**Gas Laws**

Under ordinary conditions of pressure and temperature, matter exists in either the solid liquid or gaseous state. In a solid, the particles are in contact with one another are held in a rigid fixed position, have a shape of their own and possess a definite volume. Liquid particles are in contact with one another, are free to

move, will take the shape of their container and have a definite volume. The particles of a gas are widely separated and do not interact, are in constant random motion, will fill their container and have no definite volume.

Conceptually gases are the simplest state of matter and are the easiest to describe in terms of equations. Several well known relationships used to describe gases include Boyle’s Law Charles’ Law, Avogadro’s Law, and the Perfect Gas Law.

**Boyles’ Law:**

The pressure (P) of a fixed quantity of gas held at constant temperature is inversely proportional to the volume of the gas. Mathematically this can be written as:

 **(1)**

where is the symbol for proportionality. Conversion of proportionality to equality requires the use of a proportionality constant k.

 **(2)**

Multiplying both sides of the equation **(2)** by V yields:

 **(3)**

Equation **(3)** is the usual form of Boyle’s law.

**Charles’ Law**

The volume (V) of a fixed quantity of gas held at constant pressure is directly proportional to the absolute temperature (T) of the gas.

V T **(4)**

V = kT **(5)**

= k **(6)**

Equation **(6)** is the usual form of Charles’ Law.

**Avogadro’s Law:**

The volume (V) of a gas held at constant pressure and temperature is proportional to the number of moles (n) of the gas.

V n (**7)**

V = kn **(8)**

**Perfect Gas Law:**

These three laws can be combined to give an equation that describes a gas in terms of its pressure (P), volume (V), absolute temperature (T) and the number of moles (n).

PV = nRT **(9)**

where R is the universal gas constant and has a value of 0.08205 l atm mole -1 k-1.

Equation (6) will form the basis of the following experiment in which the volumes and temperatures of a fixed amount of gas will be collected for several different conditions and analyzed to show that the quantity () is a constant.

**EXPERIMENTAL PROCEDURE**

1. Obtain the following items: transparent or translucent drinking straw with an inside diameter of approximately 0.4cm, food coloring, a votive candle(½” by 2 inches), salt, ice, a thermometer, a ruler graduated in mm, Styrofoam cups and a binder clip.

2. Fill one Styrofoam cup with water within two inches of the top and add a

few drops of green or blue food coloring. Cut off a 5” inch section of the drinking straw.

3. Shave a large flake of wax off the candle.

4. Pack flaked wax into one end of the straw, taking care not to crumble it so that it will not fall down into the straw. This is a preliminary step towards forming a wax plug in one end of the straw.

5. Pick up an intact chunk of wax between your thumb and forefinger and place it over the end of the straw. Simultaneously push the wax down into the straw while smoothing it with your thumb. Repeat with a second piece of wax.

6. Place the binder clip onto the edge of the cup with the dyed water.

7. Lower the ear of the clip so that it is pointing towards the solution. Slide the straw with the open end down, under the lowered ear of the clip.

8. Light the candle and let a puddle of molten wax form around the wick of

the candle. Carefully tilt it so that the molten wax will drip onto the end of the straw, and hold it over the wax in the straw. Fill in the plug end until the liquid wax starts to overflow. Stop just short of this point.

9. Allow the wax to harden. When the wax has solidified, raise the straw up

out of the cup with the open end down. There should be a plug of water in the end of the straw, equal in length to the depth that the end was immersed, which should remain in place and not run out. This indicates that the wax plug has sealed the other end.

10. Rotate the straw 180o so that the open end is up and the wax plug is down.

The water plug should remain in place and not drain down onto the top of

the wax plug. There should be an entrapped air pocket between the water plug and the wax plug.

11. Prepare three different water samples:

a. Moderately warm tap water. b. Cold tap water.

c. A mixture of ice and cold tap water

12. Beginning with the moderately warm tap water, immerse the straw for 5 minutes. At the end of the time period, use a black sharpie to mark the bottom of the water plug. Raise the straw from the water and measure the distance between the black sharpie mark and the top of the wax plug. Also measure the water temperature. While immersing the straw, be sure not to pinch or deform the straw as this may cause the water plug to drain down onto the wax plug.

13. Repeat step 11, for water samples 10b and c. Use different color markers to mark the position of the water plug for trials b and c. Record all data in the following table.

**Data Table Height of Air Plug and Temperature**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Height of Air plug (h)** | **Temperature**  **oC** | **Temperature**  **K** | ˚ |  |
| **Warm tap water** |  |  |  |  |  |
| **Cold tap water** |  |  |  |  |  |
| **Ice/tap water** |  |  |  |  |  |

14. Using an Excel spread sheet, plot a graph of h (y axis) versus oC (x axis)

going from -300oC to 50oC.

15. From the graph, estimate the temperature (oC) at which h goes to zero.

16. The value of  should be approximately constant which verifies Charles

Law. Explain this result (Why should this be true?).

Record your observations and any suggestions to improve this exercise.