

Name: _____ Date: _____

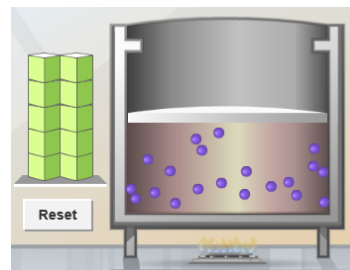
Boyle's Law and Charles' Law

Prior Knowledge Question (Do this BEFORE using the Gizmo.)

A small helium tank measures about two feet (60 cm) high. Yet it can fill over 50 balloons! How can such a small tank contain enough helium to fill so many balloons?

Gizmo Warm-up

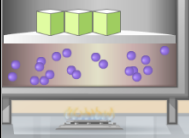
The *Boyle's Law and Charles' Law* Gizmo™ shows a container of gas. In the container, the small purple spheres represent molecules.



1. Observe the particles. Are they all moving at the same speed?
2. How do the particles interact with the walls and lid of the container?

These interactions contribute to the **pressure** on the walls of the container. Pressure is defined as force per unit area. The SI units of pressure are newtons per square meter (N/m²), or pascals (Pa).

3. Slowly drag the temperature (**T**) slider back and forth. (Note: In this Gizmo, the **Kelvin scale** is used to measure temperature. On the Kelvin scale, 0 degrees is **absolute zero**, the coldest possible temperature. Absolute zero is equal to -273.15 °C or -459.67 °F)
 - A. How does the change in temperature affect the speed of the molecules?
 - B. How does the change in temperature affect the volume of the container?

Activity A: Boyle's law	Get the Gizmo ready:	
	<ul style="list-style-type: none"> Set the temperature (T) to 300 K. Check that the mass (m) is set to 0 kg. 	

Question: How does pressure affect the volume of a gas?

1. Form hypothesis: In this experiment, you will pile weights on the lid of the container of gas. What do you think will happen as more weight is added to the lid?

2. Notice: Look at the DESCRIPTION pane. What is the mass of the lid?

How much pressure does the lid exert on the gas?

3. Collect data: With the temperature held constant at 300 K, use the **Select mass** slider to place weights on the lid. Record the pressure and volume of the gas for each added mass.

Added mass on the lid	on	Total mass (lid + added mass)	Pressure*	Volume
0 kg		10 kg		
10 kg		20 kg		
20 kg		30 kg		
30 kg		40 kg		

*This model does not include atmospheric pressure, which is 101,325 N/m².

4. Analyze: As the pressure increases at constant temperature, what happens to the volume of the gas?

This relationship is called **Boyle's law**.

5. Calculate: Compare the pressure and volume values in your data table.

A. How did doubling the pressure change the gas volume?

B. How did tripling the pressure change the gas volume?


C. How did quadrupling the pressure change the gas volume?



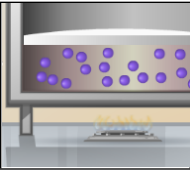
- Predict:** If the added mass on the lid was 50 kg, a total mass of 60 kg would exert pressure on the gas inside the container. What will be the volume of the gas?
- Test:** Test your prediction using the Gizmo. What is the volume of the gas?

Was your prediction correct? _____

- Create a graph:** On the GRAPH tab, select **V vs. P**. Set **m** to 0 kg, and click **Record** to plot a point on the graph. Plot a point for each possible mass to create a graph showing the relationship between pressure and volume.

When your graph is completed, click the **camera** icon () to take a snapshot. Paste the image into a blank word-processing document, and label the graph "Volume vs. Pressure."

- What is the shape of the graph?
 - How does this graph illustrate Boyle's law?
 - How do you think the graph might change if the temperature was held constant at a higher temperature, say 400 K?
- Apply:** Think about a small helium tank that can fill 50 balloons. What must be true about the helium in the tank compared to the helium in the balloons?

Activity B: Charles' law	<u>Get the Gizmo ready:</u>	
	<ul style="list-style-type: none"> On the SIMULATION pane, set T to 100 K and m to 0 kg. 	

Question: How does temperature affect the volume of a gas?

- Form hypothesis:** How do you think the volume of a gas will change as the temperature rises and falls?

2. Collect data: Without changing the mass on the lid, record the pressure and volume of the gas at each of the given temperatures.

Temperature	Pressure*	Volume
100 K		
200 K		
300 K		
400 K		
500 K		

3. Analyze: As the temperature increases at constant pressure, what happens to the volume of the gas?

This relationship is called **Charles' law**.

4. Explain: Based on the motions of the gas molecules, why do you think the volume changed as it did when the temperature was increased?
5. Think about it: Why do you think the pressure was the same in each test?
6. Calculate: Compare the pressure and volume values in your data table.
- A. How did doubling the temperature affect the gas volume?
 - B. How did tripling the temperature affect the gas volume?
 - C. How did quadrupling the temperature affect the gas volume?



7. Predict: Suppose the temperature was 50 K. What will be the volume of the gas?

8. Test: Test your prediction using the Gizmo. What is the volume of the gas?

Was your prediction correct?

9. Create a graph: On the GRAPH tab, select **V vs. T**. Set **T** to 50 K, and click **Record** to plot a point on the graph. Plot a point every 50 degrees to create a graph showing the relationship between temperature and volume.

When your graph is complete, click the **camera** icon to take a snapshot. Paste the image into your document, and label the graph "Volume vs. Temperature."

A. What is the shape of the graph?

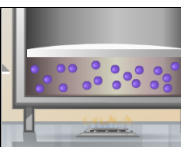
B. How does this graph illustrate Charles' law?

10. Apply: Based on what you learned, what would happen to a balloon placed in the freezer?

What would happen to a balloon placed in a warm oven? (Assume it doesn't pop.)

11. Think and discuss: Consider temperature, pressure, and volume. How does the mathematical relationship in Boyle's law compare to that in Charles' law?



Activity C: Gay-Lussac's Law	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> On the SIMULATION pane, set T to 100 K and m to 0 kg. 	
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Question: How does temperature affect the pressure of a gas when volume is constant?

- Form hypothesis: If the volume of a gas is held constant, how do you think the pressure will change as temperature increases?
- Collect data: Record the volume and pressure when $T = 100$ K and $m = 0$ kg. Then, change T to 200 K. Adjust the m slider until the volume is the *same* as it was when T was 100 K. Record the volume and pressure. Then, repeat for the other temperatures.

Temperature	Volume	Pressure	Pressure Temperature
100 K			
200 K			
300 K			
400 K			
500 K			

- Analyze: Divide the pressure by the temperature to fill in the last column of the table.
 - When the volume is held constant, how does the pressure change as temperature increases?
 - What do you notice about the ratio of pressure to temperature, when volume is constant?

Gay-Lussac's law states that, at constant volume, the ratio of pressure to temperature is constant. As temperature increases, pressure increases as well.

- Explain: Based on the motions of the gas molecules, why do you think the pressure changed as it did when the temperature was increased?



