syringe barrel. Calculate the area **A**, using the formula:

   $$A = \pi r^2$$

   where **r** is **1/2** of the diameter.
7. Calculate the pressure **P**, of each data point by taking the average of the two volumes for each run, using the relationship:

   $$P = F/A$$

   where **F** is the gravitational force exerted by the weight and **A** is the area of the syringe barrel.
8. Plot the volume **V**, versus **P** for each data point. Record the temperature **T**.

Verification of Charles' Law:

1. Heat a beaker full of water to 90°. Beaker must be large enough to immerse completely the syringe barrel.
2. Draw 30 cc of air into the syringe and cap the end.
3. Place the syringe and a thermometer into the water, using the provided block of wood as a support. The thermometer fits in the smaller hole.

See picture on the previous page!

4. Allow 3 to 5 minutes for equilibration.
5. Record the volume in the syringe as well as the temperature.

   To get an accurate volume measurement, push on the piston and then release it. Record the volume. Then pull back the piston and release it. Record this second volume and average the two volumes.
6. Allow the water to cool and take successive volume and temperature readings every 10°C or so. To speed cooling, you can add ice to the beaker when the temperature is below 35°C or so.
7. Plot the volume **V**, versus the temperature **T**. You should get a straight line.

Determining gas constant R:

We know that **P** is inversely proportional to **V** or $V \propto \frac{1}{P}$

and that **V** is directly proportional to **T** or $V \propto T$

We can combine both relationships and write: $V \propto \frac{T}{P}$

Introducing a constant **K**, we now have:

$$PV = KT$$

But the constant K is related to the amount of gas present times the gas constant R. We express the amount of gas present in terms of the number of moles present, n. Therefore:

$$PV = nRT$$

where:

P is pressure in atmospheres (atm)
V is the volume in litres
T is the absolute temperature in degrees Kelvin
n is the number of moles of gas present.

Rearranging, $R = \frac{PV}{nT}$

R has the units of $\frac{litres \ . \ atm}{moles \ . \ °K}$

We now calculate R by plugging in the quantities we measured for P, V and T. We get n, the number of moles present, by recognizing that air is made up of 79% N_2 and 21% O_2 by weight. (We will ignore other constituents of air for now.)

The density of air is about 1.20 g/l at 20°C. So 35 ml of air will weigh 1.20 g/l x .0351 = 0.042 g. We calculate "molecular weight" of air:

28.0 is the molecular weight of nitrogen, N_2
32.0 is the molecular weight of oxygen, O_2

28 x 0.79 = 22.12
32 x 0.21 = 6.72
28.84

Therefore 35 ml of air is about: $\frac{0.042}{28.84} = 0.00146$ "mole" of air.

Try using the data you collected for the Boyles Law experiment to calculate the gas constant **R**.

Repeat using Charles Law data.

The accepted value for **R** is:

$$0.082 \frac{litres\ .\ atm}{moles\ .\ °K}$$

This little demonstration can be surprisingly accurate. (check out the sample run we performed below.

Sample Run:

Syringe diameter = 23.8 mm

Area of syringe is then A $= \pi r^2$

$= 3.14\ (.937/2)^2$

= 444.65 sq mm = 4.45 sq cm

Pressure = Force/ Area,
To this we add 1.0 atm to arrive at Abs pressure.

We calculate the number of "moles" of air as:

35 cc = 0.035 l

Density of air is 1.20 g/l
There are 1.20 g/l x.035 1 = 0.042 g of air.

This equals:
0.042 g/28.8 g/mole = 0.00146 "mole" of air.

The experiment was done at 25°C which is
25°C + 273°C = 298°K.

So the product of n and T is:
0.00146 x 298 = 0.43458

We convert syringe volumes to litres by dividing by 1000.

Vol (litres)	Force (KG)	Presure (Atm)	P * V	T * n	R
0.035	0.00	1.00	0.0350	0.434	0.081
0.025	2.00	1.45	0.0362	0.434	0.083
0.019	4.00	1.90	0.0361	0.434	0.083
0.015	6.00	2.35	0.0352	0.434	0.081
0.013	8.00	2.80	0.0364	0.434	0.084
0.011	10.00	3.25	0.0357	0.434	0.082