Unit Objectives

By the end of this unit, students should be able to:

- Understand the relationships between gas pressure, temperature, volume, and moles.
- Calculate the final values for volume, pressure, temperature, or moles of a gas sample based on a given set of data.
- **Predict the spatial distribution, interaction, and motion of particles in a gas sample as variables are changed.**
- Interpret trends in data by examining the graph associated with each of the gas laws.
- Compare the density of gases based on their behavior.
- **Use simulations to better understand the behavior of gases.**
- **Understand how pressure, temperature, volume, and molecular weight affect how particles in a gas behave.**
- Apply the concepts of gas laws to stoichiometry problems.
- Carry out stoichiometry problems with solid, aqueous, and gaseous states

Commented [LC1]: The bolded objectives are my focus for this section, and for my annotated changes. I would also add an objective, "students will learn that the kinetic molecular theory offers an explanation of the behavior of gas particles as described by the ideal gas laws."

Major Links to Florida State Standards:
"interpret the behavior of ideal gases in terms of kinetic molecular theory" (SC.912.P.12.10)

"explain that a scientific theory is the culmination of many scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have to offer" (SC.912.N.3.1),

"describe the function of models in science, and identify the wide range of models used in science" (SC.912.N.3.5) (CPalms, 2017, n.p.).

Please note that all my original added content is colored in red.

1: Introduction to Gas Laws Unit

Discussion (15 mins)

Begin class by getting students to think about what gas is, what they know about it, and how they interact with it every day.

- What is gas?
  - Ask students to offer definitions.
  - Compare definition to: "A substance that can only be contained if it is fully surrounded by a container (or held together by gravitational pull); a substance whose molecules have negligible intermolecular interactions and can move freely" (Boundless, 2016).
- When have you seen gases used in everyday life?
  - Ask students to offer examples of gases they encounter in real life. Possible answers include:
    - Air (oxygen, carbon dioxide)
    - Neon Lights (Neon, argon & xenon)
    - Soda (carbon dioxide)
    - Fuel (propane, natural gas, butene)
    - Cleaners (Ammonia)
    - Chlorine
    - Sulphur Dioxide (winemaking & refrigerant

        - Ozone
        - Nitrogen (fire suppression)
- How do we describe gas properties in science?
    - "What does science tell us about the behavior of gases? How does it change when its conditions change?"
    - Allow students to chime in if they know anything about the gas laws already.
    - Introduce the concept of gas laws. Review "what is a scientific law?" – "a brief statement that summarizes past observations and predicts future ones" (Tro, 2011).

Commented [LC2]: The concept of laws, theories, and how they are different but related, should be a continuing theme in the course. Students may or may not have been introduced to this concept earlier in the course, depending on the order in which subjects have been approached. If this is the first time they are hearing the concept, there should be a longer discussion. If not, it should be reviewed, and the definition written on the board.

Videos (15 mins)

- Have students visualize the gas laws (10 mins)
    - https://teachchemistry.org/classroom-resources/gases-animation
    - Introduce this unit to your students with the Gases Animation which allows students to visualize how volume, pressure, temperature, and quantity of a gas are related. Both qualitative and quantitative relationships are explored.
    - For more interaction and inquiry learning, play the video through once, then again a second time. On the second round, after each relationship is played out, pause and ask the students:
        - Do you remember what happens [when pressure is decreased]?
        - Why does this happen?
        - What would happen if [the opposite happened]?
        - As you go, write on the board the relationships the students come to (which, with guidance, should match the gas laws).
        - Identify and label each completed formula: Boyle's Law, Charles's Law, and Gay-Lussac's Law.

Commented [LC3]: I think this pause-and-discuss step is important; otherwise, the video is so brief that students could easily miss the implications.

- Provide Historical Context (5 mins)
    - Remind students how scientific laws are developed: they are not invented! They are discovered by researchers who do many different, but related experiments, trying to find patterns. Once they have found and verified a pattern in the natural world many times, and others are able to reproduce the results in other situations, times, and parts of the world - they have discovered a law of nature.
    - Show the **Founders of Chemistry** Robert Boyle video which tells the story of the great chemist and discoverer of Boyle's Law, and describes the relationship between pressure and volume of a gas.
    - https://teachchemistry.org/classroom-resources/robert-boyle-video

Gas Pressure Activity (REMOVED)

After the class discussion, have your students get active with the Gas Pressure Lab which will allow them to better understand what causes pressure in a container and the variables that affect pressure (volume, temperature, number of moles) by mimicking molecular motion of gases. This activity will further help your students visualize the behavior or gas particles. Students learn

Commented [LC4]: I have removed this activity from the lesson plan (an activity where students themselves take on the role of gas particles, bumping into eachother, and changing their behavior based on external changes). While it would be a good activity for younger children in an open space, it is too risky in a high school classroom. There is not enough room in the classroom and there is a lab in the back of the room. Also, many teenagers feel strongly about their personal space. Therefore, so as not to put them on the spot, I don't believe high school teacher should rely on any activity where the students are making physical contact with one another.

better by doing. This activity allows students to experience "pressure" by taking on the role of a gas particle. Students have fun and learn some important facts about gas pressure.

Gas Laws Simulation Lab (REMOVED)

https://drive.google.com/file/d/0BzkCUiwcF8CbZGhoNVZZNGZHZFU/view?usp=sharing

Demonstration: "Comparing Gas Density" (15 mins)

Summary

In this demonstration, students will observe a reaction between baking soda and vinegar in the presence of a variety of different heights of lit candles. The initial environment has plenty of oxygen present in order to sustain the candle's flame; however the reaction will produce carbon dioxide which will cause the lit candles to extinguish in order of height. Students will analyze and compare the presence of the gases in the container and make determinations about the densities of each.

This demonstration can either be shown in the attached video, or done in person using the procedures available in the teacher's guide. (https://drive.google.com/open?id=0BzkCUiwcF8Cbc1pkazk3VUlubTQ).

Objectives

By the end of this demonstration, students should be able to:

- Determine that carbon dioxide has a higher density than air based on their observations.
- Compare the density of gases based on their behavior.
- Understand that oxygen is necessary for a combustion reaction to occur.

Demonstration

- View Video of Phenomenon: https://www.youtube.com/watch?v=abEKehIPMt8
- Students should observe closely (the candles will go out sequentially from shortest to tallest and there will be fizzing/gas produced to indicate a reaction has taken place).

Worksheet

Key discussion points and explanations for this demonstration:

- What is vinegar? What is baking soda?
- How do you know a chemical reaction is taking place?
- Reaction: $NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$
- Note that one of the products of this chemical reaction is carbon dioxide (CO_2)
- Which has a higher density – CO_2 or air?
- Why do you think the candles went out at different times?

Commented [LC5]: I removed this "Lesson 2: Gas Laws Simulation" because it was a more elementary computer simulation that is covered much better in "Lesson 4: Understanding Gas Laws through a Simulation". In this simulation, students are restricted to only relating two variables at a time and must change to another screen before testing a different relationship; this might be fine for younger students or those at a lower learning level, but for most 11th and 12th graders I think a less obvious, more open "sandbox" environment is more interesting and encourages inquiry learning.

Commented [LC6]: For the sake of time (assuming a 40-minute class period), I make the assumption here that the teacher will show the demo as a video; but it would be better practice if they were able to do it in person, since students will be more engages with an in-person demonstration. Also, providing a physical demonstration helps diversify the modes of instruction in this lesson, since it has already been very video-heavy.

Commented [LC7]: This can be done as class discussion. Since there has been a lot of whole-class discussion in this days, and since the class will likely be coming to an end soon, I would recommend instead providing the students with a worksheet with these questions, allowing them to break up into small groups to work on the worksheet for the time they have let in the class. They will be instructed to complete the worksheet at home (they can work collaboratively, but they must give complete explanations in their own words). They may consult reference materials if necessary; if so, they should give credit to the information source.

NOTE: I plan to provide a space on the bottom of all take-home assignments for references used. They won't need to be in a formal format (APA or MLA, etc.), but will need to provide minimal information, such as author and title of book, or web URL.

  - *Desired answer: CO_2 is forming from the reaction in the bottom of the tank, and since it is denser than the oxygen in the container is getting pushed up higher/out of the container. Without oxygen the flame is not sustainable.*
- What reactants are needed for combustion?
  - *Desired answer: Both oxygen and a fuel (the candle) are needed for the combustion reaction to take place. Since CO_2 has a higher density than oxygen, it builds up in the bottom of the tank, replacing the oxygen.*
- Which of the gas laws are at work in this demonstration? How?

Homework

- Complete worksheet
- Read text pages on gas laws to reinforce the concepts learned today, and as background for tomorrow's demos.

2: Demonstration Day

Discussion

- Briefly review the worksheet from the previous day.
- No further discussion; keep the flow of the class moving forward, and transition right into the first demonstration.

Demonstration 1: "Make the Water Rise!" (15 mins)

In this demonstration, students will observe the impact of temperature change on a gas through an engaging demonstration using simple household materials. This demonstration can either be shown in the attached video, or done in person using the following procedure:

This is a quick demonstration, so you may want to do this multiple times in order for students to understand what is happening, and connect their observations to the content.

Objectives

By the end of this demonstration, students should be able to:

- Understand that oxygen is needed in order for a flame to sustain burning.
- Recognize relationships between temperature, volume and pressure of a gas.

Materials

- water (~25ml)
- petri dish or small plate/saucer
- glass bottle, graduated cylinder, or glass cup
- candle (tea light works best or cut end from long stem candle)

Commented [LC8]: Engages the student in inferential inquiry: they do not necessarily know why this happened, but through their observations, reasoning skills, and research if needed, they can come to a reasonable explanation.

The instructor should collect these worksheets tomorrow and examine these questions in particular. Errors here may reveal some systematic misunderstandings that can be cleared up in tomorrow's discussion.

Commented [LC9]: These are good questions, but they needed a little something more to tie them back into the point of the unit.

Commented [LC10]: I think it's important for the class to communally discuss their answers to the worksheet; this is a good opportunity for a progression assessment to get an idea of the class's level of understanding.

However, discussion should not linger; the previous day focused on hypothetical discussion. Today's focus is on observing, analyzing, and interpreting data.

Commented [LC11]: An interesting way to do this, rather than class discussion, would be for students to take a few minutes to illustrate the experiment. Have them fold a piece of paper twice to create four boxes; then, in each box, draw a different stage of what they saw, draw and label sample molecules and how they're moving, and write brief explanations of what's happening in each box.

- lighter or matches

Procedure

1. Add water to the petri dish or plate. The water should be pretty shallow; the candle will float on top. Make sure the water isn't filled completely to the edge of the dish/near overflowing.
2. Place the tea light/candle on the water and light it.
3. Cover the tea light/candle with the glass jar.
4. The candle will continue to burn for a few moments, and the air inside the container will increase in temperature. You may notice bubbles escaping from the jar into the surrounding water due to the increase in temperature, and pressure inside the jar. The gas molecules are moving faster due to the increase in temperature, pushing on the inside of the jar to increase the volume.
5. When the candle has reacted with all of the oxygen inside of the jar, the flame will go out. The temperature will then begin to drop as the flame begins to dim, and so will the pressure of the gas. This decrease in temperature will cause the gas molecules to get closer together, along with the decreasing pressure, so the water will move into the jar to occupy the empty space. You will observe the candle and water rise in the jar during the temperature change! *(Video: https://www.youtube.com/watch?v=C7c4Vi5EXDg)*

Lab/Demonstration 2: "Balloon & Flask" (30+ mins)

Summary

In this demo, students will witness the relationship between temperature and volume as well as temperature and pressure. This is a great substitute for the imploding soda can demonstration that doesn't always work.

Objectives

By the end of this lesson, students should be able to:

- Understand that temperature and volume are directly related.
- Understand that temperature and pressure are directly related.

Materials:

- 200-mL Erlenmeyer flask
- 12-inch balloon
- Water
- Hot plate
- Tongs
- Sink

Safety

- Always wear goggles when working in a lab setting.
- Exercise caution when using a heat source. Hot plates should be turned off and unplugged as soon as they are no longer needed.

Class Discussion

- Prior to performing the experiment, hand out the student worksheet (https://drive.google.com/file/d/0BzkCUiwcF8CbVWdvallLcFVuMmc/view). Ask them to make fill it out as the experiment is performed.
- Discuss the procedure with the class and ask them to predict what will happen to the balloon and support their answer with a reason. This usually leads to an interesting discussion, which exposes students to misconceptions. The prediction and discussion result in the students being more interested in the final result.
- Oftentimes, students will say a vacuum is created inside the flask as an explanation for why the balloon is sucked inside. This is a good opportunity to discuss what a vacuum is.
- This is a much more reliable way to demonstrate temperature and pressure relationships than a soda can in water. This could be done by students in groups or two or as a full class demonstration.
- Before the demonstration, students should complete the PreLab question on their worksheet: "Read the procedure and predict what will happen. Justify your prediction."

Procedure & Observations

Instruct students to make note of their observations on the worksheet as this experiment is performed.

1. Pour about 25 mL of water into the flask.
2. Heat the water on a hot plate until it boils. Allow it to boil for about two more minutes. Turn off the hot plate. There should still be water in the flask.
3. Using tongs or something to protect your hands, remove the flask from the hot plate and pour the water out.
4. Immediately place a balloon over the mouth of the flask.
5. Place the flask on the table and record observations.

Commented [LC12]: Ideally, students will be allowed to perform this experiment themselves. After they've done so, if there is time, the teacher can also perform the experiment to show it again.

Analysis & Conclusion

- Once the experiment has been performed (and repeated, if needed), the students should apply their knowledge to what they've just witnessed.
- Using arrows, sketch the molecules inside and outside of the flask that make up the air during four points in this experiment (see below). Add the balloon and what it looks like, when appropriate. Use arrows to indicate particles, and longer arrows to indicate faster moving molecules for each stage:
    - Room temperature
    - Boiling water
    - With balloon, after heating
    - With balloon, after being cooled.

Commented [LC13]: This is where students connect their prior learning to the phenomenon they've witnessed. This is an interpretive and inferential activity.

Rather than just answering the questions, students are asked to draw diagrams to represent molecule movement. This is a new learning modality in the unit.

- What did you learn from this experiment about temperature, pressure, and volume of gases?

Homework

- Complete lab questions if not finished in class.
- Assign a few more text pages, making sure they address kinetic molecular theory in preparation for tomorrow's activity.

3: Connecting Kinetic Molecular Theory

Discussion (5 mins)

- Quickly review yesterday's lab. Have the students hand in their homework first, then review the answers as a class.
- Review the concept of a scientific theory.
    - Ask the students to define a scientific theory and how it is different for a law.
    - Compare to the textbook definition: "A scientific theory is a *model for the way nature is* and tries to *explain* not merely *what* nature does, but *why*." (Tro, 2011 [emphasis added]).
- Introduce the five major assumptions of the Kinetic Molecular Theory. *(write them on the board, explain each one, and leave the assumptions on the board while the students do the simulation.)*
    - The volume occupied by the individual particles of a gas is negligible compared to the volume of the gas itself.
    - The particles of an ideal gas exert no attractive forces on each other or on their surroundings.
    - Gas particles are in a constant state of random motion and move in straight lines until they collide with another body.
    - The collisions exhibited by gas particles are completely elastic; when two molecules collide, total kinetic energy is conserved.
    - The average kinetic energy of gas molecules is directly proportional to absolute temperature only; this implies that all molecular motion ceases if the temperature is reduced to absolute zero.
        - (Boundless, 2016)
- Ask students to keep in mind the assumptions of the KMT as they do the simulation.

Student Computer Activity (40+ mins)

Summary

Students can get more practice explaining the relationship between gas temperature, pressure, and volume with this activity. Through the use of an online program, students investigate gas

Commented [LC14]: In order to encourage equal participation, whenever a homework like this is reviewed, choose students in a rotating fashion to offer answers. Consider preparing students the day before by telling them who will be responsible for what questions the following day; that way they will be prepared and confident. This encourages the students to display their mastery of the content by properly preparing, instead of setting them up for potential embarrassment.

Commented [LC15]: Again, this may be new, or this may be review. Spend a little more time if this is a new concept. If it is review, don't linger too long, just long enough to refresh their memories.

laws (Kinetic Molecular Theory, Partial Pressure, Boyle's Law, Charles Law, and Gay-Lussac's Law).

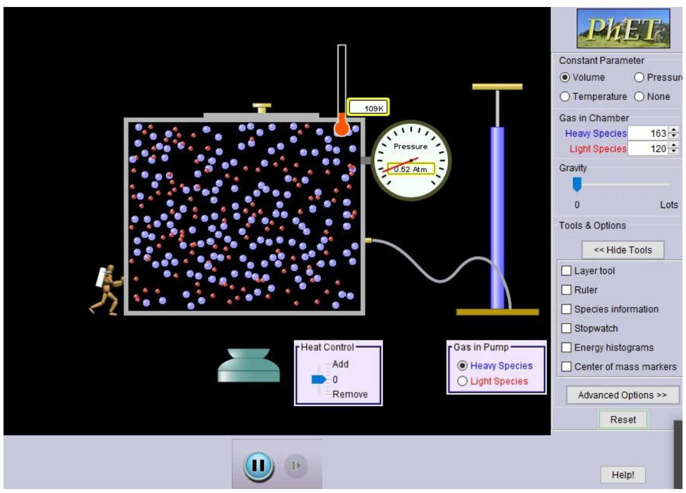
Objectives

By the end of this lesson, students should be able to:

- Explain the relationship between pressure and temperature for an ideal gas.
- Explain the relationship between temperature and volume for an ideal gas.
- Explain the relationship between volume and pressure for an ideal gas.

Materials

- Computer with internet access
- Link to Computer Program: https://phet.colorado.edu/en/simulation/gas-properties (requires java installed on computer & browser)



1: Screenshot of Gas Laws Computer Simulation.

Commented [LC16]: The software is somewhat annoying to download and run; it would most certainly have to be pre-loaded on the classroom computers. For simplicity, I have provided here a screen shot of the program which provides a general idea of its structure and features.

Teacher Notes

Before beginning this activity, make sure students know the school's policy on internet usage. It may be helpful to walk around the room as students work.

Full worksheet with illustrations at https://drive.google.com/open?id=0BzkCUiwcF8CbTkNaRGZ2WGxuRmM

Pre-Activity Questions

Draw diagrams of what you think ten gas particles would look like if you could zoom really close in to see them. Use ● for particles, → to show their movement. Bigger arrows mean more velocity. The box is the container.

Boxes shown for:

- Low Temperature vs. High Temperature
- Low Pressure vs. High Pressure
- Low Volume vs. High Volume

Procedure

- Visit pHet simulations and complete all four parts below.

Part I: Kinetic Molecular Theory

- Use the pump to put one pump of gas into the box.
    - What happens to the clump of particles?
- To answer the following questions, keep your eye on one particle and notice how it moves.
    - How do the particles move? (straight line, circular, random, etc.)
    - Do the particles stay at a constant speed? If not, what causes the speed to change?
    - Do they always move in the same direction? If not, what causes their direction to change?
- Using the settings on the right side of the screen, put 100 “heavy species” in the container. Allow the pressure to stabilize.
    - Record the pressure (the number will jump around, determine a reasonable average value).
    - Reset the number of “heavy species” to zero, and the “light species” to 100. Record the pressure.
    - Does the mass of the particles significantly affect the pressure of the container? Explain.

Part II: Partial Pressures

- Put 100 of “heavy species” and no “light species.” Record the pressure.
- Put 50 of the “light species” and no “heavy species”. Record the pressure.
- Put 50 “light species” AND 100 “heavy species” together. Record the pressure.
- How does this compare to the pressures from 3a and 3b? Explain.

Part III: Boyle’s Law

- Since Boyle’s Law deals with pressure and volume, temperature must be constant.
- On the constant parameter box in the top right, select temperature to be constant. Place 200 “heavy species” in your container.
- Use the little man to change the volume of the container.
- What happens to the pressure as the volume changes?

Commented [LC17]: Remind students that all experiments begin with a hypothesis.

Commented [LC18]: These questions are excellent. I think they are perfect questions to guide students through the explorations.

Commented [LC19]: This is a new concept; the students would not have been introduced to it yet. When partial pressures are discussed later, we will recall this exercise.

- As the volume goes______________ the pressure goes____________________.
- This is a(n) ______________________ relationship.
- Play around with the number of species, volume and pressure. What combination do you need to blow the top off?
- Diagram the particles in the boxes that would model Boyle's Law. (Include arrows.) Label the variables below each box.

Part IV: Charles' Law

- Since Charles' Law deals with temperature and volume, _____ ____________ must be constant.
- Place 200 "heavy species" in your container. On the constant parameter box in the top right, select the appropriate constant.
- Use the flame at the bottom to heat up the container.
- What happens to the volume as the changes?
- As the temperature goes______________ the volume goes____________________.
- This is a(n) ______________________ relationship.
- Play around with the temperature and volume. What combination do you need to blow the top off?
- Diagram the particles in the boxes that would model Charles' Law. (Include arrows.) Label the variables below each box.

Part V: Gay-Lussac's Law

- Since Gay-Lussac's Law deals with pressure and temperature, ____________________ must be constant.
- On the constant parameter box in the top right, select the appropriate constant. Place 200 "heavy species" in your container.
- Use the flame to change the temperature of the container.
- What happens to the pressure as the temperature changes?
- As the temperature goes______________ the pressure goes____________________.
- This is a(n) ______________________ relationship.
- Play around with the number of species, temperature and pressure. What combination do you need to blow the top off?
- Diagram the particles in the boxes that would model Gay-Lussac's Law. (Include arrows.) Label the variables below each box.

Conclusion

- Review your initial assumptions about the behavior of gases and compare them to the results of your experiments.
- Do your results match your predictions? If not, did the experiment help you understand why the gas behaves the way it does?

Bonus Questions (Do at home)

- What are the five basic assumptions of the Kinetic Molecular Theory of Gases? *(Check your textbook for a refresher)*
- Why are the gas laws called the "Ideal Gas Laws"? What is an "ideal gas"?
- Under what conditions does a real gas act like an ideal gas?
- Why do you think scientists use approximations like "ideal gases"? How is it useful to do this?
- Give an example of a time you've used an approximation or simplification. How was it useful to use it?

Homework

- Have the students bring their worksheets home to complete any unanswered questions. *Make sure that they have answered all the questions that required the simulation in class; perhaps star those on the worksheet.*
- Inform students that they will be doing active lab experiments the following day. Provide them the lab procedures so they can read through them.
- No text reading; students should focus on their worksheet and browsing the lab details.

Commented [LC20]: High temp, low pressure

Commented [LC21]: I would give this assignment a more significant grade than regular homework; perhaps use it as a quiz grade. Students should be informed, however, of the heavier weight of the grade. If students treat it as casually as normal homework, they may not put in as much effort as they would otherwise, and that would invalidate the grades.

Commented [LC22]: The next day's labs are part of the full unit plan but not part of this abbreviated annotated section.

References

American Association of Chemistry Teachers. (2017). The Gas Laws Unit Plan. Retrieved June 17, 2017, from https://teachchemistry.org/classroom-resources/the-gas-laws-unit-plan

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