Gizmos

Name: _____ Date: _____

Student Exploration: Boyle's Law and Charles' Law

Vocabulary: absolute zero, Boyle's law, Charles' law, Gay-Lussac's law, Kelvin scale, pressure

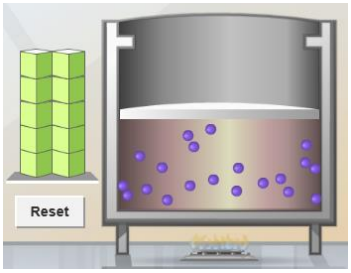
Prior Knowledge Question (Do this BEFORE using the Gizmo.)
A small helium tank measures about two feet (60 cm) high. Yet it can fill over 50 balloons! How can such a small tank contain enough helium to fill so many balloons?

_____

_____

_____

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/m^2), or pascals (Pa).

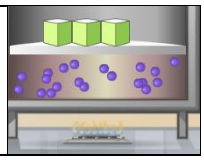
3. Slowly drag the temperature (***T***) slider back and forth. (Note: In this Gizmo, the **Kelvin scale** is used to measure temperature. On the Kelvin scale, 0 degrees is **absolute zero**, the coldest possible temperature. Absolute zero is equal to -273.15 °C or -459.67 °F)

   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: • 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	**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/m^2.

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? _____

(Activity A continued on next page)

Activity A (continued from previous page)

6. 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? _____

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

   Was your prediction correct? _____

8. 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. Right-click the image, and click Copy Image. Paste the image into a blank word-processing document, and label the graph "Volume vs. Pressure."

   A. What is the shape of the graph? _____

   B. How does this graph illustrate Boyle's law? _____

   _____

   C. How do you think the graph might change if the temperature was held constant at a higher temperature, say 400 K? _____

   _____

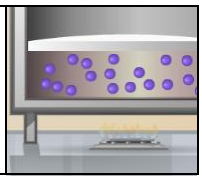
9. Apply: Think about a small helium tank that can fill 50 balloons. What must be true about the helium in the tank compared to the helium in the balloons?

   _____

   _____

   _____

   _____

Activity B: **Charles' law**	Get the Gizmo ready: • On the SIMULATION pane, set ***T*** to 100 K and ***m*** to 0 kg.	

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

1. 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		

*This model does not include atmospheric pressure, which is 101,325 N/m^2.

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? _____

   _____

(Activity B continued on next page)

Activity B (continued from previous page)

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.) _____

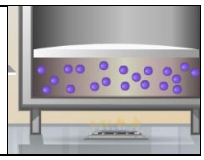
    _____

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**	Get the Gizmo ready: • On the SIMULATION pane, set ***T*** to 100 K and ***m*** to 0 kg.	

Question: How does temperature affect the pressure of a gas when volume is constant?

1. Form hypothesis: If the volume of a gas is held constant, how do you think the pressure will change as temperature increases? _____

2. 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	$\frac{\text{Pressure}}{\text{Temperature}}$
100 K			
200 K			
300 K			
400 K			
500 K			

3. Analyze: Divide the pressure by the temperature to fill in the last column of the table.

   A. When the volume is held constant, how does the pressure change as temperature increases? _____

   B. 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.

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

_____

(Activity C continued on next page)

Activity C (continued from previous page)

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

   A. At constant volume, how did doubling the temperature affect the pressure? _____

   _____

   B. How did tripling the temperature affect the pressure? _____

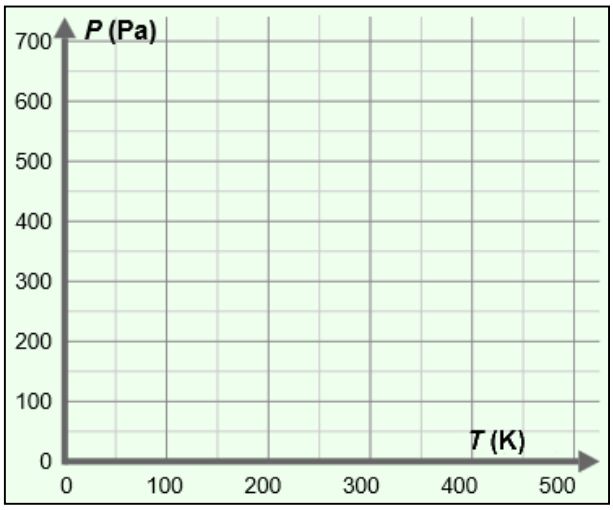
   C. How did quadrupling the temperature affect the gas volume? _____

6. Create a graph: Use your data from the previous page to create a graph of temperature vs. pressure on the blank grid to the right, assuming a constant volume of 0.85 m^3. Draw a line or curve to connect the points on the graph.

   What is true about the line connecting the points? _____

   _____

   _____



7. Apply: Based on what you learned, what do you think would happen if you placed a sealed container of gas into a fire? _____

   _____

8. Challenge: Combine Boyle's law, Charles' law, and Gay-Lussac's law into a single proportional relationship between pressure (*P*), volume (*V*), and temperature (*T*). Use the symbol "∝" to represent "is proportional to."

   Explain your reasoning. _____

   _____

   _____

   _____

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