What's Holding On the Jar Lid?
Gas Laws Unit Plan

(Four Traditional-Length Class Days)

Topic: Gas laws, their relationship to each other, and their application to real-world situations

Rationales:
- Students will be better able to differentiate between gas laws if they have experience working with the concept before being "told" what they are.
- Students will be better able to remember gas laws if they have experience working on an activity where they can experience the law "at work".
- Students will be better able to address real-world situations that involve gasses if they see the connection between the equations, and the gas laws "at work".
- Students will be better able to understand the relationship between the data they gather, and the law that was derived from the data if they graph and derive equations and statements on their own, before being "told" what they are.
- Students will be better able to understand the process of developing theories and hypotheses if they are given a set of data to discuss, and a chance to derive an introductory understanding of the concept before being told the specific content and vocabulary.
- Students will be better able to transfer the knew understanding of the concepts to the next portion of the gas unit if they are given a chance to derive their own Enduring Understandings.

Population: Non-Honors Level Chemistry course; homogeneous socio-economic level student population (98% African-American/Carribbean-American, Title I school); IEP inclusion-model

PA State Standards:

3.2.10C	Apply the elements of scientific inquiry to solve problems.
3.4.10A	Explain concepts about the structure and properties of matter. (Predict the behavior of gases through the use of Boyle's, Charles' or the ideal gas law, in everyday situations.)
3.7.10D	Utilize computer software to solve specific problems.

Core Competencies: SWBAT
- Recognize each of the gas laws (Boyle's Law, Charles' Law, Gay-Lussac's Law, Avogadro's Law, Ideal Gas Law).
- Explain the relationship between the variables in each of the gas laws.
- Create graphs using data derived from experimentation that accurately represent the relationship between the variables in each of the gas laws.
- Develop equations/statements that describe the resultant graphs and the patterns of the data on the graphs.
- Recognize the relationship between the gas laws.
- Solve problems using the gas laws.
- Observe different real-world situations and develop and argument for which variable (pressure, temperature, volume) is the most important variable in each situation.
- Develop and write Enduring Understandings about the gas laws.

Activity Overview:

*****Daily DO NOW and Exit Tickets will reflect each day's content.*****
Day One: Introductory Activity; Gas Properties Simulator
Day Two: POGIL; Discussion of Gas Properties Simulator
Day Three: Lab Activity
Day Four: Lab Discussion; Revisiting the Introductory Activity

Alternative Plans:
It is not anticipated that alternatives are needed for students who need special accomodations, because they will be assigned groups that will be able to provide assistance to address individual needs (for instance, group members can read any text aloud, for students that need this accommodation).

Assessment:
Assessment will be conducted through a combination of the following methods:
- Observation of student dialogue during classroom discussion and debate
- Observation of student dialogue and group interactions during group work
- Instructor survey and questioning of individual students and groups
- Analysis of group products (Gas Properties Simulator packet, POGIL and problems, Lab Write-Up)
- Observation of changes in understanding between the statements made during the Introductory Activity, and Revisiting the Introductory Activity, at the close of the four days.
- Observation and analysis of development of Enduring Understandings

Differentiation:
- Students will be placed into heterogenous skill-level groups, so that students that are more advanced in understanding can assist those that are more basic in understanding. All work will be conducted in these groups. Students will have already been working in these groups, so time will not be spent assigning groups.
- Groups will submit a group product for Gas Law Simulation and Lab.
- Activities address different modes of learning.
- Lessons will be provided to IEP student study center if student prefers to work with his/her special ed teacher for additional assistance

Textbook:
<u>Chemistry</u> (Holt, Rinehart & Winston)

Day One: Introductory Activity; Gas Properties Simulator

<u>Introductory Activity -</u>

Video (2:41) "Preserving Food for Winter" (A Segment of: *The Alaska Experiment: Part 02: What Did We Get Ourselves Into?)*

See the Jars

- Give each group a jam jar with lid and ring in place.
- Explain that these are the types of jars that are used in canning.
- Have them press on the lid to see that it "pops" (an indicator that it is not sealed).
- Explain that a sealed lid will not pop.
- Have the groups discuss and write an answer on chart paper to the following questions:
  - Based on what you saw in the video, what do you think will cause the jar to seal, and what could make the seal malfunction?
  - The video makes reference to the following three concepts when the canning process is discussed: volume, temperature, pressure, amount of contents. How are each referred to, and is any one of them more or less important than the others in the canning process? Why/why not?
  - Is there something else that is helping the lid to stay on? Does gravity have anything to do with it?
  - Remember that air has mass and weight. Does this have anything to do with it?
  - At higher altitudes, jars have to be boiled for a longer period of time. Why?
- Have groups share out answers and post chart paper on wall to review after end of unit.

<u>Gas Properties Simulator -</u>

Download Gas Properties Simulator before class (http://phet.colorado.edu/simulations/sims.php?sim=Gas_Properties)

Have groups use the Gas Properties Simulator to complete the worksheet and related activities (**see attached**).

See handout for procedure

<u>Homework -</u> Complete Gas Properties Simulator activities if not completed.

Day Two: Discuss Gas Properties Simulator; POGIL & Problems

<u>Discuss Gas Properties Simulator -</u>
Groups will share out results of the graphs, and statements/equations that were derived from the graphs, and discuss similarities and differences in the statements/equations between groups.

<u>POGIL and Problems –</u>
Groups will complete the POGIL (**see attached**) and some chapter problems. Groups will take turns giving answers to the questions on the POGIL and in the chapter problems.

Homework: Write one paragraph, connecting what you learned in the POGIL and problems, and the data your group collected, and the graphs your group created in the Gas Properties Simulator Activity. Answer questions #11 – 30 in textbook.

Day Three: Lab

Groups will rotate through each of four stations, completing the tasks and collecting data at each station using the handout (**see attached**). More than one group may have to be at each station. In addition, some of the items cannot be reused after a group is finished. Prepare equipment accordingly.

*** See lab handout for procedure.***

Equipment

Station One: soda bottles (2 liter plastic) Water Eye dropper Beaker with colored water	**Station Two:** balloons Hair dryer Deep bucket of ice water (be sure to leave plenty of empty volume in container)
Station Three: soda cans Water Ring stand and Bunsen burner Bucket of ice water Tongs	**Station Four:** balloons Balance Hand pump (for balls/tires) String Scissors CO_2 (instructor will give out the carbon dioxide!)

Day Four: Lab Discussion; Revisit Introductory Activity

Lab Discussion –
Groups will share out lab results and discuss similarities and differences in their findings.

Revisiting the Introductory Activity –

- Groups will Carousel (see http://interactiveclassroom.com/materials_books_tsd.html for description of Carousel) the five questions from the Introductory Activity.
- Answers will be discussed and debated.
- Students will write Enduring Understandings to be posted on the EU wall.

Homework –
For extra credit, students can research canning jars and write a short paper about 1) what REALLY is holding those lids on, and 2) why it is necessary to boil cans for longer time periods at higher elevations.

Gas Properties Simulator Activity

Task #1 - Open the Gas Properties Simulator on your computer's desktop. Follow the instructions for each section, and fill in the charts with the appropriate data.

Task #2 - Put your data into Excel spreadsheets and create a scatterplot graph for each set of data.

Task #3 - Try and derive an equation OR write a sentence that describes the behavior shown on each graph.

Part One: Changing Pressure and Volume

- Click constant temperature.
- Open up "Measurement Tools" and click on the ruler.
- Move the handle on the left so that the chamber measures nine nanometers in length (edge will be under the "1")
- Raise the amount of Heavy Species in the chamber to 500.
- Allow the pressure gauge to level. Record the pressure.
- Reduce the length of the chamber by one nanometer. Allow the pressure gauge to level. Record the pressure.
- Continue reducing the length of the chamber by one nanometer at a time, recording the pressure each time, until the length of your chamber is three nanometers.
- Answer the questions next to the table.

Length of chamber	Pressure
9 nm	
8 nm	
7 nm	
6 nm	
5 nm	
4 nm	
3 nm	

1) If you decrease the length of the chamber, what other dimension is also decreasing?

2) Did the pressure increase or decrease as you decreased the length of the chamber?

3) What do you think will happen to the pressure if you increase the length of the chamber, again?

Part Two: Changing Temperature and Volume

- Click "Reset"
- Click constant pressure.
- Your ruler should still be open
- Raise the amount of Heavy Species in the chamber to 500.
- Allow the volume to reduce to its level. Record the length of the chamber. The temperature should read 300K.
- Increase the temperature by approximately 100K. You will not be able to do this exactly, so be sure to record your temperature, as well as the new length of the chamber.
- Continue increasing the temperature by 100K increments, recording the temperature and chamber length each time, until you reach approximately 900K.
- Answer the questions next to the table.

Temperature	Length of Chamber
300K	

1) If you increase the length of the chamber, what other dimension is also increasing?

2) Did the length of the chamber increase or decrease as you increased the temperature?

3) What do you think will happen to the length of the chamber if you decrease the temperature, back again?

Part Three: Changing Temperature and Pressure

- Click "Reset"
- Click constant Volume.
- You do not need the ruler for this one, but you do not have to put it away.
- Raise the amount of Heavy Species in the chamber to 500.
- Allow the pressure to level. Record the pressure. The temperature should read 300K. This is already in your chart.
- Increase the temperature by approximately 100K. You will not be able to do this exactly, so be sure to record your temperature, as well as the new pressure.
- Continue increasing the temperature by 100K increments, recording the temperature and pressure, until you reach approximately 900K.
- Answer the questions next to the table.

Temperature	Pressure
300K	

1) Did the pressure increase or decrease as you raised the temperature?

2) What do you think will happen to the pressure if you lower the temperature back to 300K?

Part Four: Changing moles

- Click "Reset"
- Click constant Temperature.
- If your ruler is not open, open it.
- Raise the amount of Heavy Species in the chamber to 100. Record the temperature and volume.
- Click "Reset"
- Raise the amoung of LIGHT Species in the chamber to 100. Record the temperature and volume.
- Repeat process for 200, 300, 400, 500, 600, for both Heavy and Light. Remember to reset between heavy and light, each time.

# of molecules	Length of Chamber (Heavy)	Pressure (Heavy)	Length of Chamber (Light)	Pressure (Light)
100				
200				
300				
400				
500				
600				

1) What do you notice about the pressure and length of chamber for the heavy and light species at each molecule amount?

The Ideal Gas Law
POGIL Activity
(adapted from Chemistry: A Guided Inquiry by Moog and Farrell)

Information

- **T (K)** = Kelvin or Absolute temperature = T(°C) + 273.15
  T (K) is always > 0

- **Boyle's Law (1660):** The volume of a sample of a gas varies inversely with pressure, if the temperature is held constant.

  $V = k_B\, 1/P$ at constant n and T
  Where n is the number of moles of gas, and k_B is a constant.

- **Charles' Law (1887):** The volume of a gas varies linearly with temperature, if the pressure is held constant.

  $V = k_C\, T$ at constant n and P
  Where n is the number of moles of gas, and k_C is a constant.

- **Gay Lussac's Law (1809):** The pressure exerted on a container's sides by a gas varies linearly with temperature, if the volume is held constant.

  $P = k_{GL}\, T$ at constant n and V
  Where n is the number of moles of gas, and k_{GL} is a constant.

- **Avogadro's Hypothesis (1812):** Samples of different gases which contain the same number of molecules – of any complexity, size, or shape – occupy the same volume at the same temperature and pressure.

  $V = k_A\, n$ at constant T and P
  Where n is the number of moles of gas, and k_A is a constant.

Model 1: The Ideal Gas Law Equation.

$$P\,V = n\,R\,T$$

Where R is a constant called the **ideal gas constant**.

The numerical value of the ideal gas constant is calculated from the fact that one mole of gas occupies 22.414 L at a pressure of one atmosphere and a temperature of 0°C (273.15K).

R = PV/nT
= (1atm) (22.414 L) / (1 mole) (273.15 K)
= 0.08206 L atm/K mol

Critical Thinking Questions

1. How does the volume of a gas (at constant *n* and *P*) change as the temperature is raised?

2. How does the volume of a gas (at constant *n* and *T*) change as the pressure is increased?

3. How does the pressure of a gas (at constant *n* and *V*) change as the temperature is increased?

4. How does the volume of a gas (at constant *T* and *P*) change as the number of molecules is increased?

5. For each case, rearrange the Ideal Gas Law Equation to show that it is consistent with the given law or hypothesis and obtain an expression for the corresponding constant.
   a. Boyle's Law, k_B

   b. Charles' Law, k_C

   c. Gay-Lussac's Law, k_{GL}

   d. Avogadro's Hypothesis, k_A

Exercises and Problems (complete on loose-leaf)

1. Calculate the volume of 20.5 of NH_3 at 0.658 atm and 25°C.
2. Calculate the volume of 359 g of CH_3CH_3 at 0.658 atm and 75°C.
3. Calculate the volume of 525 g of O_2 at 25.7 torr (60 torr – 1 atm) and 25°C.
4. A spherical space colony proposed by Gerald O'Neill (Princeton University) has a diameter of 1.00 km. How many grams of N_2 are needed to fill the interior of the colony at one atmosphere and 20°C (room temperature)?
5. A 2.00L container is placed in a constant temperature bath and is filled with 3.05g of CH_3CH_3. The pressure stabilizes at 800 torr. What is the temperature of the constant temperature bath?
6. Complete the following problems from your textbook: pg. 425 #1-4, pg. 428 #1-4, pp. 430-431 #1-4, pg. 435 #1-4.

Think About It

Discuss which law applies to each graph from your Gas Properties Simulation activity. Are the statements/equations that you wrote similar to the ones in this POGIL? How/How not?

BE PREPARED TO SHARE OUT ANSWERS!!!!

Gas Laws Lab

- Your lab group will visit each of four stations. You will be assigned your first station.
- You will have approximately ten minutes to complete the activity at each station. This is not very much, so be efficient!
- When the signal is given, your group must move to the next station.
- If you cooperate and effective, you will have no problem with finishing all of the work at each station!
- Be sure to answer the questions for each station!

<u>Station 1: Boyle's Law</u> - Pressure and volume are inversely proportional.

BEFORE YOU BEGIN: Read the instructions, and write down a prediction of what will occur.

Instructions:

Fill the soda bottle with water. Immerse the tip of the medicine dropper into the beaker of colored water, squeeze and then release. Squeeze drops out of the dropper until it is about half full. Drop the medicine dropper into the bottle, add more water to completely fill the bottle and tightly screw on the cap.

1. Where is the medicine dropper? Why?

2. Now squeeze the plastic bottle and hold. What happens to the medicine dropper?

3. What happens to the volume of the air bubble? Why would this volume change make the dropper behave the way it did?

4. Write a brief statement describing Boyle's Law in your own words.

5. Did the outcome match your prediction? How/How not?

<u>Station 2: Charles' Law</u> - Temperature and volume are directly proportional

BEFORE YOU BEGIN: Read the instructions, and write down a prediction of what will occur.

Instructions:

Fill a balloon with air to about ¾ full.

1. Carefully heat the balloon using the hair dryer. DO NOT HOLD THE DRYER CLOSE TO THE BALLOON, AS IT WILL CAUSE THE BALLOON TO POP! Describe your observations of the balloon.

2. Take the balloon and dunk it into the bucket of ice water. Describe your observations of the balloon.

3. Explain why the balloon behaved as it did, both when you were heating it, and when you cooled it in the ice water.

4. Write a brief statement describing Charles' Law in your own words.

5. Did the outcome match your prediction? How/How not?

<u>**Station 3: Gay-Lussac's Law**</u> - Pressure and temperature are directly proportional

BEFORE YOU BEGIN: Read the instructions, and write down a prediction of what will occur.

Instructions:

Pour about 10 ml of water into the soda can and place it on the ring stand over the Bunsen burner. Place the beaker of ice-cold water within easy reach. Heat the soda can until most of the water has boiled out. (This should only take a few minutes.) Now very quickly and carefully, using your tongs turn the soda can upside down into the beaker of cold water.

1. Describe your observations of the soda can.

2. Explain why the soda can behaved the way it did.

3. Write a brief statement describing Gay-Lussac's Law in your own words.

4. Did the outcome match your prediction? How/How not?

<u>Station 4: Avogadro's Hypothesis</u> - Equal volumes of gas (at the same temperature and pressure) will have the same number of molecules

BEFORE YOU BEGIN: Read the instructions, and write down a prediction of what will occur.

Instructions:

Mass a balloon.

1. Use the pump to fill the balloon with air. Mass the balloon with the air. Subtract the mass of the balloon from the mass of the balloon with the air. This is the mass of the air. If the molar mass of air is 29 g/mol, how many moles of air did you collect in the balloon?

2. BEFORE YOU EMPTY THE BALLOON, CUT A PIECE OF STRING THAT FITS AROUND THE CIRCUMFERENCE OF THE BALLOON! Empty the balloon of air, completely. See your instructor to get it filled to a point that the balloon will have the same circumference as your air-filled balloon. Mass the balloon with the carbon dioxide. Subtract the mass of the balloon from the mass of the balloon with the CO_2. This is the mass of the CO_2. Calculate how many moles of CO_2 are collected in the balloon.

3. Considering #2, why was it important to use a pump for #1, and not your lung power?

4. Did the number of moles match/come close? How close? If they didn't, what could account for the discrepancy?

5. Write a brief statement describing Avogadro's Hypothesis in your own words.

6. Did the outcome match your prediction? How/How not?