Lesson Plan RET CoMET Summer Program 2018

Michael Lopatka WPHS/OCPS

Applying MEMS Pressure and Temperature Piezoelectric Receptors to Determine Specific Ideal Gas Law and Molar Quantities through Chemical Analysis and Mathematical Modeling.

Chemistry/Honors Chemistry: 2003340, 2003350

Learning Objectives:

1. **Generation of a Hypothesis Using the Scientific Method: SC.912. N.1.1** Define a problem based on previously researched knowledge, of Stoichiometry and Gas Laws, and complete the following tasks:
   a. Pose questions about your research
   b. Examine books resources of information to see what is already known about your topic.
   c. Review the lab procedures and have a specific plan to conduct your experiment.
   d. Generate your hypothesis based on your research. Your hypothesis may be in the form of an if/than statement.
   e. Conduct organized observations during your experiment and record your data.
   f. Pose answers, explanations, or descriptions of your experiment.
   g. Use appropriate evidence and reasoning to justify these explanations to others
   h. Communicate results of scientific investigations through your lab report.
   i. Evaluate the merits of the explanations produced by others.

2. **Stoichiometry: SC.912. P.8.9** Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

3. **Gas Laws: SC.912. P.12.10** Interpret the behavior of ideal gases in terms of kinetic molecular theory.

Daily Procedures

Day 1: Students will take a pretest, then research specific topics (via a research activity) related to the learning objectives.

Day 2: Students will continue their research and use this research to begin the first steps of the scientific method (learning objective 1).

Days 3/4: Lecture/Class Discussion (learning objectives 2 and 3).

Days 5 and 6: Solving Stoichiometry and Gas Laws Problems (learning objectives 2 and 3).

Day 7: Begin the lab activity and collect data (learning objectives 2 and 3).

Day 8: Continue the lab activity. Use appropriate evidence and reasoning to justify data explanations to other lab groups (learning objectives 2 and 3).

Day 9: Begin writing rough draft of lab report and complete any lab activities (learning objective 1).

Day 10: Write lab report and submit the rough draft (learning objective 1).

Day 11: Evaluate the merits of the explanations produced by others, one-page report with specific examples and justifications (learning objective 1).

Day 12: Class Discussion and Post Test

Background Information

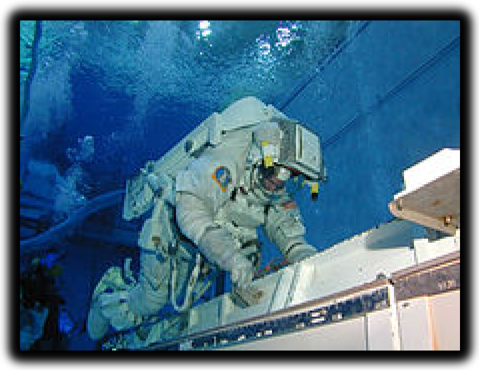
MEMS or Micro-electro-mechanical signifies a technology of infinitesimal devices, predominantly those with moving parts. MEMS fuses electronics at the nano-scale often referred to as nanotechnology. MEMS are often times called micro-machines. Shared uses of MEMS devices include: inkjet printers, smart phones, pressure and temperature sensors, accelerometers (in cars for deployment of airbags), and bio/chemo sensors used in medical and health applications. Using these devices allows the researcher to produce very accurate results. Accuracy and precision is critical in many applications to function properly.

Piezoelectricity represents an electric charge that amasses in some solid materials. These materials include but are not limited to biological matter (cartilage), silicon, and certain ceramics and when a stress is applied electricity is produced. The word *piezoelectricity* means electricity consequentially from either pressure such as squeezing the device or from heat. Piezein is a term derived from the Greek meaning to squeeze or press. Electricity is a term derived from the word electron, which means amber, an early source of electric charge. Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie.

The **Ideal Gas Law** represents the volume (V), moles (n), pressure (P), and temperature (T) in degrees Kelvin of a gas. The relationship/formula for these variables is written as PV = nRT, where R is a gas constant (based upon which unit of pressure measured, such as atm, mmHg, or kPa).

In chemistry, calculations that relate quantities of substances are known as stoichiometry problems. Therefore, **Stoichiometry** is a study of the quantitative or measurable relationships that exist in chemical formulas and chemical reactions. **Molar qualities** represent the number of atoms or other particles in 1 mole of a substance.

Practical applications of temperature and pressure include the **Neutral Buoyancy Laboratory** (NBL) located at the **Sonny Carter Training Facility**, near the Johnson Space. This facility is used for astronaut training in a neutral buoyancy environment pool and is run by NASA. The NBL is a large indoor swimming pool water, in where astronauts learn simulated extra-vehicle activates, EVA, to prepare for space missions. Astronaut trainees wear neutral buoyancy suits to mimic the microgravity that will experience in space.



The **swimming pool** is 202 feet (62 m) in length, 102 feet (31 m) wide, and 40 feet 6 inches (12.34 m) deep, and contains 6.2 million gallons (23.5 million liters) of water. The NBL contains life size components found on International Space Station (ISS). These include both modules and payloads. Additionally, the pool has models from visiting vehicles such as the Japan Aerospace Exploration Agency (JAXA) HTV, the European Space Agency ATV, the SpaceX Dragon, and the Orbital Sciences Corporation Cygnus. In recent years, many simulations have been removed such as the Space Shuttle payload bay and Hubble Space Telescope.

Pre-test

(Day 1)

1. What is a MEMS senor?

   ____

2. What is meant by the term Piezoelectric?

   ____

3. Describe the Ideal Gas Law? Provide the mathematical equation for the Ideal Gas Law.

   ____

4. What is meant by linear regression and mathematical modeling?

   ____

5. How may stoichiometry be related to the study of gas laws?

   ____

6. Why is the relationship between pressure and temperature in gases?

   ____

7. Describe the steps in writing a professional lab report?

   ____

8. Why is it important to read the lab procedures prior to beginning the actual lab activity?

   ____

9. How would you write a good hypothesis?

   ____

10. Why is it important to share and discuss your lab results with other lab groups?

    ____

Research Activities

(Days 1 and 2)

1. **Define the following terms and provide an example of each, either a description or picture with a caption.**
   a. MEMS
   b. Piezoelectric
   c. Hypothesis
   d. Scientific Method
   e. Mole
   f. Law of Conservation of Mass
   g. Kinetic Molecular Theory
   h. Ideal Gas Law
   i. Boyles Law
   j. Charles Law
   k. Percent Yield
   l. Percent Error
   m. Mathematical Model

2. **Research the following topics.**
   a. Why would a MEMS pressure and temperature piezoelectric receptor be used during a chemistry lab? Be specific in your explanation.
   b. What is meant by Linear Regression, and can this be used in modeling in scientific applications?
   c. What is the relationship between pressure and volume?
   d. What is the relationship between pressure and temperature?
   e. What is the relationship between temperature and volume?
   f. Why is stoichiometry valuable in chemistry?

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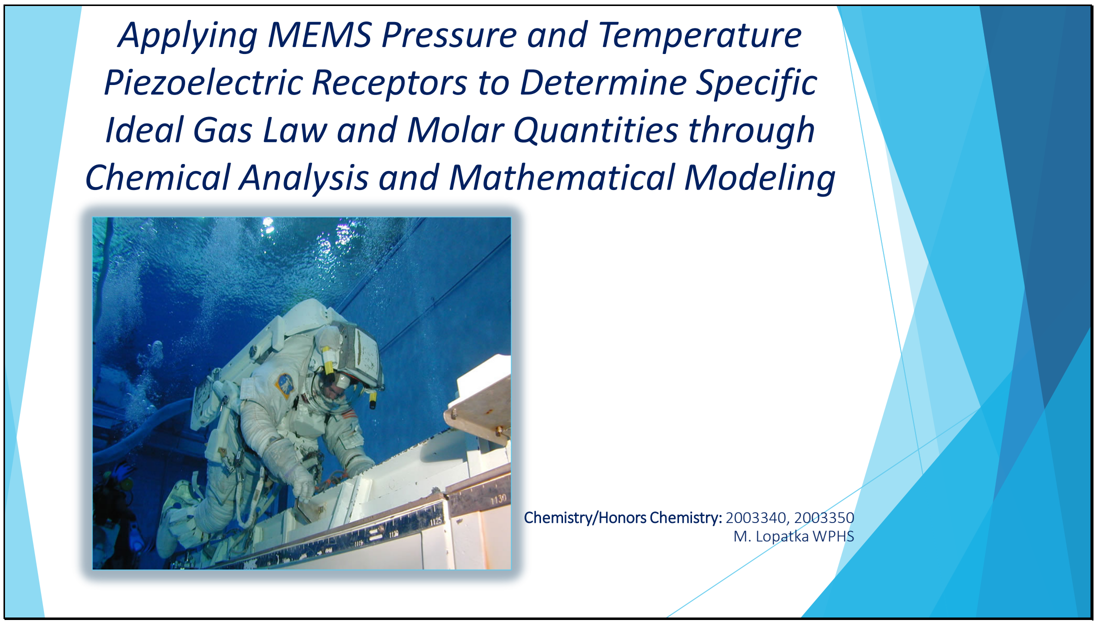
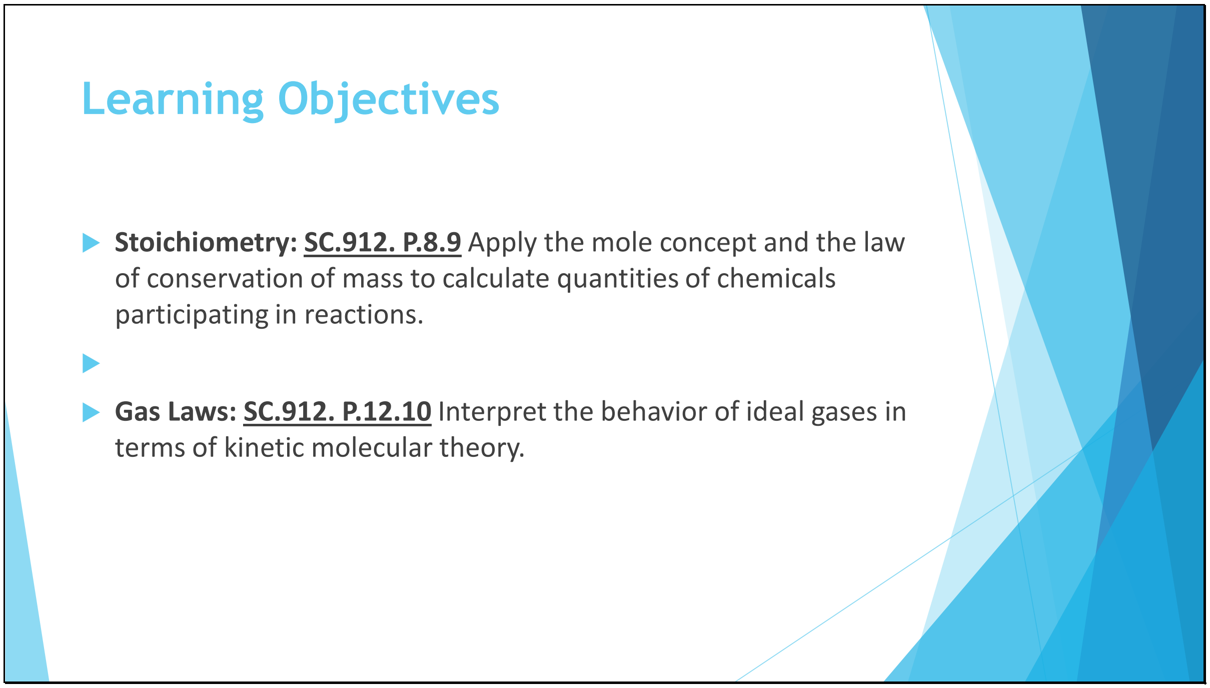
PowerPoint Presentation/Class Discussion

(Days 3 and 4)

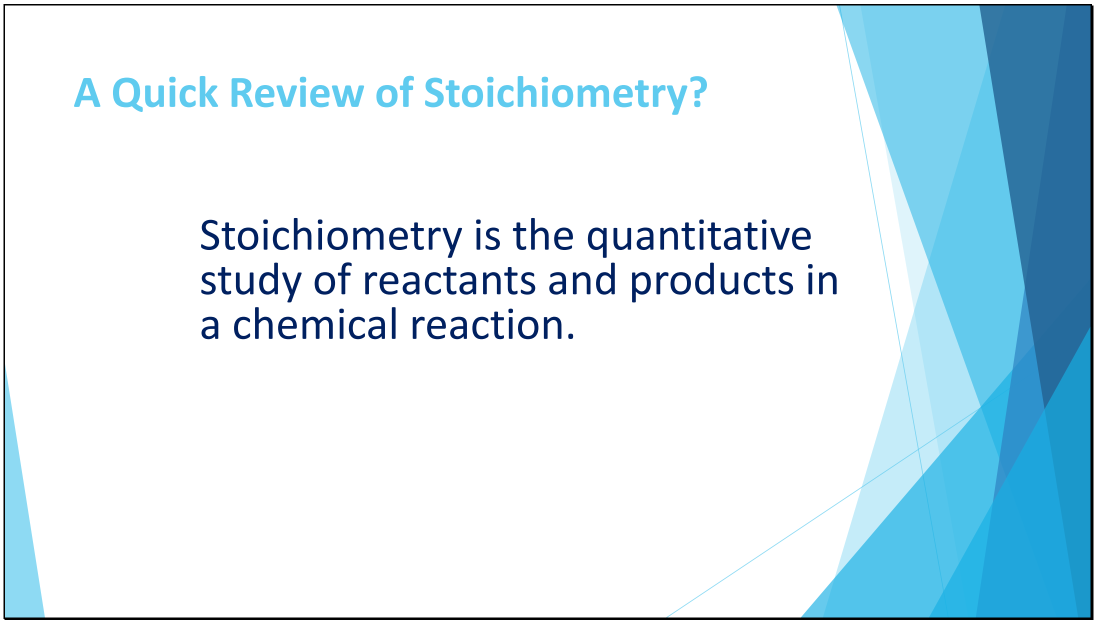
Slide 1



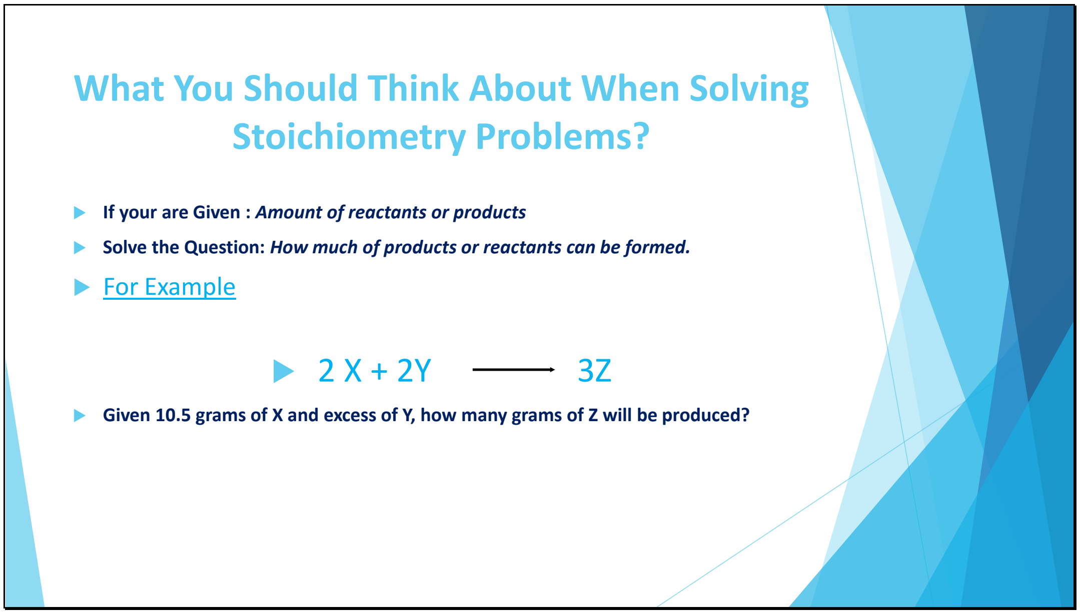
Slide 2


Learning Objectives
Stoichiometry: SC.912. P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.
Gas Laws: SC.912. P.12.10 Interpret the behavior of ideal gases in terms of kinetic molecular theory.

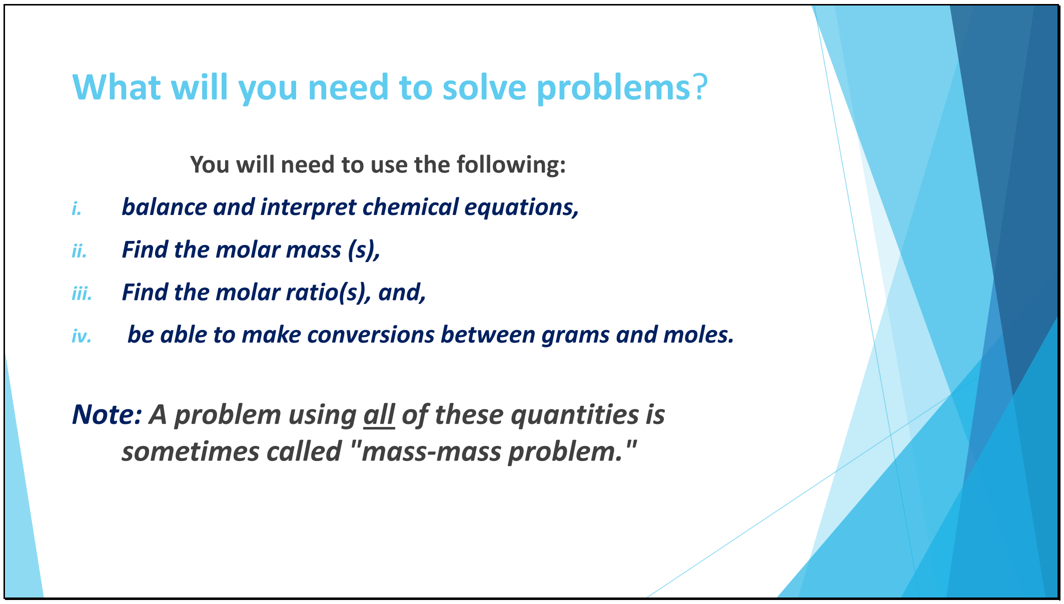
Slide 3


A Quick Review of Stoichiometry?
Stoichiometry is the quantitative study of reactants and products in a chemical reaction.

Slide 4

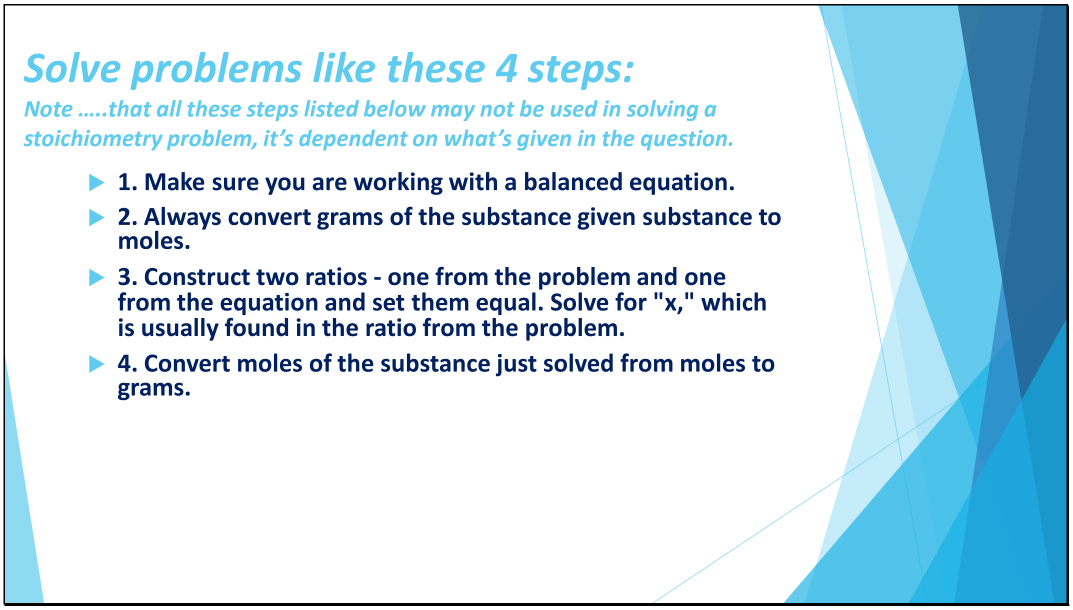

What You Should Think About When Solving Stoichiometry Problems?
If your are Given : Amount of reactants or products
Solve the Question: How much of products or reactants can be formed.
For Example
2 X + 2Y → 3Z
Given 10.5 grams of X and excess of Y, how many grams of Z will be produced?

Slide 5

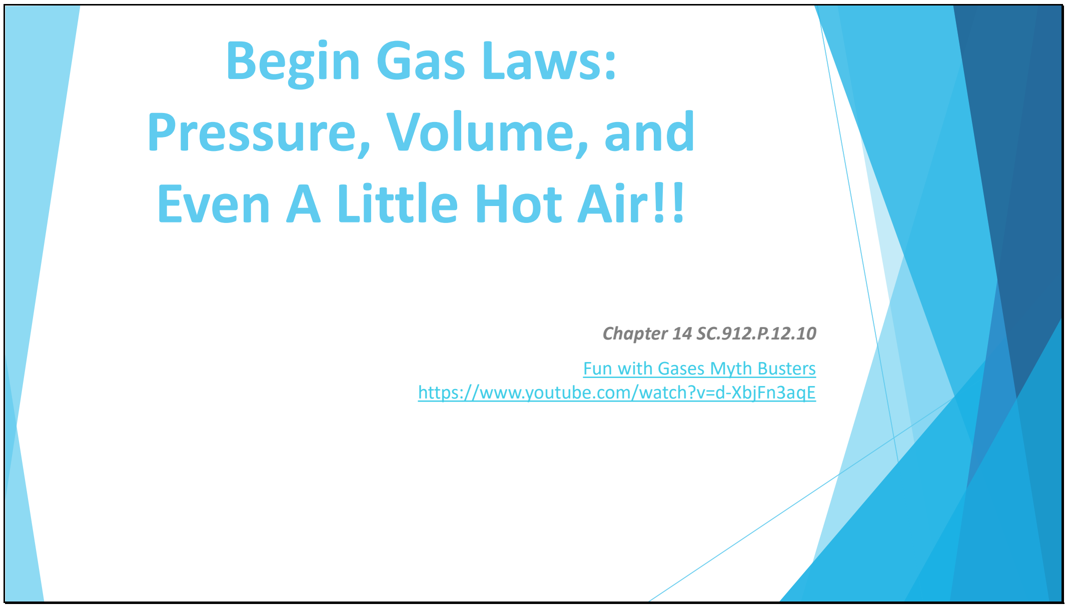


What will you need to solve problems?
You will need to use the following:
i. balance and interpret chemical equations,
ii. Find the molar mass (s),
iii. Find the molar ratio(s), and,
iv. be able to make conversions between grams and moles.
Note: A problem using all of these quantities is sometimes called "mass-mass problem."

Slide 6

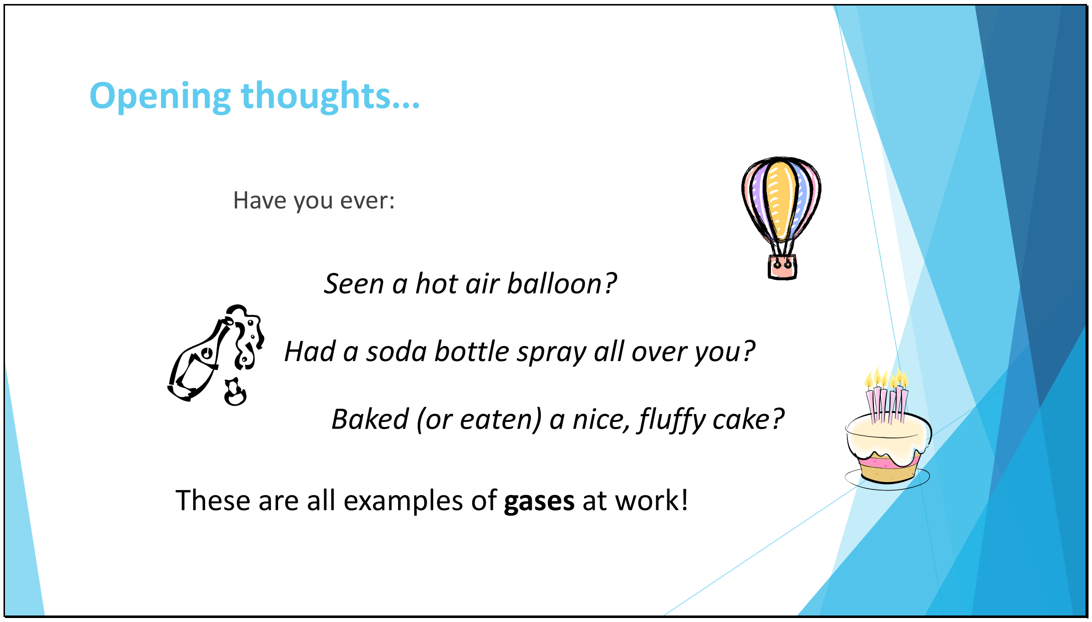

Solve problems like these 4 steps:
Note …..that all these steps listed below may not be used in solving a stoichiometry problem, it's dependent on what's given in the question.
1. Make sure you are working with a balanced equation.
2. Always convert grams of the substance given substance to moles.
3. Construct two ratios - one from the problem and one from the equation and set them equal. Solve for "x," which is usually found in the ratio from the problem.
4. Convert moles of the substance just solved from moles to grams.

Slide 7



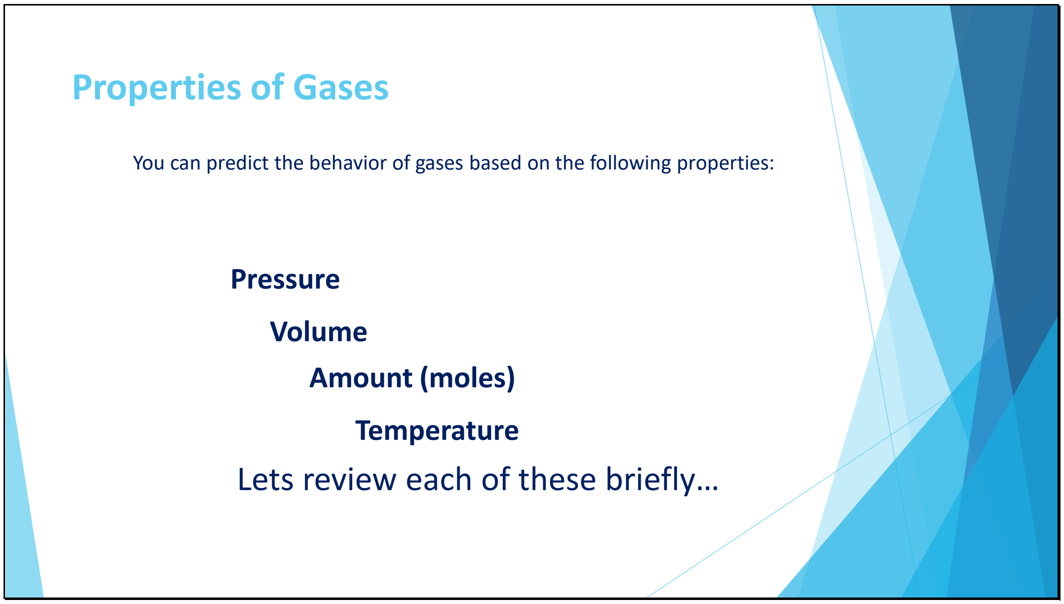
Begin Gas Laws:
Pressure, Volume, and
Even A Little Hot Air!!
Chapter 14 SC.912.P.12.10
Fun with Gases Myth Busters
https://www.youtube.com/watch?v=d-XbjFn3aqE

Slide 8

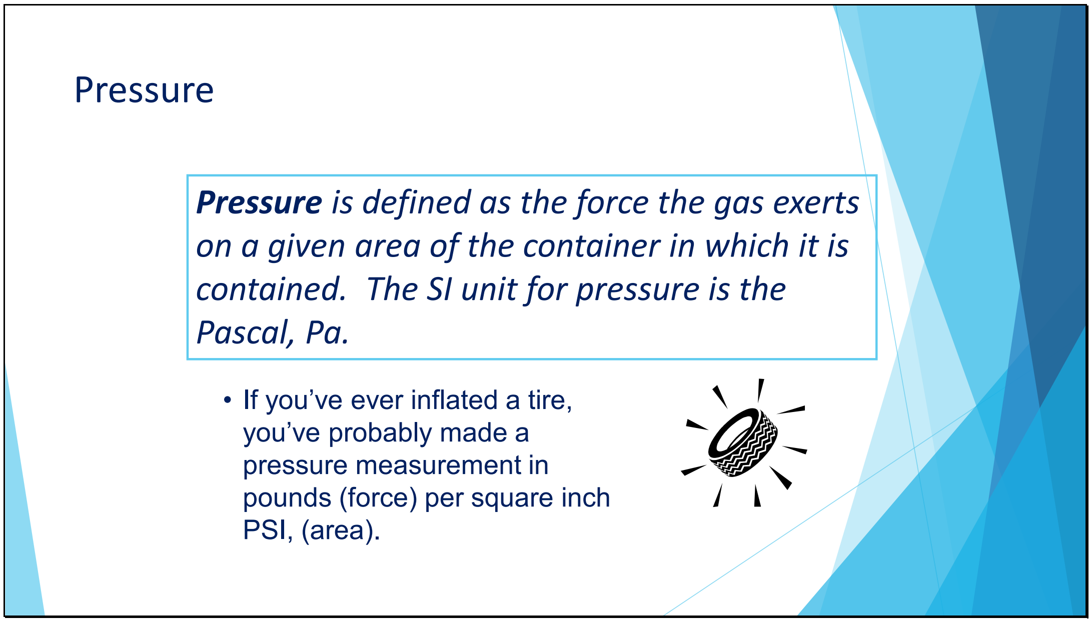


Opening thoughts…
Have you ever:
Seen a hot air balloon?
Had a soda bottle spray all over you?
Baked (or eaten) a nice, fluffy cake?
These are all examples of gases at work!

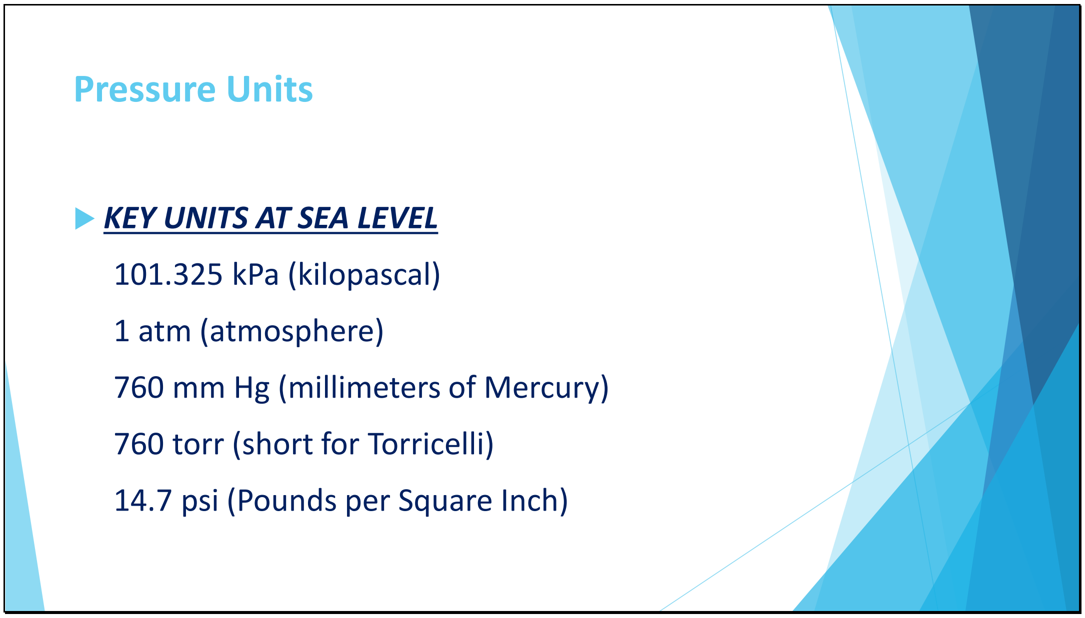
Slide 9


Properties of Gases
You can predict the behavior of gases based on the following properties:
Pressure
Volume
Amount (moles)
Temperature
Lets review each of these briefly…

Slide 10


Pressure
Pressure is defined as the force the gas exerts on a given area of the container in which it is contained. The SI unit for pressure is the Pascal, Pa.
If you've ever inflated a tire, you've probably made a pressure measurement in pounds (force) per square inch PSI, (area).

Slide 11


Pressure Units
KEY UNITS AT SEA LEVEL
101.325 kPa (kilopascal)
1 atm (atmosphere)
760 mm Hg (millimeters of Mercury)
760 torr (short for Torricelli)
14.7 psi (Pounds per Square Inch)

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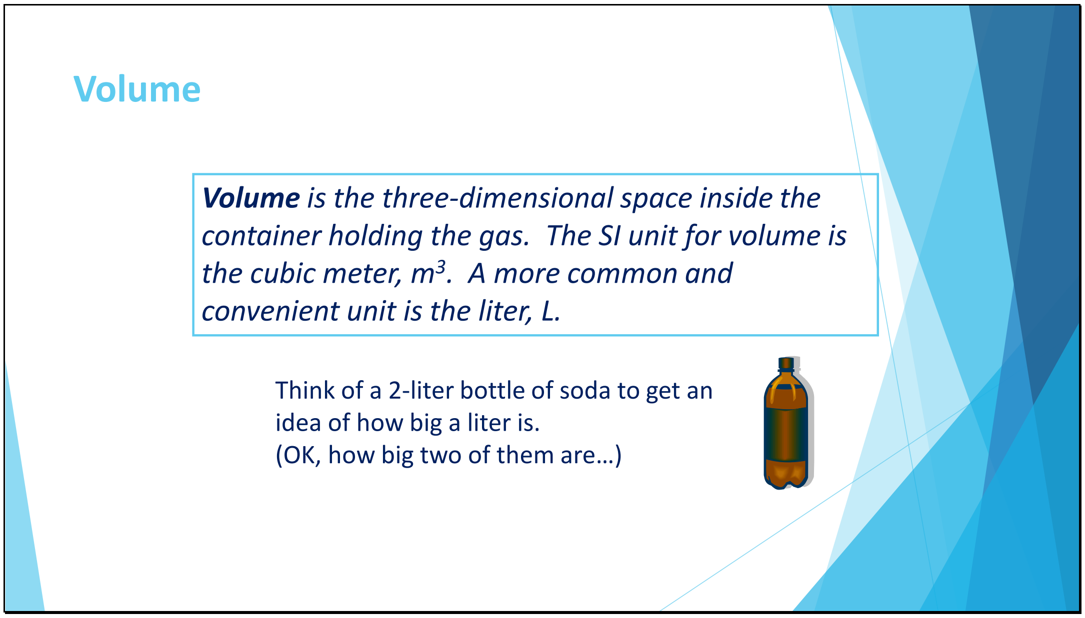
Slide 12



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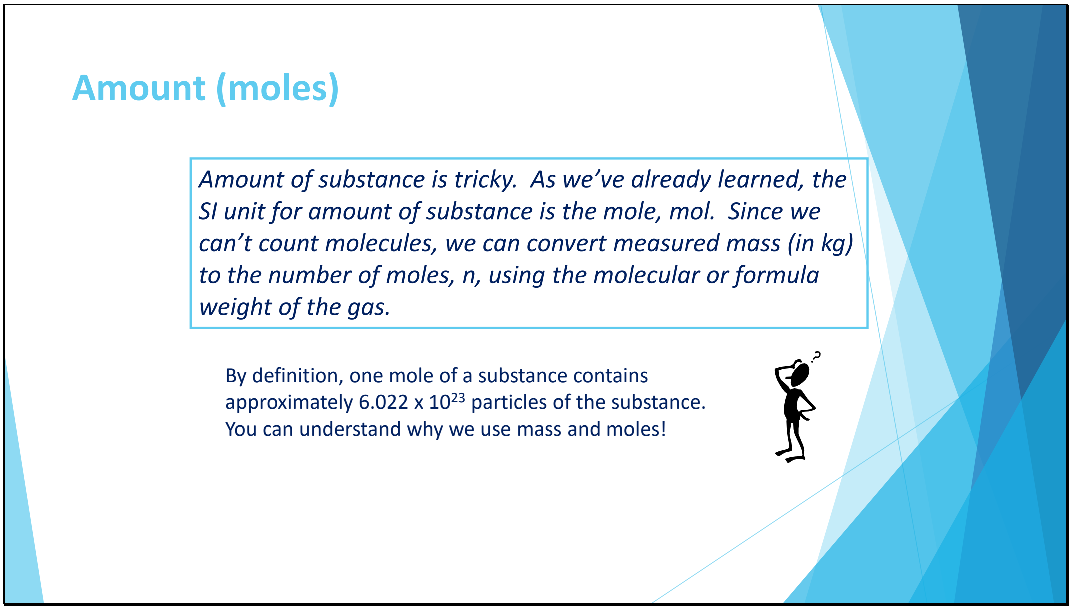

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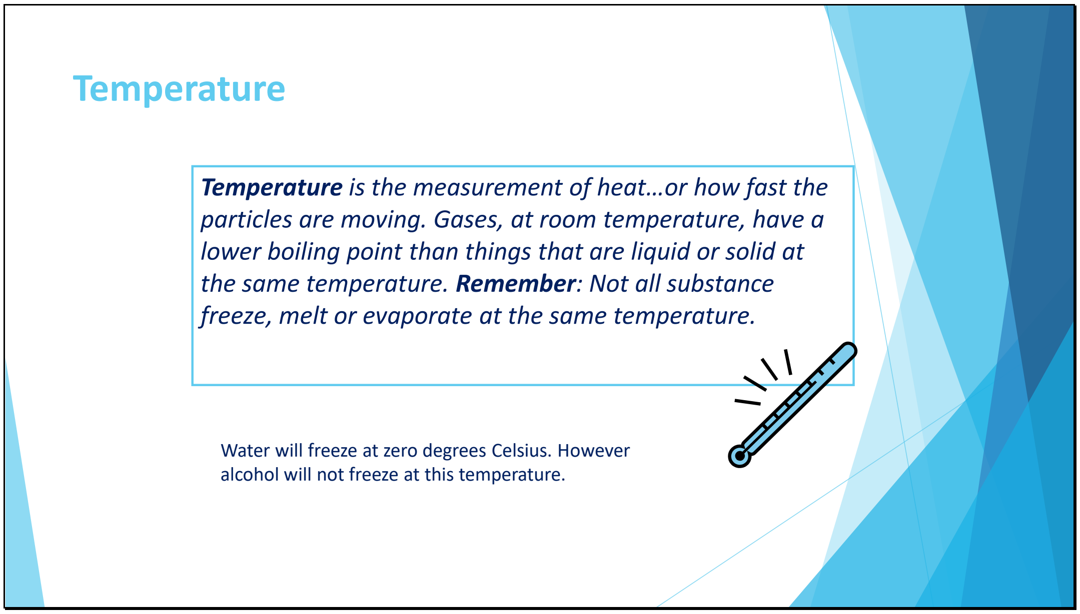
Slide 14



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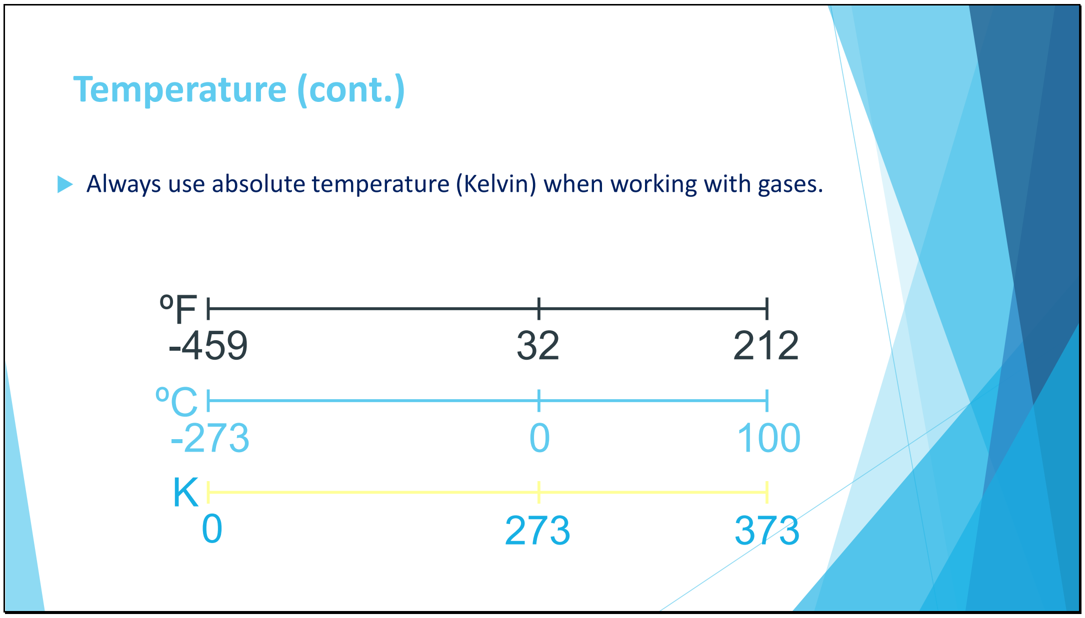
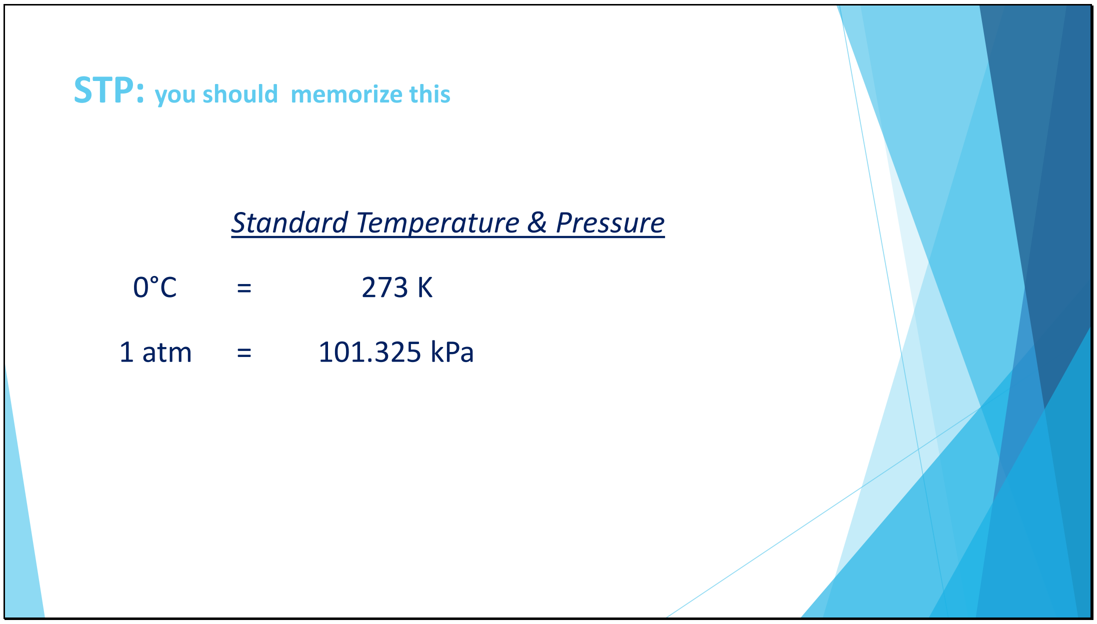
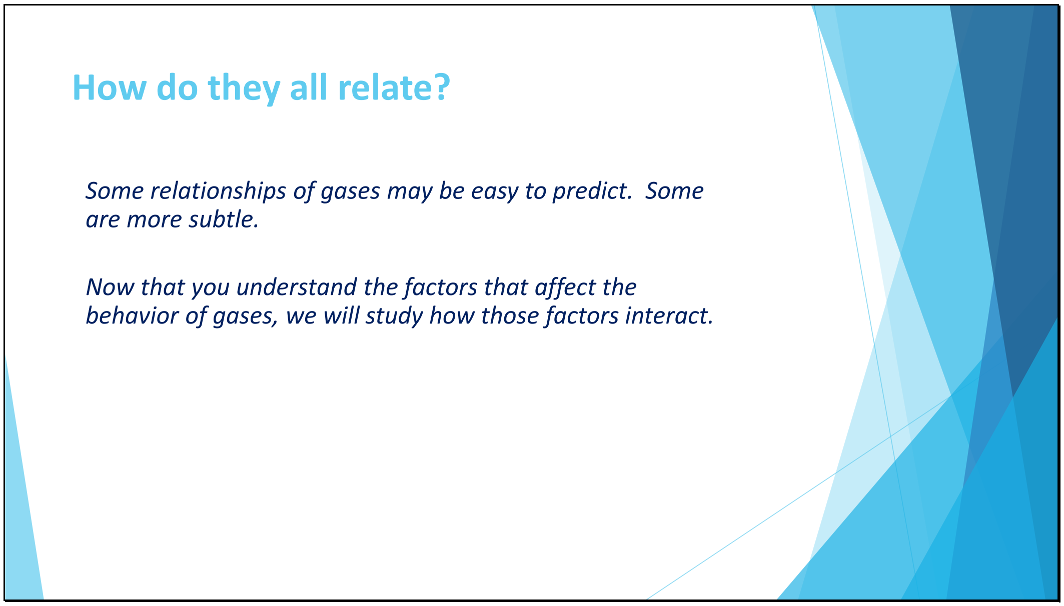

Temperature (cont.)
Always use absolute temperature (Kelvin) when working with gases.
ºF
-459
32
212
ºC
-273
0
100
K
0
273
373

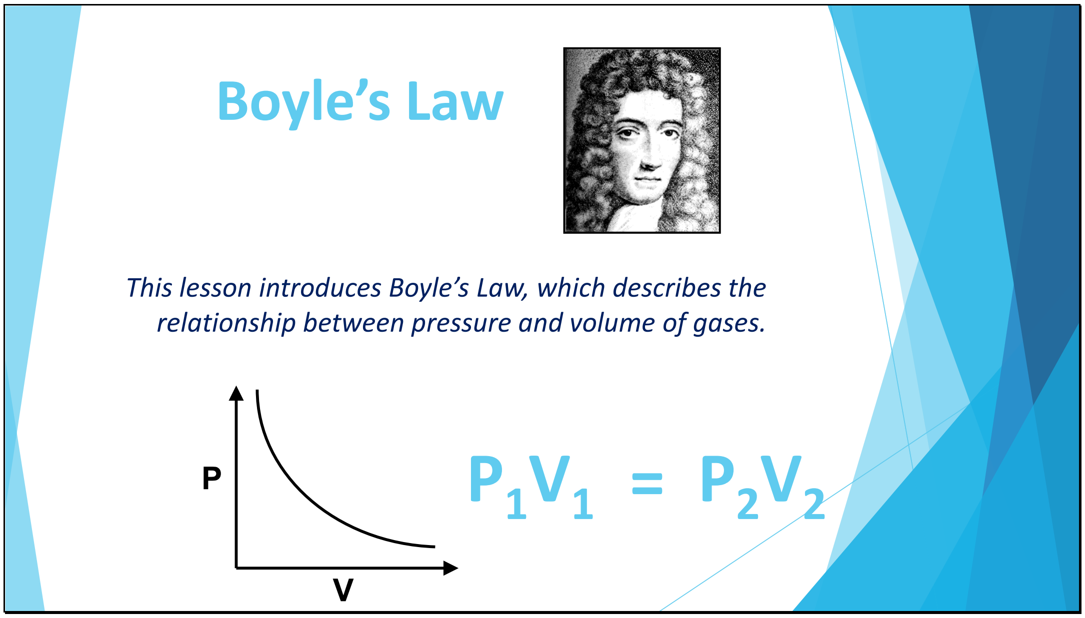
Slide 16


STP: you should memorize this
Standard Temperature & Pressure
0°C = 273 K
1 atm = 101.325 kPa

Slide 17

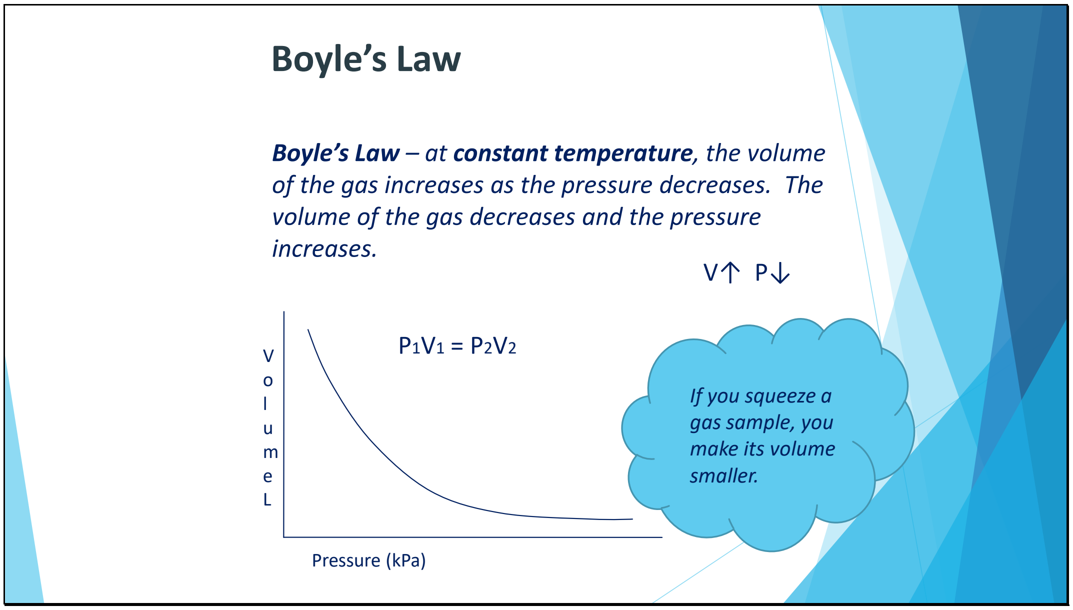

How do they all relate?
Some relationships of gases may be easy to predict. Some are more subtle.
Now that you understand the factors that affect the behavior of gases, we will study how those factors interact.

Slide 18

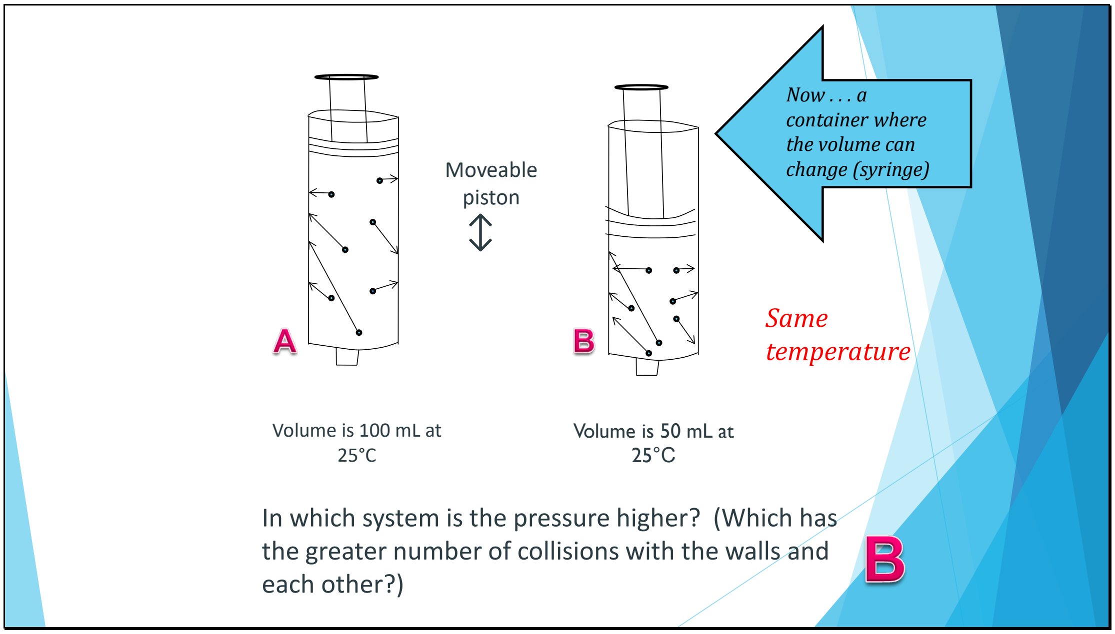


Boyle's Law
This lesson introduces Boyle's Law, which describes the relationship between pressure and volume of gases.
P
V
$P_1V_1 = P_2V_2$

Slide 19


Boyle's Law
Boyle's Law – at constant temperature, the volume of the gas increases as the pressure decreases. The volume of the gas decreases and the pressure increases.
V↑ P↓
P1V1 = P2V2
VolumeL
Pressure (kPa)
If you squeeze a gas sample, you make its volume smaller.

Slide 20


Moveable piston
Now . . . a container where the volume can change (syringe)
A
B
Same temperature
Volume is 100 mL at 25°C
Volume is 50 mL at 25°C
In which system is the pressure higher? (Which has the greater number of collisions with the walls and each other?)
B

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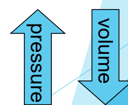
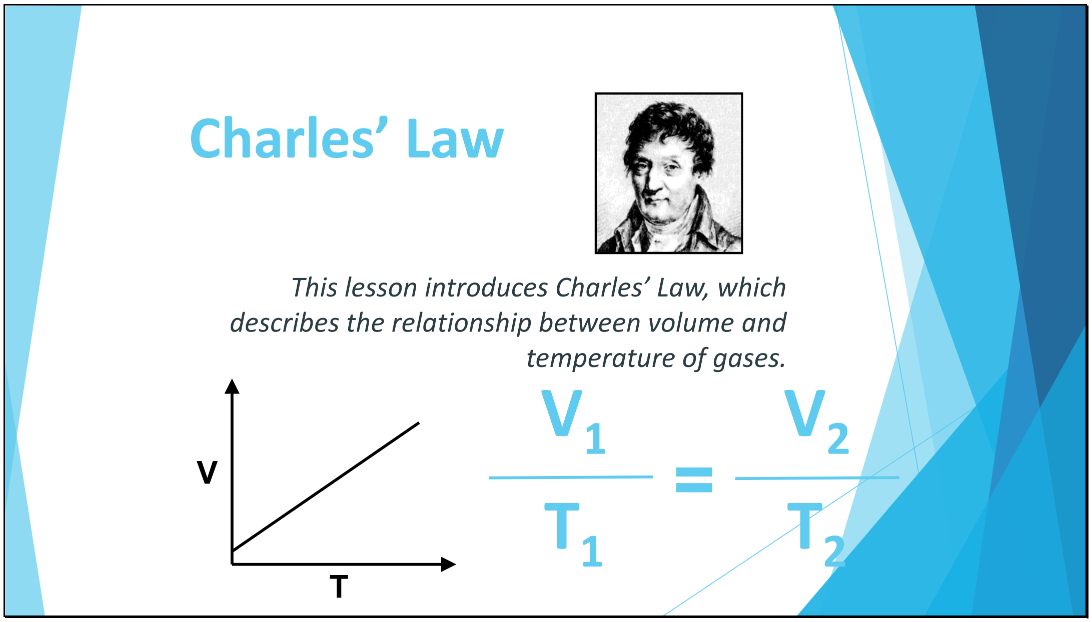
Slide 21

Boyle's Law

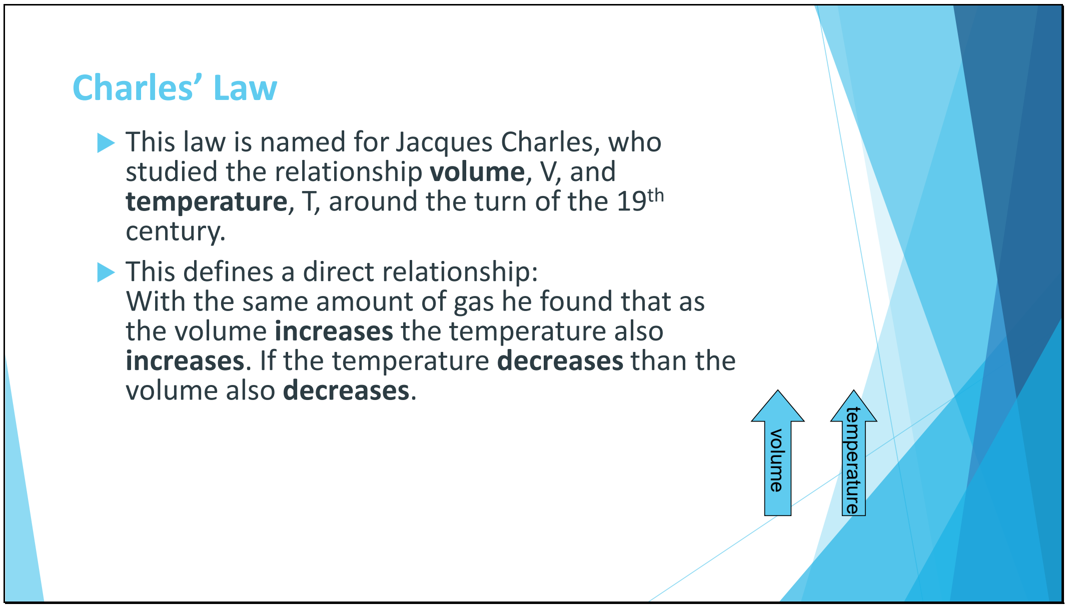
- This law is named for Charles Boyle, who studied the relationship between **pressure**, p, and **volume**, V, in the mid-1600s.
- Boyle determined that for the same **amount** of a gas at constant **temperature,** results in an **inverse relationship**:
  when one goes up, the other
  comes down.



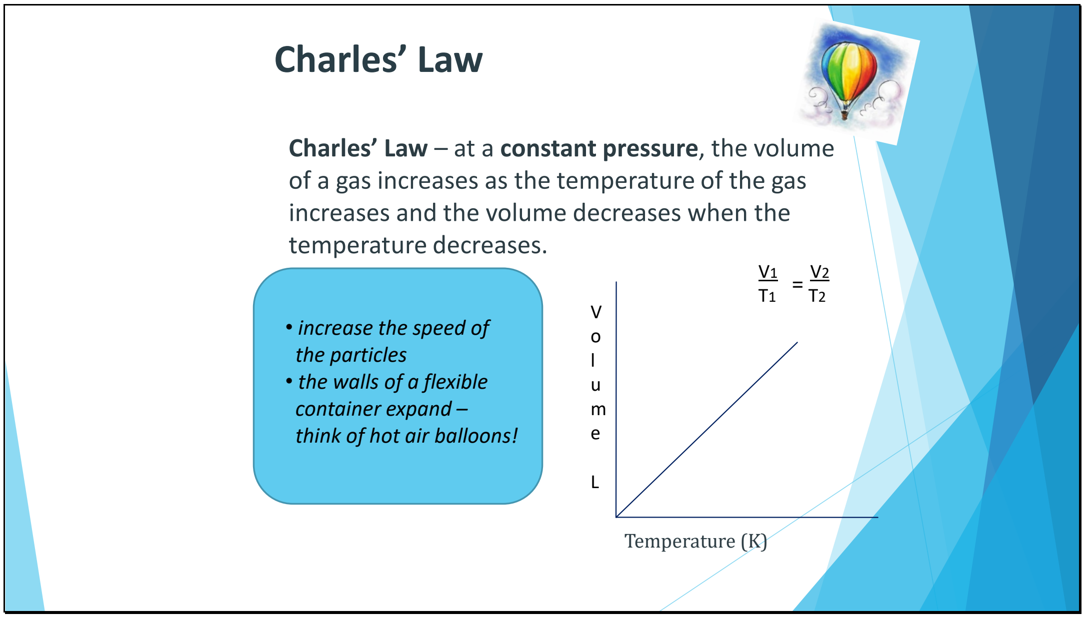
Slide 22


Charles' Law
This lesson introduces Charles' Law, which describes the relationship between volume and temperature of gases.
V
T
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Slide 23


Charles' Law
This law is named for Jacques Charles, who studied the relationship **volume**, V, and **temperature**, T, around the turn of the 19th century.
This defines a direct relationship: With the same amount of gas he found that as the volume **increases** the temperature also **increases**. If the temperature **decreases** than the volume also **decreases**.
volume
temperature

Slide 24


Charles' Law
Charles' Law – at a constant pressure, the volume of a gas increases as the temperature of the gas increases and the volume decreases when the temperature decreases.
• increase the speed of the particles
• the walls of a flexible container expand – think of hot air balloons!
V1/T1 = V2/T2
Volume L
Temperature (K)

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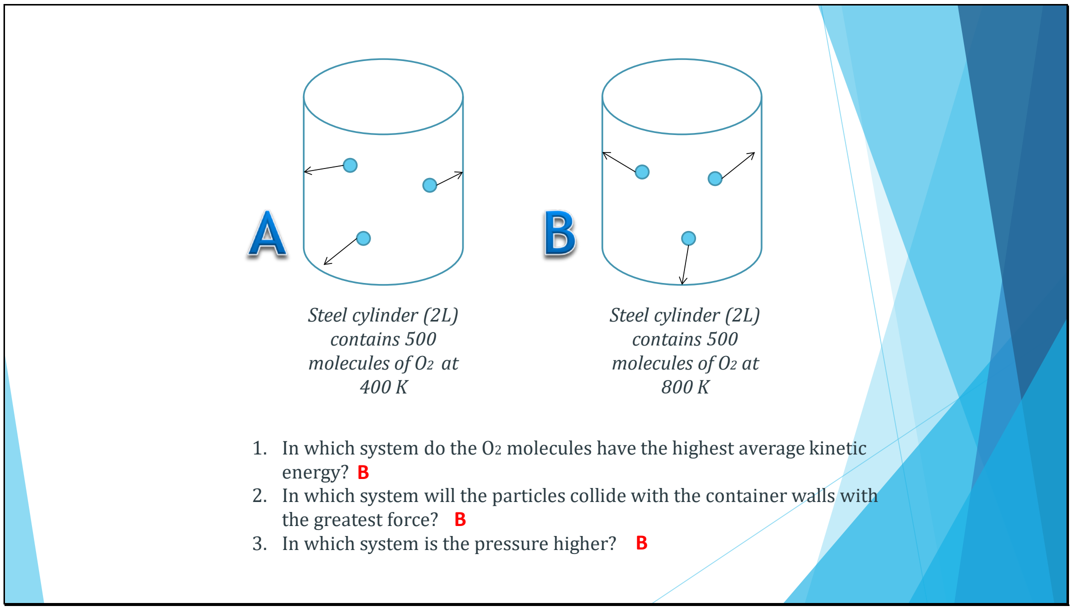
Slide 25



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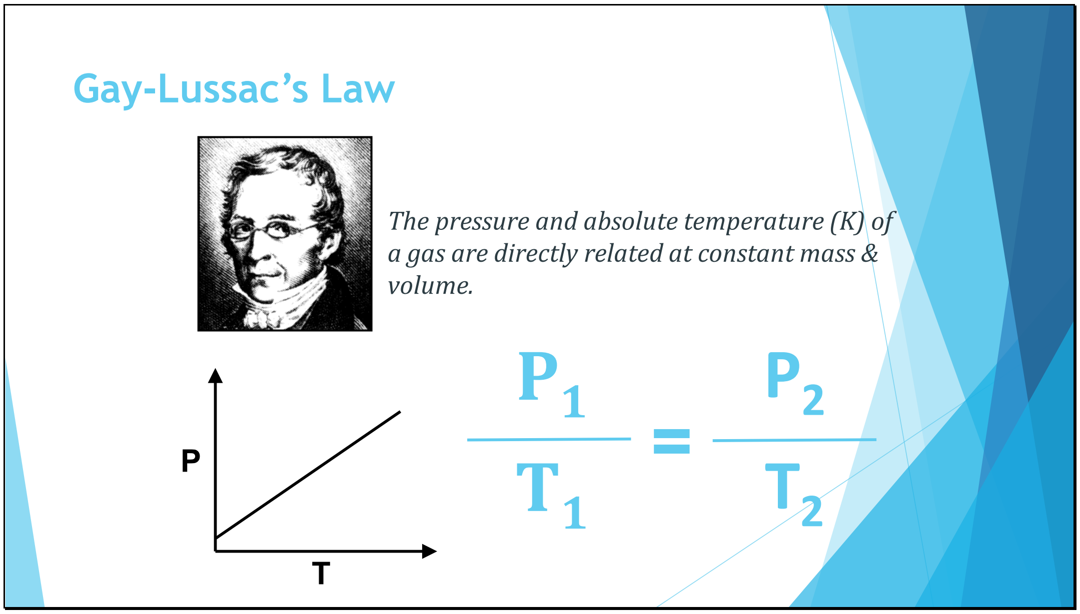

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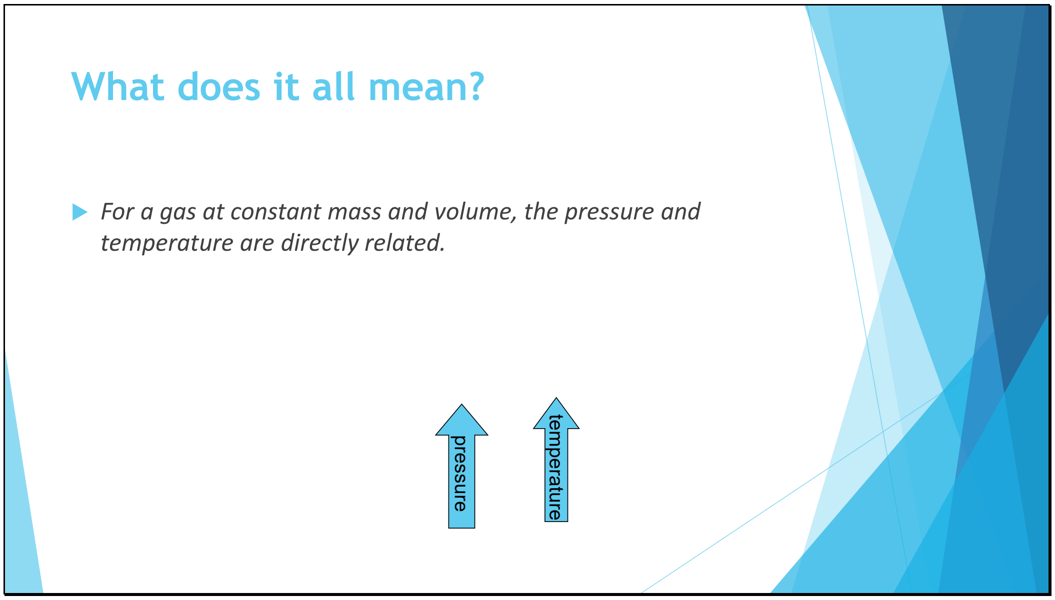
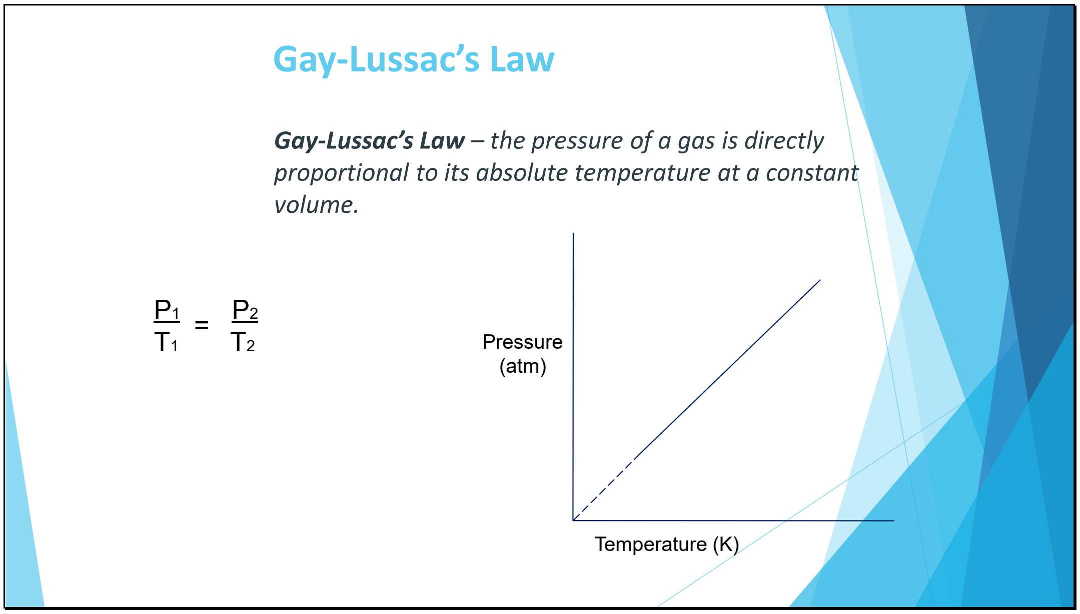
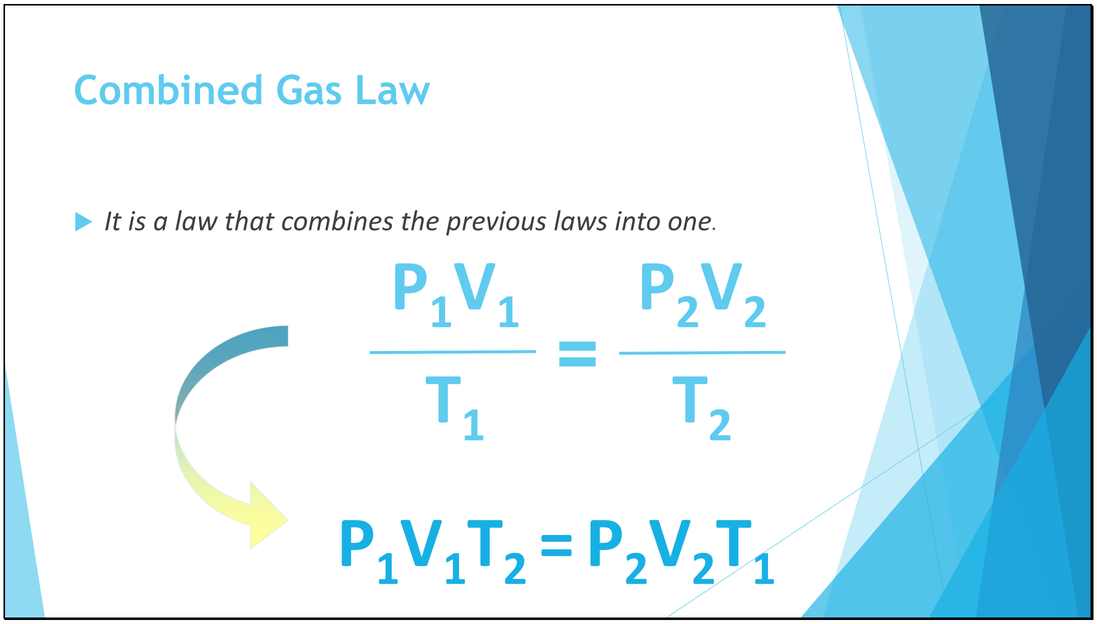

What does it all mean?
For a gas at constant mass and volume, the pressure and temperature are directly related.
pressure
temperature

Slide 28


Gay-Lussac's Law
Gay-Lussac's Law – the pressure of a gas is directly proportional to its absolute temperature at a constant volume.
P1/T1 = P2/T2
Pressure (atm)
Temperature (K)

Slide 29


Combined Gas Law
It is a law that combines the previous laws into one.
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
$P_1V_1T_2 = P_2V_2T_1$

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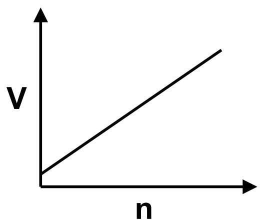
Slide 30

Avogadro's Principle

- Equal volumes of gases contain equal numbers of moles
  - at constant temp & pressure
  - true for any ideal gas



$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

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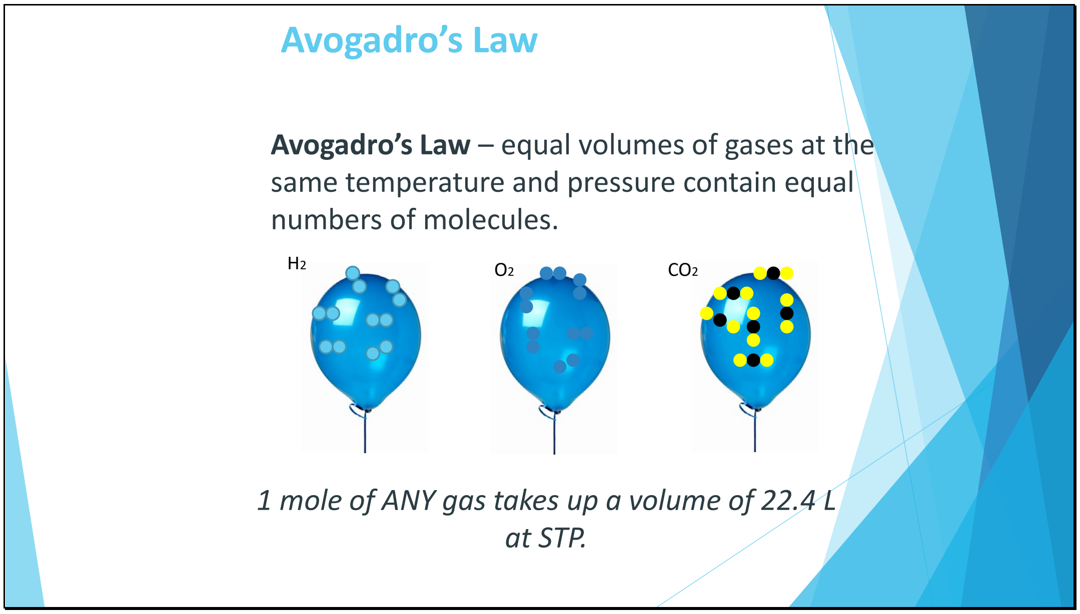
Slide 31



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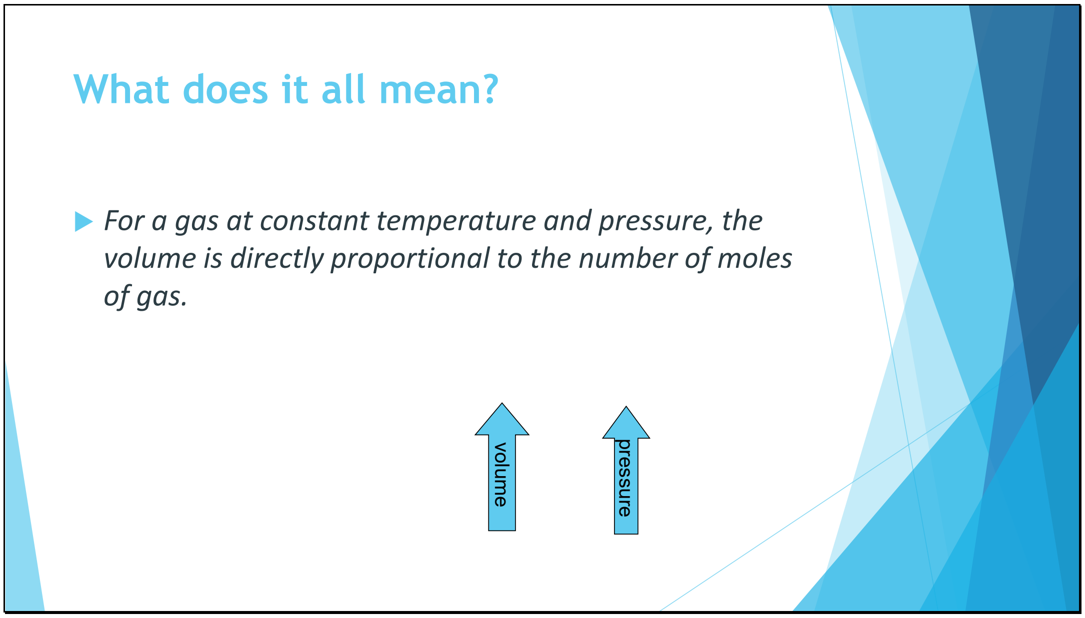

What does it all mean?
For a gas at constant temperature and pressure, the volume is directly proportional to the number of moles of gas.
volume
pressure

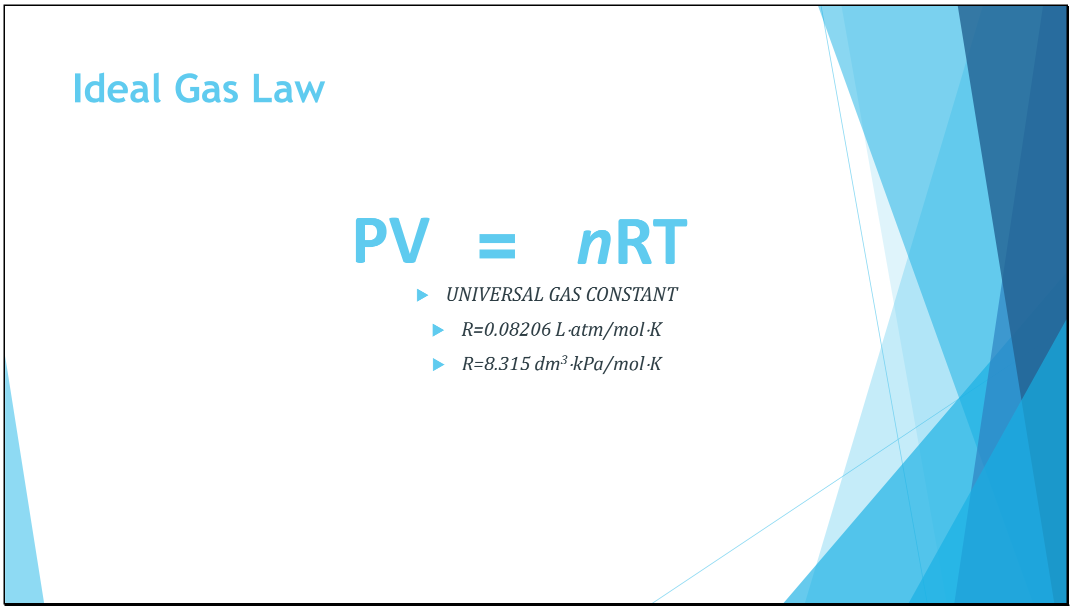
Slide 33

Dalton’s Law of Partial Pressures

The total pressure of a mixture of gases equals the sum of the partial pressures of the individual gases.

$$P_{total} = P_1 + P_2 + \dots$$

Slide 34


Ideal Gas Law
PV = nRT
UNIVERSAL GAS CONSTANT
R=0.08206 L·atm/mol·K
R=8.315 dm³·kPa/mol·K

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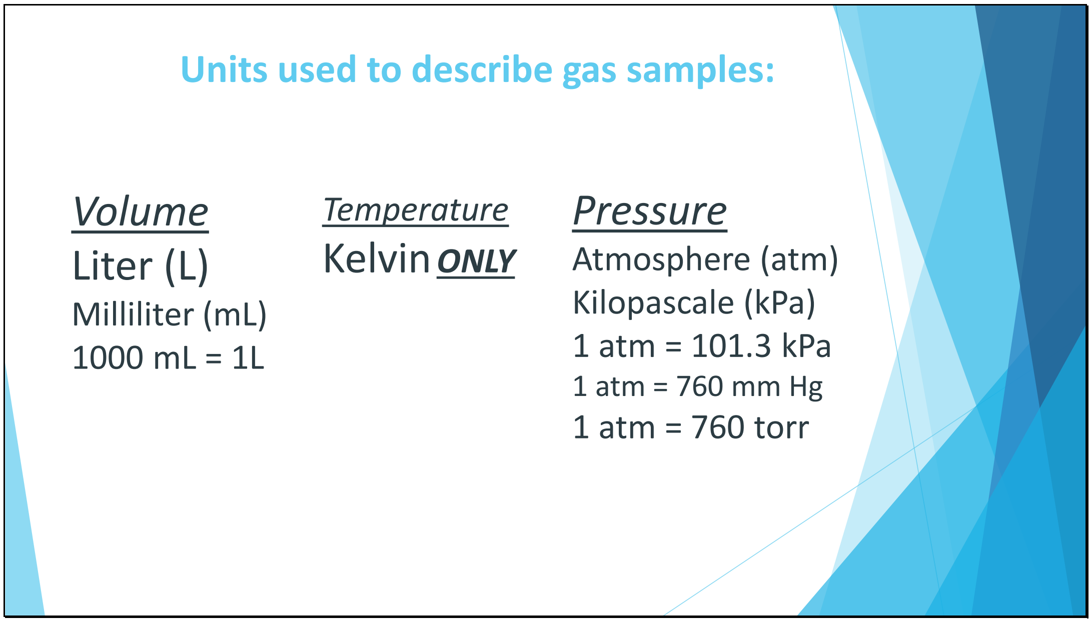

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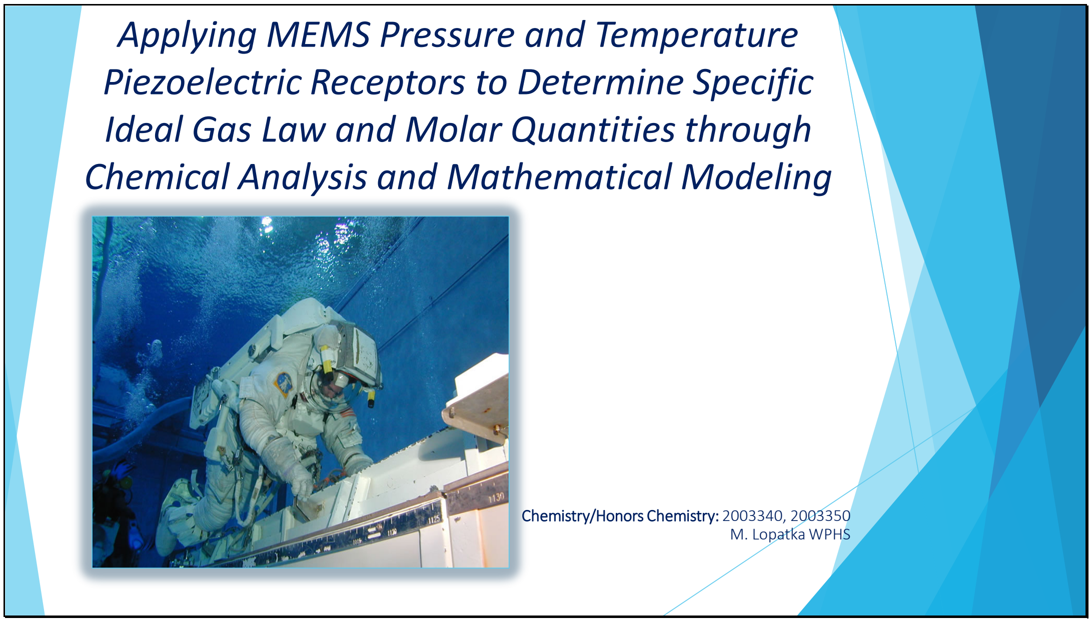
Slide 37


Applying MEMS Pressure and Temperature Piezoelectric Receptors to Determine Specific Ideal Gas Law and Molar Quantities through Chemical Analysis and Mathematical Modeling
Chemistry/Honors Chemistry: 2003340, 2003350
M. Lopatka WPHS

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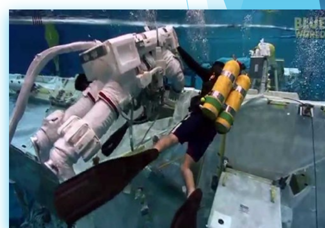
Lab Lesson Plan and Lab Activity

- Daily Procedures

- Day 1: Students will take a pretest, then research specific topics (via a research activity) related to the learning objectives.
- Day 2: Students will continue their research and use this research to begin the first steps of the scientific method (learning objective 1).
- Day 3: Lecture/Class Discussion (learning objectives 2 and 3).
- Day 4: Solving Stoichiometry and Gas Laws Problems.
- Day 5: Begin the lab activity and collect data.
- Day 6: Continue the lab activity. Use appropriate evidence and reasoning to justify data explanations to other lab groups.
- Day 7: Begin writing rough draft of lab report and complete any lab activities.
- Day 8: Write lab report and submit the rough draft.
- Day 9: Evaluate the merits of the explanations produced by others, one-page report with specific examples and justifications.
- Day 10: Class Discussion and Post Test



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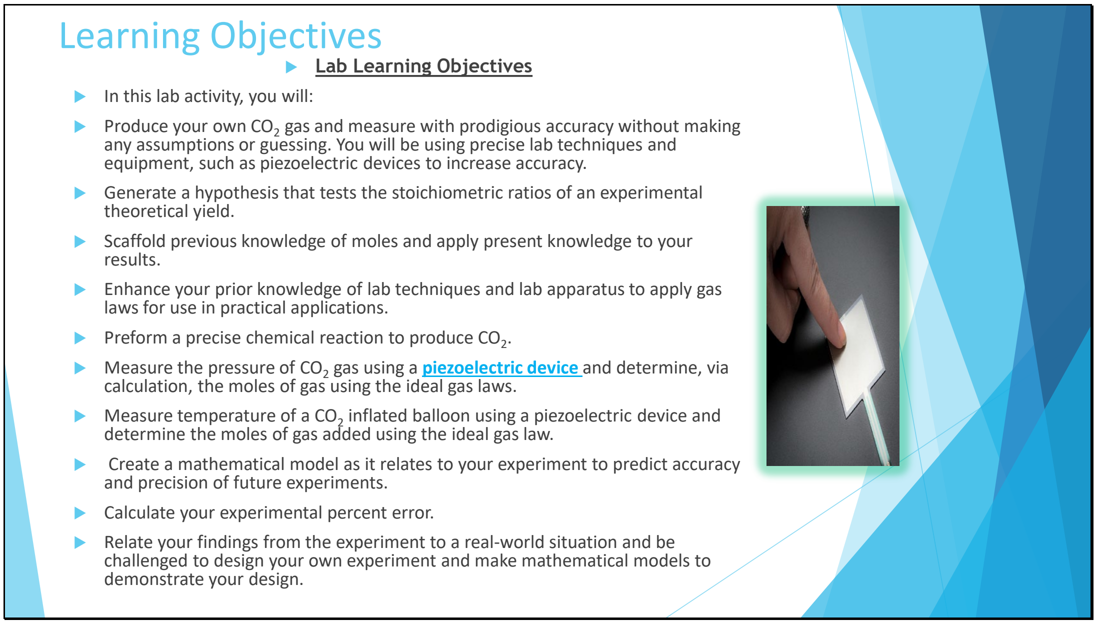
Slide 39



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Solving Stoichiometry/Gas Laws Problems

(Days 4 and 5)

Stoichiometry and Gas Laws Problems: Solve the following problems and be sure to show your work. You may use internet resources, your textbook, the periodic table, chemistry formulas, and you may discuss any of these problems with other students. Getting to the solution is important, however it is more important to understand how to solve each problem type.

1. How many moles of Aluminum (Al) are found in 5.25 moles of Aluminum Sulfide Al_2S_3?

2. Determine the mass of 1.00 mole for each of the elements/compounds below:
   a. Elemental Oxygen
   b. Sulfur
   c. CO_2
   d. Li_2CO_3
   e. $Sr(NO_3)_2$

3. Find the percentage composition of each element from the compounds below:
   a. Hydrochloric Acid, HCl
   b. Sodium Bicarbonate, $NaHCO_3$

4. Balance the equations below:
   a. ___$Na_2S_2O_{3(aq)}$ + ___$Cl_{2(g)}$ + ___$H_2O_{(aq)}$ + ___$NaHSO_{4(aq)}$ + ___$HCl_{(aq)}$
   b. ___$Al_{(s)}$ + ___$Fe_2O_{3(s)}$ + ___$Al_2O_{3(s)}$ + ___Fe

5. Aluminum sulfate is produced from the following balanced chemical reaction:

   ___$AlCl_{3(aq)}$ + ___$H_2SO_{4(aq)}$ + $Al_2(SO_4)_{3(aq)}$ + ___$HCl_{(aq)}$

   Aluminum sulfate is very soluble in water. To isolate $Al_2(SO_4)_3$ the final solution has to be evaporated until it is completely dehydrated. HCl can be heated to a temperature of about 200°C to causing this dehydration to occur. A chemistry student measures a mass of 25.0g of $AlCl_3$ and reacts this with 30.0g of H_2SO_4. Following this reaction, the student measures an isolated yield of 28.46g of pure $Al_2(SO_4)_3$. What is the percent yield of $Al_2(SO_4)_3$ from this experiment? **Hints:** You will need to follow the protocol for solving stoichiometry problems in the following order:
   a. Make sure the equation is balanced.

b. Make sure to change g to moles.
c. Find the limiting reagent.
d. Get the mole ratio from the balanced equation to find moles of $Al_2(SO_4)_3$.
e. Change moles of $Al_2(SO_4)_3$ to grams
f. Determine the percent yield using actual and theoretical values.

6. Oxygen gas has a volume of 500 mL at 500 mm of Hg. What will its final volume be if the pressure is changed to 300 mm of Hg?

7. Nitrogen gas in a flexible container has a volume of 10 liters at 25°C. What is the new volume, in liters, of nitrogen gas if the temperature is increased to 75°C?

8. The air in a SCUBA tank left in a hot car in Florida in August is found to be a temperature 40°C at a pressure of 3000 psi. If the air in the SCUBA tank reaches a pressure of 5000 psi the burst disk in the tank will "pop" safely releasing all of the air in the tank. Assuming the volume stays the same, at what temperature will the bust disk "pop"?

9. Neon gas has a volume of 200 ml at STP. If the volume of the gas changes to 240 ml at 30°C and what is the ending pressure in atm?

10. A chemistry student has an unidentified amount of CO_2 gas in a container and measures the gas parameters to be:
    a. 50°C at a
    b. 2.5 atm
    c. 50ml

    How many moles of CO2 does the student have in the container?

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Lab Activity

(Days 6,7 and 8)

Lab Learning Objectives

In this lab activity, you will:

1. Produce your own CO_2 gas and measure with prodigious accuracy without making any assumptions or guessing. You will be using precise lab techniques and equipment, such as piezoelectric devices to increase accuracy.
2. Generate a hypothesis that tests the stoichiometric ratios of an experimental theoretical yield.
3. Scaffold previous knowledge of moles and apply present knowledge to your results.
4. Enhance your prior knowledge of lab techniques and lab apparatus to apply gas laws for use in practical applications.
5. Preform a precise chemical reaction to produce CO_2.
6. Measure the pressure of CO_2 gas using a piezoelectric device and determine, via calculation, the moles of gas using the ideal gas laws.
7. Measure temperature of a CO_2 inflated balloon using a piezoelectric device and determine the moles of gas added using the ideal gas law.
8. Create a mathematical model as it relates to your experiment to predict accuracy and precision of future experiments.
9. Calculate your experimental percent error.
10. Relate your findings from the experiment to a real-world situation and be challenged to design your own experiment and make mathematical models to demonstrate your design.

Materials/Equipment

1. Piezoelectric Pressure probe with tubing and a quick release coupler.
2. Piezoelectric Temperature probe
3. 12.7cm or smaller Balloon
4. Chemicals: 6M HCL (in a 150ml beaker), Sodium Bicarbonate ($NaHCO_3$)
5. 250 ml Erlenmeyer flask with Safety glasses and aprons
6. 2000 ml graduated cylinder to measure CO_2 volume.
7. Electronic Balance with weighing tray
8. Funnel
9. Scoopula

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Safety Considerations

1. Wear safety goggles and aprons. HCl is a powerful acid, that will burn and can make holes in your cloths.
2. Under high pressure, the balloon can pop.

Pre-Lab Questions

1. Generate a problem (a question you ask) and hypothesis (if/than statement) from your background research.
2. Assume that you have a balloon with a fixed volume that is kept at constant temperature. What procedure(s) might you follow to increase the pressure of the balloon?
3. Consider the following balanced chemical equation: **$NaHCO_3$ + HCl ➡ NaCl + H_2O + CO_2** Using your knowledge of stoichiometry, determine the theoretical yield of carbon dioxide in grams using 2.6 grams of sodium bicarbonate reacted with an excess of hydrochloric acid.
4. Using your theoretical yield from question 2, assume a chemistry student performs the chemical reaction above with 2.5 grams of sodium bicarbonate and obtains a yield of 1.2g of CO_2. Calculate the % error **and** % yield for the student's experiment?
5. Can you determine any relationship(s) between your calculations of experimental % error and the % yield, if any?
6. If more moles of gas are placed into the balloon at a constant temperature, what will happen to the pressure? Explain why?
7. Explain and provide one example why accuracy and precision are important in any chemical experiment?

$$\%\ \text{Error} = \left|\frac{\text{measured - accepted}}{\text{accepted}}\right| \text{x100}$$

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

Procedures:

1. Put on your safety goggles and lab apron.
2. Place a weighing tray on the electronic balance.
3. Tare the electronic balance to read 0.00 g
4. Using a scoopula measure 2.5 g of sodium bicarbonate ($NaHCO_3$) on the weighing tray.
5. Record the exact mass of the sodium bicarbonate on a data table.
6. Obtain a 150 mL beaker of hydrochloric acid (HCl) and **carefully** pour all the acid into a 250 mL Erlenmeyer flask. (*Rinse skin with cold water if acid comes into contact)*
7. Obtain a deflated balloon, one-hole rubber stopper, and tubing.
8. Set up the flask with the rubber stopper and tubing so that you can collect the CO2 gas into the balloon during the chemical reaction.
9. Stretch open the balloon neck, and carefully and slowly pour the sodium bicarbonate into the deflated balloon by using the funnel to transfer the sodium bicarbonate into the balloon over the sink. (Avoid spilling)
10. When all of the sodium bicarbonate has been added, tap the side of the balloon to make sure the powder is inside the main part of the balloon and none is in the opening.

11. While one partner pinches off the neck of the balloon to keep the powder in the balloon, the other partner stretches the mouth of the balloon over the mouth of the flask. Then **Very Carefully** stretch the balloon end over the mouth of the flask, making sure the $NaHCO_3$ does not fall into the flask.
12. Once the balloon nozzle has been placed over the mouth of the flask, have a partner hold it on so that it cannot fall off the Erlenmeyer flask.
13. Once the balloon is firmly fastened, the other partner should stop pinching the balloon to release all of the powder from the balloon into the flask containing the acid.
14. While the balloon inflates, keep holding the flask neck to keep the balloon on the flask so none of the gas escapes
15. When the reaction stops (*no more bubbles*), pinch the end of the balloon and **slowly peel** it from the flask
16. Tightly tie or clamp off the balloon end so it is closed (*avoid losing any gas from the balloon)* Using a paper towel, carefully wipe off any liquid that splashed up onto the balloon nozzle, and rinse your hands.
17. Using the piezoelectric pressure meter carefully insert the end tubing into the balloon without releasing any of the CO_2 gas. Record your pressure the data table.
18. Clamp or tie the balloon without releasing any of the CO_2 gas.
19. Using a 2000 ml graduated cylinder, partially filled with water of a known quantity, submerge the balloon into the cylinder and measure the displacement, this represents the volume of the balloon, and record this on your data table.
20. Measure the room temperature with a piezoelectric thermometer to a 0.1 °C and record it in the data table.
21. Dispose of the balloon and return all equipment
22. Rinse the flask in lab sink
23. Wash your hands and complete lab report.

Lab Questions

(Be sure to include your solutions in your lab report)

1. What happened to the pressure in the balloon following the chemical reaction?
2. What would happen to the pressure in the balloon if more sodium bicarbonate is added to the HCl?
3. Using PV = nrt, calculate the number of moles of CO_2 gas produced.
4. The number of moles of gas is inversely related to the pressure. True or false? Explain your answer.

5. Graph the linear regression of pressure vs sodium bicarbonate. The x-axis # of moles of CO_2 gas (independent variable) and pressure on the y-axis (dependent variable). You will have only one data point on your graph.
6. Determine the linear regression by drawing a straight line from the 0,0 point on your graph and through your one data point.
7. From your linear regression graph, are you able to make a mathematical model to predict the relationship between pressure and moles of a gas?
8. Does your hypothesis support your data? Explain!
9. What does the slope of the linear regression model represent in context with this experiment?
10. What does the y-intercept of the linear regression model represent in this experiment?
11. Provide insight to any sources of error that you may have had in your experiment.

Lab Analysis/Practical Application

At sea level, there is 1 atmosphere of air pressure is on your body. When diving in the National Buoyancy Lab (NBL), for roughly each 10 meters in the pool, one additional atmosphere of pressure is acting on the diver (at sea level there is one atmosphere). With a water temperature of 37°C in the NBL, a support diver consumes, on average, 14.16 liters of gas per minute for every atmosphere of pressure.

1. How many ***liters*** of gas would be required to keep a support diver down for 3 hours at a depth of 8 m? The surface of the NBL pool is at sea level.

2. How many moles of gas are consumed by a support diver during a 3-hour dive at a depth of 8 m?

3. Using a 2,832-liter twin cylinder dive tank system, how long could a support diver stay under water (at 8 m) before all the gas is used?

4. Using a 4,530-liter twin cylinder dive tank system, how long could a support diver stay at the bottom of the pool before all the gas was used?
5. Do the answers given in questions 3 and 4 give the maximum amount of time the support diver could stay at the depths listed? Explain your answer.

Data Table/Lab Report

(Days 9, 10, and 11)

1. Make your own lab table to collect data.
2. See separate document with your lab report format

Format for Writing the Lab Report

Lab Report Plan

Your lab report should contain the following components, and in this precise order:

1. **Title** – Clear and Concise Explanation of your Lab
2. **Abstract** – Very important, spend lots of time and thought writing this component.
3. **Introduction** – Background Information
4. **Materials and methods** – The what and how you prepared and conducted your experiment!
5. **Results** – Your Data.
6. **Discussion** – Explanation of your data.
7. **Citations** – Documenting your resources.

Description of Each Lab Plan Component

1. **Your title** ought to have approximately **ten** words and ought to mirror the representative content you finalized in your lab. Lab reports titles are never "cutesy" terms that you may encounter in an advertising campaign, such as "To chemically react or not to chemically react". How does that title highlight what the experiment is achieving? Use keywords that explain your lab processes.

2. **Your abstract** ought to direct and provide the reader towards a summary of your entire lab activity. It's comparable explaining your entire summer break in one paragraph. A complete abstract ought to be about 200 words and a concise summary of the purpose of the lab, your data, methods/materials and conclusions. In other words, the abstract is a brief summary of the entire lab activity. The abstract appears first in your report, yet it must to be the last component you write, since it comprises your conclusion.

3. **Your introduction** defines the topic of your report. This is actually background information (initial research for example) that will assist the reader understand what you are trying to achieve in your lab? Try to focus your background to information that is directly related to the lab. You ought to embrace the following research questions:
    - What is the purpose of your lab activity?

- What previous information, or similar labs are available from research literature?
- What is the specific purpose your lab activity? Include your hypothesis and discuss the lab procedures.

4. **Your Methods and Materials** ought to include following components:
    - A **list** of what materials were used, include all apparatus, reagents and safety equipment?
    - Describe how you used your materials.

5. **Your Results** include the data that you collect during your lab activity.
6. **Your Discussion** ought to highlight your interpretation of the data. You ought to include recommendations and improvements within your experimental design technique. In your discussion your will either accept or reject your hypothesis.
7. **Your Citations** are documenting the sources that you used to help you with your experiment.

Important Annotations to Assist in Writing Your Lab Report

1. Be sure that you always use the metric system for all of measurements.
2. All your numbers that are greater than ten or numbers used in a measurement, such as 3g, or 14cm should be in numeral value and not spelled out. Never begin a sentence with a number, always spell out the number, even if the number is less than ten.
3. Be sure to divide your paragraphs correctly and to use starting and ending sentences that indicate the purpose of each paragraph. Never make a lab report to be one large paragraph.
4. Use proper English in all sentences.
5. Don't use slang words.
6. Don't use first person, such as, I or we. Your writing must be objective, and in the third person. For example, do not say "We measured 20mL of HCl in a graduated cylinder," instead write, "Twenty mL of HCl were measured in a graduated cylinder."

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Post Test and Class Discussion

(Day 12)

1. What is a MEMS senor?

   ____

2. What is meant by the term Piezoelectric?

   ____

3. Describe the Ideal Gas Law? Provide the mathematical equation for the Ideal Gas Law.

   ____

4. What is meant by linear regression and mathematical modeling?

   ____

5. How may stoichiometry be related to the study of gas laws?

   ____

6. Why is the relationship between pressure and temperature in gases?

   ____

7. Describe the steps in writing a professional lab report?

   ____

8. Why is it important to read the lab procedures prior to beginning the actual lab activity?

   ____

9. How would you write a good hypothesis?

   ____

10. Why is it important to share and discuss your lab results with other lab groups?

    ____

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