



Name: _____

Date: _____

Student Exploration: Ideal Gas Law

Vocabulary: atmosphere, Avogadro's law, Boyle's law, Charles's law, dependent variable, directly proportional, Gay-Lussac's law, ideal gas, ideal gas constant, ideal gas law, independent variable, inversely proportional, Kelvin temperature scale, kilopascal, mole, pressure, proportionality, STP, volume

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

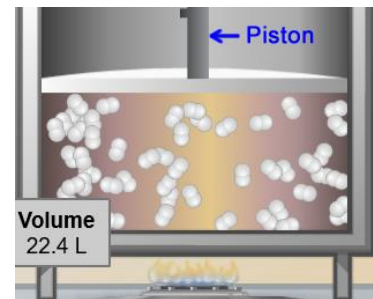
1. Why is it often necessary to add air to your car tires during the winter? _____



2. Why do you think it might be a bad idea to throw an aerosol can into a fire? _____

Gizmo Warm-up

The *Ideal Gas Law* Gizmo shows molecules moving within a chamber fitted with a movable piston. As the piston moves up and down, the **volume** of the chamber changes. Since gases expand to fill their container, any changes in the volume of the chamber changes the volume of the gas within.



1. Next to **Dependent variable**, check that **Volume** is selected. Using the green slider, change the **pressure**. Note what happens to the temperature, volume, and amount of gas.

What changes? _____ What stays the same? _____

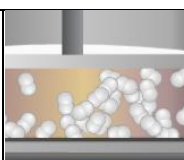
2. Using the purple slider on the tank of gas, adjust the number of **moles**, or amount of gas.

What changes? _____ What stays the same? _____

3. Now make **Pressure** the dependent variable. Use the red slider to change the temperature.

What changes? _____ What remains the same? _____



Activity A: Volume relationships	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> • Select Volume as the dependent variable. • Set Pressure (P) to 1.0 atm, Moles (n) to 1.0, and Temperature (T) to 100 K. 	
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Introduction: The **dependent variable** changes in response to a change in the **independent variable** in an experiment. Independent variables are controlled by the experimenter and are manipulated to see what effect they might have on the dependent variable.

Question: What are some factors that affect the volume of a gas?

1. **Investigate:** In this Gizmo, all temperatures are measured using the **Kelvin temperature scale**. This scale is based directly on molecular motion, with 0 K equal to $-273\text{ }^{\circ}\text{C}$.

A. What do you think will happen to the speed of the molecules if a gas is heated?

B. What do you think will happen to the space between molecules, and thus the volume of a gas, as it is heated? _____

2. **Analyze:** Select the TABLE tab to see your data. With temperature set at 100 K, press **Record**. Increase the temperature in 50 K increments, pressing **Record** each time.

A. What trend do you see? _____

B. If the temperature of a gas is doubled, its volume will _____.

C. If the temperature of a gas is halved, its volume will _____.

If two variables are **directly proportional**, an increase in the independent variable will cause the dependent variable to increase at the same rate. If the variables are **inversely proportional**, an increase in the independent variable will cause the dependent variable to decrease at the same rate.

D. Select the GRAPH tab. Choose **Temperature** for the x-axis. A line with a positive slope shows that two variables are directly proportional, while a curve with a negative slope reveals that two variables are inversely proportional.

Based on the graph, temperature and volume are _____ proportional.

3. **Summarize:** **Charles's law** states the relationship between the temperature and volume of a gas. Based on your observations so far, state Charles's law in your own words.

(Activity A continued on next page)

Activity A (continued from previous page)

4. **Explore:** Select the TABLE tab. Note the container's lid, which exerts pressure on the gas.

A. What do you think will happen to the volume of the gas as pressure is increased?

B. Gradually increase the pressure. Record data each time. How does volume change when pressure increases? _____

C. What happens to the volume when the pressure doubles? _____

D. Is this relationship directly or inversely proportional? _____

5. **Summarize:** The relationship between pressure and volume is summarized by **Boyle's law**. Based on your observations, state Boyle's law in your own words.

6. **Predict:** Check that **Volume** is still the dependent variable. Set **Moles** to 0.2 mol.

A. Predict: If more gas is added to the chamber, the volume will _____.

B. Gradually introduce more gas into the chamber. Was your prediction correct? _____

7. **Investigate:** On the DESCRIPTION tab, change the gas to helium and then to nitrogen. Experiment with the Gizmo, noting if the volume changes as the type of gas is changed.

A. Does the identity of the gas affect the volume of the gas? _____

B. Why do you think this is so? _____


8. **Graph:** Create a graph that shows the relationship between volume and number of moles.

A. Is the relationship between the amount of gas (indicated by moles) and the volume directly or indirectly proportional? _____

B. Therefore, if the amount of gas is tripled, the volume will _____.

9. **Summarize:** **Avogadro's law** states the relationship between volume and the amount of gas. State Avogadro's law in your own words.



Activity B: Pressure relationships	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> • Select Pressure as the dependent variable. • Set Volume (V) to 42.0 L, Moles (n) to 1.0, and Temperature (T) to 100 K. 	
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Introduction: Pressure refers to the force that the gas molecules exert on the walls of their container. Pressure always refers to force acting over a specific area: $\text{Pressure} = \text{Force}/\text{Area}$.

Question: What determines how much pressure a gas will exert?

1. Explore: Set the gas to **Hydrogen**. Observe how often the gas molecules collide with the bottom of the chamber. Now increase the temperature and observe the number of collisions.
 - A. What happens to the speed of molecules as temperature increases? _____
 - B. What happens to the number of collisions as temperature increases? _____
 - C. What happens to the pressure as temperature increases? _____
 - D. Based on your observations, why do you think the pressure increases? _____

2. Graph: Create a graph that shows the relationship between temperature and pressure.
 - A. Is the relationship between the temperature and pressure directly or indirectly proportional? _____
 - B. Therefore, if the temperature is quadrupled, the pressure will _____.

3. Summarize: The relationship between pressure and temperature (at constant volume) is given by **Gay-Lussac's law**. State Gay-Lussac's law in your own words.

4. Investigate: Select the BAR CHART tab. Make the chamber as large as possible.
 - A. Gradually decrease the volume. What happens to the pressure of the gas? _____
 - B. What happens to the pressure when the volume is cut in half? _____
 - C. What happens to the pressure when the volume is quadrupled? _____
 - D. How does volume affect pressure? _____

(Activity B continued on next page)



Activity B (continued from previous page)

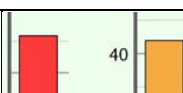
5. Graph: Create a graph showing the relationship between volume and pressure.
- A. Is the slope of the line positive or negative? _____
 - B. Based on the direction of the slope, is the relationship between pressure and volume directly or inversely proportional? _____
 - C. Which gas law summarizes this relationship? _____
 - D. Why do you think making the chamber smaller leads to an increase in gas pressure?

6. Observe: Select the BAR CHART tab. Change the number of moles and observe.
- A. What happens to the pressure as the amount of gas increases? _____
 - B. What is the relationship between the number of moles and pressure? _____

7. Infer: One mole of any substance contains Avogadro's number (6.022×10^{23}) of particles.
- A. Will doubling the number of moles double the number of particles? _____
 - B. Why does doubling the number of moles double the pressure? _____

8. Compare: Change the gas to nitrogen, which is heavier than hydrogen, and observe.
- A. Do its molecules move faster or slower than those of hydrogen? _____
 - B. Since heavier molecules exert more force each time they collide, is it likely that fewer collisions could produce the same force? _____
 - C. Observe the pressure as you change the type of gas. What can you conclude about the effect of the type of gas on pressure? _____
9. Summarize: What are three ways to increase the pressure of a gas? _____



Activity C: The ideal gas law	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> Select Volume as the dependent variable. 	
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Introduction: So far you have explored the individual relationships between P , V , T , and n . In this activity, you will combine all of these relationships into a single law, enabling you to see how the behavior of a gas is affected when several different variables are changed at one time.

Question: How do volume, pressure, temperature, and amount of gas interact?

- Analyze:** Avogadro's law states that the volume of a gas is directly proportional to the number of moles (n). If two variables are directly proportional the symbol " \propto " is used, which means "directly proportional to." Therefore, the relationship between volume and moles would be written as $V \propto n$. This type of relationship is known as a **proportionality**.

 - Volume is also directly proportional to temperature (T). Express this relationship as a proportionality, in the following form: $V \propto$ _____
 - Since volume is inversely proportional to pressure, volume is directly proportional to $1/P$. Express this relationship as a proportionality: _____
- Synthesize:** If you know that $a \propto b$ and $a \propto c$, then you can also say that $a \propto bc$, or the product of b and c . Take the above three proportionalities (including $V \propto n$) and combine them into a single proportionality in the form: $V \propto ?$ Show your work below.
- Calculate:** A proportionality is not the same thing as an equation, however. To convert a proportionality into an equation it is necessary to multiply by a mathematical constant. For example, $a \propto b$ means that $a = kb$, where k is a constant. When referring to gases, this constant is referred to as R , the **ideal gas constant**.

 - In the space at right, rewrite the proportionality you created in question 2 so that the proportionality symbol (\propto) is changed to "=" and the right side is multiplied by R .
 - Rearrange your equation to solve for the ideal gas constant: $R =$ _____
 - You should have gotten an equation equivalent to ($R = PV/nT$). Pick any set of conditions in the Gizmo you would like, and then calculate R . Show your work below.

$P =$ _____ $V =$ _____
 $n =$ _____ $T =$ _____ $R =$ _____

 - Recalculate R using a completely different set of Gizmo conditions: $R =$ _____

(Activity C continued on next page)



Activity C (continued from previous page)

4. Compare: The accepted value for R is 0.08206 L·atm/K·mol or 8.314 L·kPa/K·mol, depending on the unit of pressure used. (Your answer may differ slightly due to rounding.)

How close was your calculation? _____

5. Synthesize: The **ideal gas law** is an equation relating P , V , R , n , and T . Rewrite the formula you found in question 3A so that P and V are on one side and R , n , and T are on the other. Show your work.

6. Discover: It is important to have a baseline set of conditions to serve as a reference point. Standard temperature and pressure (**STP**) is defined as 1 **atmosphere** (atm) or 101.325 **kilopascals** (kPa) of pressure at 273 K (0 °C). STP reflects normal atmospheric conditions at sea level.

A. Use the Gizmo to find the volume of 1 mole of gas at STP. (You will need to manually enter the temperature.) What value did you find? _____

B. Choose a different gas. Does the volume change? _____

7. Calculate: Use the ideal gas law ($PV = nRT$) to solve the following. Show work for each problem. Then use the Gizmo to check your answer.

A. What is the volume of 0.5 moles of gas at STP?

$V =$ _____

B. How much pressure would 0.8 moles of a gas at 370 K exert if it occupied 17.3 L of space?

$P =$ _____

C. How much H_2 gas is necessary to exert a pressure of 1.4 atm at 430 K if occupying a volume of 15.1 L?

$n =$ _____

