

The Great Escape! Activity Three: Gas Laws

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TEACHER NOTE: If Activity One: Displacement and Buoyancy has not been previously completed, see the *introductory video activities* and the common core state mathematics standards, as well as physical science and engineering standards in that activity.

Objective:

1. Investigate the relationship between pressure and volume.

Introduction: For a simplistic example for K-8, see: <https://www.youtube.com/watch?v=BY9nm8HWPCl> for higher grades, start with the Phet interactive procedure below.

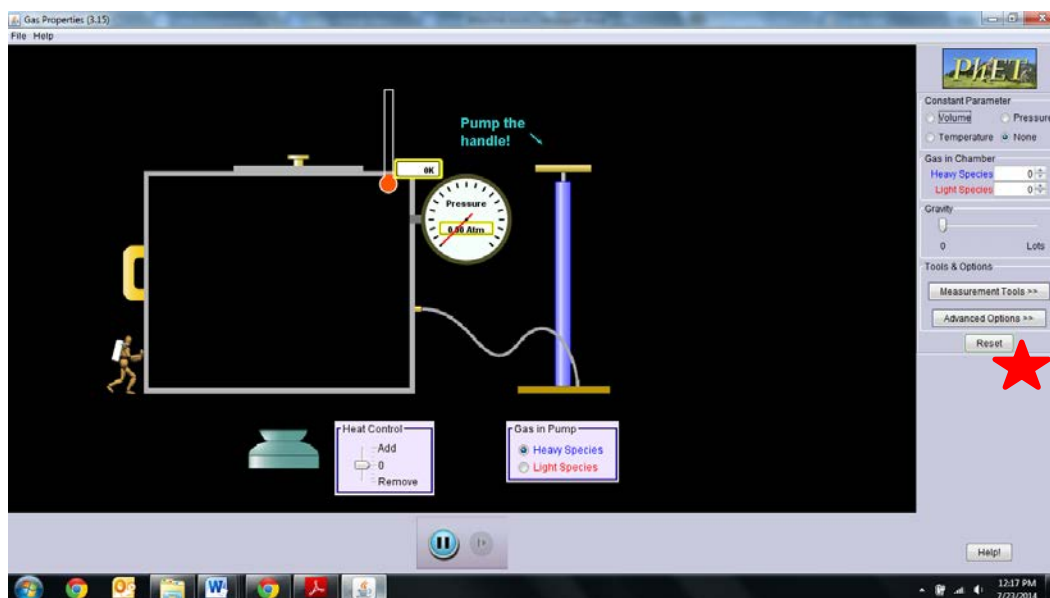
Activity 3 Procedure:

Getting Familiar

1. Visit the following URL for the Phet interactive applet. <http://phet.colorado.edu/en/simulation/gas-properties>
2. On the Intro screen, familiarize yourself with the applet by adjusting the volume of the container and pressing the pump handle.
3. Familiarize yourself with the measurement tools before beginning the activity.

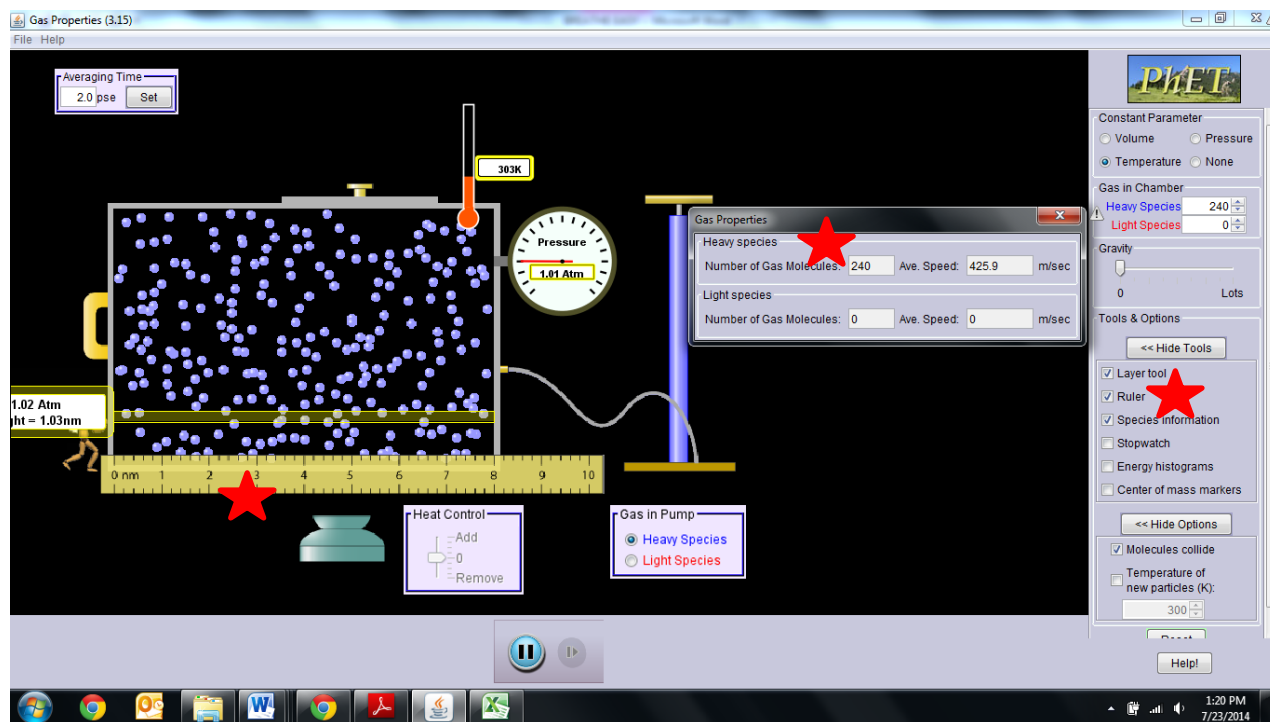
Note: Before beginning the lab activity be sure to select the “reset all” button, which will return your applet to the default settings.

<http://phet.colorado.edu/en/simulation/gas-properties>



Activity 3 Lab Setup:

1. In this activity you will investigate the relationship between volume and pressure. Therefore, you will want to select temperature as a constant parameter.



<http://phet.colorado.edu/en/simulation/gas-properties>

2. The default temperature is set at 300 K
3. The gas particles in the chamber should be set to 240
4. You should also select **species information**, **layer tool**, and **ruler**.
5. Place the ruler at the base of the container
6. Increase the length of the container to a value of 8 nm.

Note: For teacher use or for independent learners to **check their answers** to the Activity 3 Lab Procedure, Summary Questions, and Math Practice problems, see the **red typed script** following the Math Problems below, at the end of the Activity 3 Lab on Gas Laws.

Activity 3 Lab Procedure:

1. View the following video about atmospheric pressure.
<http://www.youtube.com/watch?v=jmQ8FWnMofA>

2. Reduce the length of the container by 1nm.

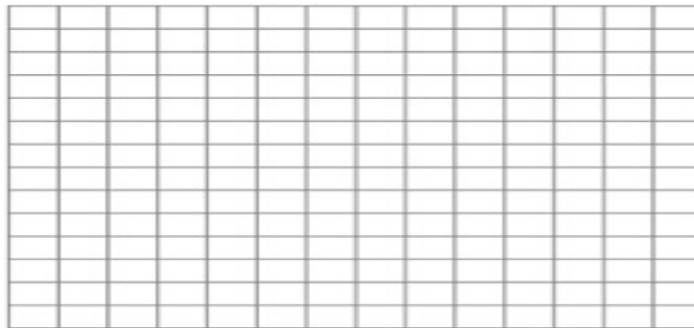
Note: Each initial movement will cause a rapid change in the pressure. Wait at least 15 seconds until the simulation has stabilized.

3. Record the change in pressure as you adjust the volume.

Note: The height of the chamber is 5.4nm, the length is 8nm, and the width is 8nm. Assume you're adjusting the length or width of the chamber $L \times W \times H = V$ ($8\text{nm} \times 8\text{nm} \times 5.4\text{nm} = 356\text{nm}^3$)

| Volume (nm ³) | Pressure (atm) | Avg Speed of Molecules |
|---------------------------|----------------|------------------------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

4. Graph your data



Summary Questions:

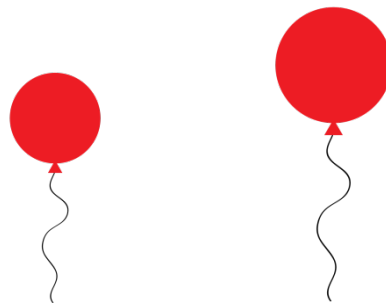
1. What is happening to the pressure as you decrease the volume of the container?

2. What is happening with the particles as you decrease the volume?

3. How would you describe the relationship between pressure (P) and volume (V) of a gas? Explain at the particle level why this occurs?

4. Suppose you increased the volume (V) of the container. How would the particles react, and how would the pressure (P) change?

5. Specifically what about the particles causes the pressure to change with changes in volume?



6. Consider these two balloons pictured above. How would you describe the relationship between the internal pressure of the balloons and the outside pressure of the atmosphere in each example? Explain your reasoning.

7. Reference your response to the previous question. Why does the balloon respond differently to changes in pressure than a typical container like the one used in the applet? Explain your reasoning.

Math Practice:

The relationship between volume and pressure is known as Boyle's Law, discovered and published by Sir Robert Boyle in 1662. Boyle's law can be expressed mathematically as

$$PV = k$$

P is the pressure of the gas, **V** is the volume of the gas, and **k** is a constant. The equation states that the product of pressure and volume is a constant for a given mass of confined gas as long as the temperature is constant

For comparing the same substance under two different sets of condition, the law can be usefully expressed as

$$P_1V_1=P_2V_2$$

1. A gas occupies 11.2 liters at 0.860 atm. What is the pressure if the volume becomes 15.0 L?
2. A sample of gas has a volume of 12.0 L and a pressure of 1.00 atm. If the pressure of gas is increased to 2.00 atm, what is the new volume of the gas?
3. Boyle's Law deals what quantities?
 - a. pressure/temperature
 - b. pressure/volume
 - c. volume/temperature
 - d. volume temperature/pressure
4. What pressure is required to compress 196.0 liters of air at 1.00 atmosphere into a cylinder whose volume is 26.0 liters?

Check your answers to the questions in Activity 3 Gas Laws: Lab Procedure, Summary Questions, and Math Practice problems using the **red typed script**

for the repeated questions below.

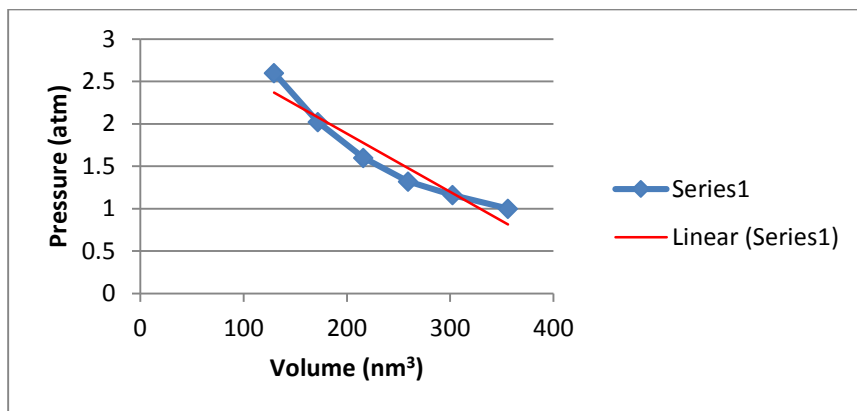
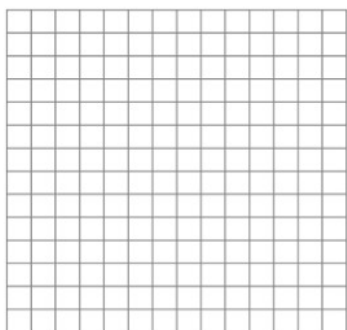
Answers

5. Record the change in pressure as you adjust the volume.

Note: The height of the chamber is 5.4nm, the length is 8nm, and the width is 8nm. Assume you're adjusting the length or width of the chamber $L \times W \times H = V$ ($8\text{nm} \times 8\text{nm} \times 5.4\text{nm} = 356\text{nm}^3$)

| Volume (nm ³) | Pressure (atm) | Avg Speed of Molecules |
|---------------------------|----------------|------------------------|
| 356 | 1.00 | 425 |
| 302 | 1.16 | 425 |
| 259 | 1.32 | 425 |
| 216 | 1.60 | 425 |
| 172 | 2.02 | 425 |
| 130 | 2.60 | 425 |

6. Graph your data



Summary Questions:

1. What is happening to the pressure as you decrease the volume of the container?

The pressure is increasing

2. What is happening with the particles as you decrease the volume?

The particles are bouncing off the inside walls of the container more frequently

3. How would you describe the relationship between pressure (P) and volume (V) of a gas? Explain at the particle level why this occurs?

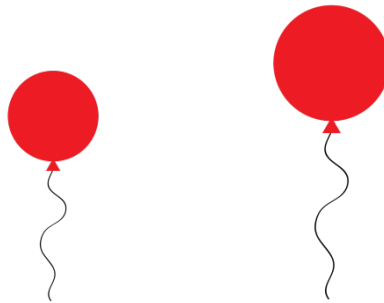
The pressure is inversely proportional to the volume of a gas. When the volume is decreased the particles bounce off the insides of the container more frequently, therefore generating a stronger force.

4. Suppose you increased the volume (V) of the container. How would the particles react, and how would the pressure (P) change?

The particles would bounce off the inside walls of the container less frequently. The pressure would decrease

5. Specifically what about the particles causes the pressure to change with changes in volume?

The collision of the molecules with the inside walls of the container produce an outward force on the container. Collectively, the average of all the collisions generates the outward force.



6. Consider these two balloons pictured above. How would you describe the relationship between the internal pressure of the balloons and the outside pressure of the atmosphere in each example? Explain your reasoning.

The inside pressure of the balloons is equal to the outside pressure of the atmosphere.

7. Reference your response to the previous question. Why does the balloon respond differently to changes in pressure than a typical container like the one used in the applet? Explain your reasoning.

The balloon is not rigid, so the outward force caused by collisions of the particles on the inside walls of the container stretch the balloon so that the internal pressure of the balloon can balance with the outside pressure.

Math Practice:

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For comparing the same substance under two different sets of condition, the law can be usefully expressed as

$$P_1V_1=P_2V_2$$

1. A gas occupies 11.2 liters at 0.860 atm. What is the pressure if the volume becomes 15.0 L?

$$(11.2 \text{ liters}) (0.860 \text{ atm}) = (P) (15.0 \text{ L}); x = 0.642 \text{ atm}$$

2. A sample of gas has a volume of 12.0 L and a pressure of 1.00 atm. If the pressure of gas is increased to 2.00 atm, what is the new volume of the gas?

$$(1.0 \text{ atm}) (12.0 \text{ L}) = (2.00 \text{ atm}) (V); x = 6 \text{ L}$$

3. Boyle's Law deals what quantities?

e. pressure/temperature

f. pressure/volume

g. volume/temperature

h. volume temperature/pressure

4. What pressure is required to compress 196.0 liters of air at 1.00 atmosphere into a cylinder whose volume is 26.0 liters?

$$(1.00 \text{ atm}) (196.0 \text{ L}) = (P) (26.0 \text{ L}); x = 7.53 \text{ atm}$$