GRADE 11 CHEMISTRY, UNIVERSITY PREPARATION – SCH 3U

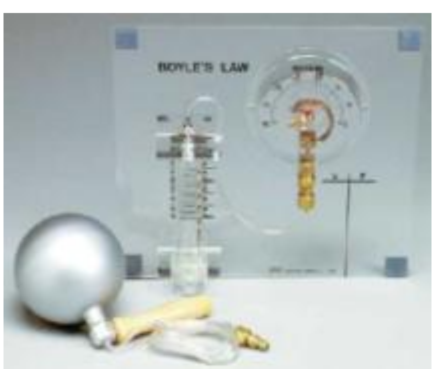
<u>Gases and Atmospheric Chemistry Unit</u> – Investigating Gas Laws

<u>Previous knowledge</u> – Before beginning this lesson the students should have already had a lesson to introduce some of the common gases and their uses. They should also be familiar with how to measure temperature, pressure and volume. Introduce the SI units for measurement of temperature (Kelvin), pressure (Pascal), and volume (litres). Practice converting units from other measurement devices into these SI units (such as degrees Celsius or Fahrenheit into Kelvin, centimetres^3 into litres, pound per square inch into kilopascals, etc.)

A grade 11 chemistry textbook such as <u>Addison Wesley Chemistry 11</u> pages 336-344 can be used to supplement the lesson theory and provides graphs and derives the equations for students requiring some additional information and questions.

THE LESSON - THREE GAS RELATIONSHIPS

(1) BOYLE'S LAW – *The Relationship between Pressure and Volume*



Using a Boyle's Law Apparatus, such as the one shown here that can be used with an overhead projector, derive the relationship between pressure and volume by graphing the obtained data and then plotting the inverse. Instructions are included with the apparatus. The result should be the most useable form of Boyle's law ($P_1V_1 = P_2V_2$).

Using a large syringe with a cap, have students remove the plunger and place a mini-marshmallow inside. Replace the plunger. Predict what will happen to the marshmallow when you push on the plunger and the volume in the syringe is reduced. Try it. What did you see? Explain.

Remove the cap from the syringe and push on the plunger until it is almost in contact with the marshmallow. Replace the cap, ensuring a good seal. Predict what will happen to the marshmallow when you pull back on the plunger and the volume in the syringe is increased. Try it. What did you see? Explain.

If large syringes are not available a similar demo could be done using a regular size marshmallow and a filter flask. Connect the flask to a water aspirator or hand pump and reduce the pressure in the flask.

An online tool to explore gas relationships is available at http://phet.colorado.edu/en/simulation/gas-properties . This could be done in class if each student can have access to a computer or on an LCD/SMARTboard as a demonstration. It could also be assigned for homework if students have access to the internet at home. Have students set the temperature to constant. Select the rule function from the tools options. Pump the handle a couple of times to put some gas into the chamber. Adjust the size of the container to make it as large as possible and record the pressure. What will happen to the pressure if the container size is halved? Test this and record the pressure. Now reduce the size of the container by half again. Record the pressure. What do you notice happens in order to keep the temperature constant? (Keep this in mind for the next part of the lesson.) Reset the simulation. This time continue to pump in more gas without adjusting the volume. What eventually has to happen?

Assign word problems to practice using Boyle's Law.

(2) CHARLES'S LAW – *The Relationship between Volume and Temperature*

Remind students what had to happen in the previous online simulation in order to keep the temperature constant. Temperature must play a role in these relationships also.

To investigate Charles's law, create the graph and derive the equation have students fill a syringe about 1/3 full of air and seal the tip with the cap or some modelling clay. Place the syringe in an ice water bath with a suspended thermometer. Record the volume on the syringe and the temperature on the thermometer as the temperature of the gas (should start as close the 273 K as possible). Begin warming the ice water bath on a hot plate stirring constantly. Record the volume of the gas with every 5 Kelvin change in temperature and record this information in a data table. Plot the graph of volume versus Kelvin temperature. It should be proportional. Use this to derive the equation and present students with the most useable form of the equation $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

For other demonstrations of Charles's Law the most obvious is liquid nitrogen being poured over a balloon to decrease the temperature and the volume. If liquid nitrogen is not available several demonstrations of this can be seen at www.youtube.com with a simple search. Alternatively, a ping pong ball works well. Have students press on a ping pong ball to place a small dent in it. Then place the ball in a beaker of water. Heat the beaker on a hotplate until the water boils. What do you predict will happen to the ball? As the gas inside the ball is heated the volume attempts to increase as well pushing out the dent.

Return to the simulation website http://phet.colorado.edu/en/simulation/gas-properties . Reset the simulation if necessary. Set the pressure to constant. Add 50 particles of light species gas into the chamber. What do you predict will happen to the volume of gas if the temperature is reduced by half? Cool the gas down to test your prediction. Now increase the temperature in increments of 25 K, what happens to the volume of the gas? What do you notice about the behaviour of the gas particles? Explain. Now change the constant parameters setting to none. What do you expect will happen to the temperature if the volume of the container is reduced by half? Test your prediction. Now make the container as large as possible. What happens to the temperature?

Follow up with some word problems to practice using the equation for Charles's Law.

(3) GAY-LUSSAC'S LAW – *The Relationship between Pressure and Temperature*

Using the overhead apparatus from the Boyle's law lab work, disconnect the syringe and connect the pressure gauge to the sphere of gas. Set up several large basins of water at different temperatures ranging from an ice bath (0 °C) to a tub of boiling water (100°C). Begin by submerging the sphere of gas in the ice water bath and record the temperature and pressure. Repeat the procedure for the other water baths until all data is obtained. Convert temperatures to Kelvin. Plot the graph of pressure against temperature. Pressure should be proportional to temperature. Use this to derive the useful form of the equation where $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

To further demonstrate Gay-Lussac's law place a small amount of water in an empty pop can and bring to a boil. Using gloves and tongs quickly flip the can upside down into a basin of ice water. Describe what happens to the can. Can this be explained using Gay-Lussac's law? Is Gay-Lussacs law the only law represented in this demonstration? Students should begin to realize at this point that situations where one variable is constant are rare and often we have a situation where pressure, temperature and volume are affected. Come back to this in a few minutes.

Return to the simulation website http://phet.colorado.edu/en/simulation/gas-properties . Reset the simulation if necessary. Set the volume parameter to constant. Pump a small amount of gas into the container. Record the temperature and pressure. What do you predict will happen to the pressure if you cool the gas by half? Test your prediction. Now cool the gas as much as possible. Describe what occurs. Now return the temperature of the gas back to its initial setting. Predict what will happen if you double the temperature. Test your prediction. Now continue to add heat. Describe what happens. Why does this occur? When you put air in the tires of your car the recommended pressures in the owner's manual are for cold pressure, explain what this means and why it is important.

Follow up with some word problems to practice solving questions using the equation for Gay-Lussacs Law.

Follow up – The Combined Gas Law

Relate back to the pop can demonstration from Gay-Lussacs Law. Were pressure and temperature the only variables involved? What happened to the volume of the can? Since it would be rare to find a situation where one variable is always held constant, is there a way to combine these laws so that all three variables can be taken into consideration?

Write the three equations side by side on the board. Students will usually be quick to point out that pressure and volume are always in the numerator and temperature is always in the denominator. This can lead into a lesson and practice problems using the combined gas law.

More Demos

A quick search online will help to locate many other demos involving gas laws.

Another of my favourites after having completed the lesson is the egg in a bottle. Make the students figure it out by giving them a hard boiled egg and an Erlenmeyer flask. Their job is to use what they know about the gas laws to get the egg into and back out of the bottle in one piece. Demonstrations of this can be found on youtube if you have never seen it done before.

Ivory brand bar soap floats on water because it contains air. If you take a small piece of ivory (1 cm^3) and place it on a plate in the microwave for less than 1min. (Note: Microwaves vary greatly in their heating ability. Test yours first and watch it carefully when heating.) The volume will increase dramatically. Students should be able to explain what is happening.