GAS PRESSURE AND VOLUME RELATIONSHIPS

Name ____ Section_______

Log on to the Internet. Type the following address into the location-input line of your browser:

https://media.pearsoncmg.com/bc/bc_0media_chem/chem_sim/kmt/KMT.php

The simulation will open to an image of a volume of gas at a particular temperature and pressure in a container on a hotplate, which is quickly replaced with a new screen with an Overview page. You are welcome to read the Overview Page, and by clicking on the Learning Outcomes tab near the top of the display, you may read the Learning Outcomes Page. After reviewing these two pages click on the Experiment tab. When the screen changes the page will show two buttons: Run Demonstration button and Run Experiment button. You are welcome to click on the Run Demonstration button, but the instructions below are for the Run Experiment button. After clicking on the Run Experimental button the screen will look like Figure I.

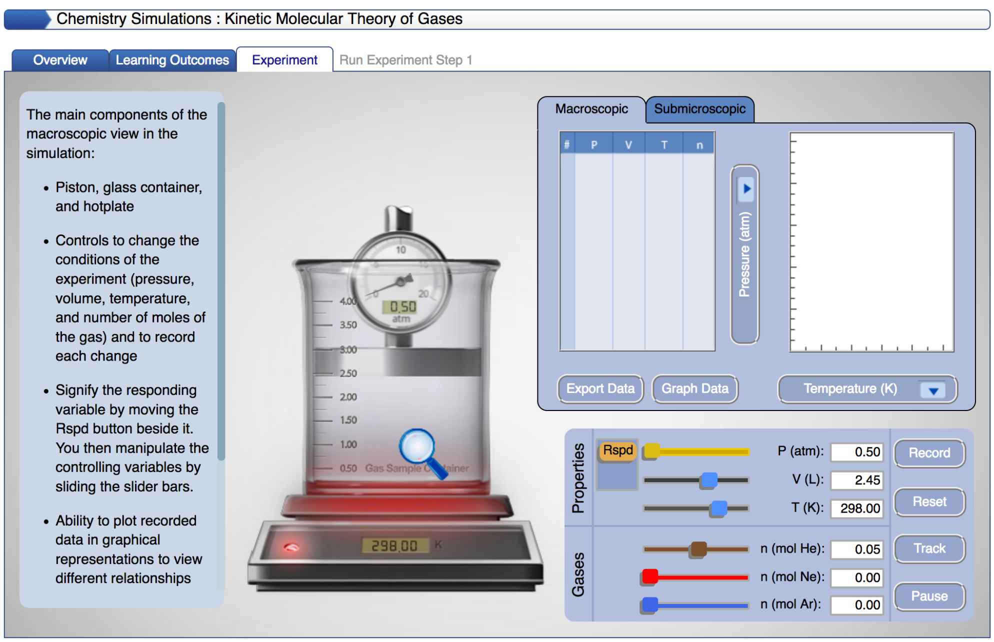


Figure I.

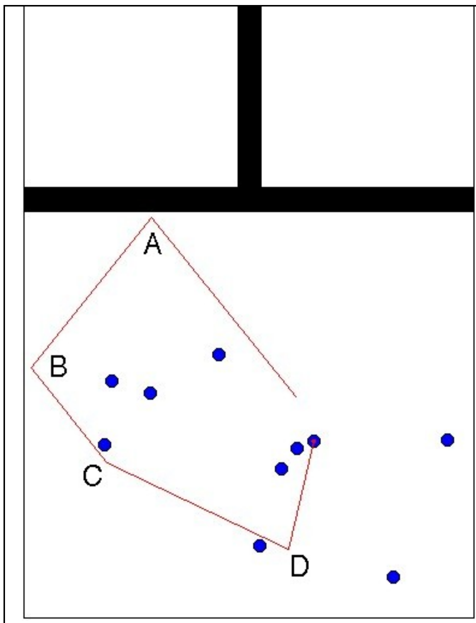
Problem Statement: How are the pressure and volume of a gas sample related?

I. Data Collection

A. In the Experimental mode click on the submicroscopic tab in the upper portion of the simulation screen. Observe the behavior of the particles and describe, in the space below, the activity you observe. Consider using some or all of the following terms in your description: particles, atoms, molecules, collisions, speed, energy, force.

Atoms/particles are moving around the container (in straight-line motion), colliding with other atoms/particles and with the walls of the container. The atom's/particle's speed and direction changes when colliding with another atom/particle, but only the direction changes when colliding with the walls of the container. When colliding with another particle the kinetic energy of the two particles will change, so the energy changes with collisions between particles. The force of the particle collisions with the walls of the container accounts for the pressure exerted by the gas.

B. Click on the Track button to enable the tracking function and trace the path of a particle from one side of the screen to the other in the space below. Explain any changes in speed or direction that you observe.



The particle collides with the wall of the container at point A and changes direction, however the velocity of the particle does not change with the collision with the wall of the container. The same behavior is observed when the particle collides with another wall at point B. There is a change in direction, but not in the velocity. The velocity is the same before the collision with the wall at point B as the velocity after the particle collides with the wall. However, at point C both the particle's direction and velocity change when colliding with another particle. This behavior is observed a second time at point D. The particles direction and velocity change when colliding with the particle. It is also interesting to note that in collisions at point C and D, the direction shift is not as predictable or as symmetric as the collisions at points A and B. Also the change in velocity that occurs at points C and D are different.

C. Record the values for pressure, volume, and temperature on the digital read-outs in the lower right portion of the simulation window.

After clicking on the Reset button the digital read-outs are:

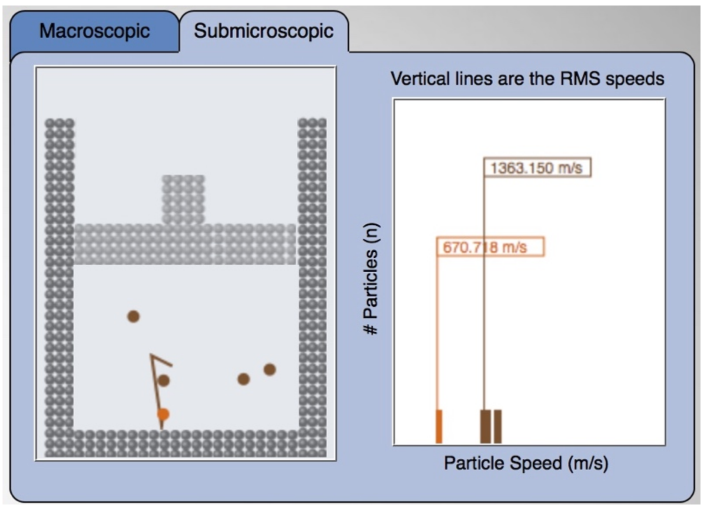
P(pressure) = 0.50 atm

V (volume) = 2.45 L

n (mole) = 0.05 mol (of He)

T (temperature) = 298 K

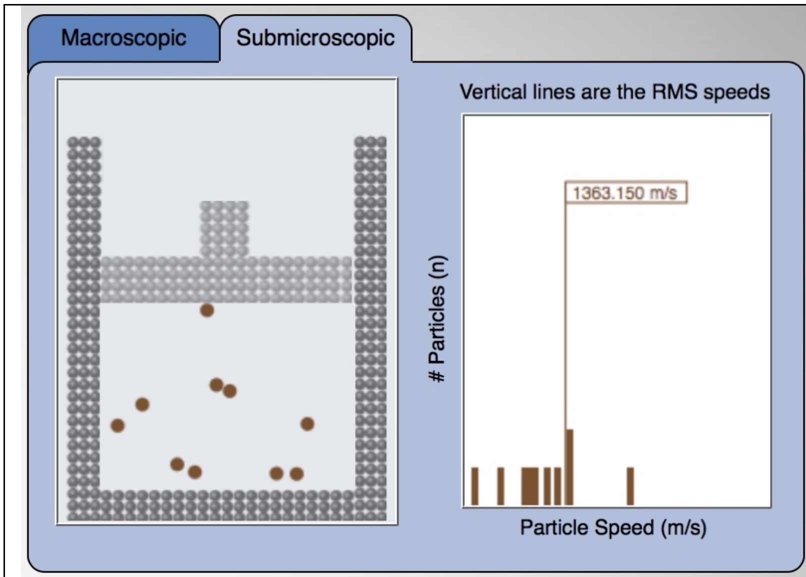
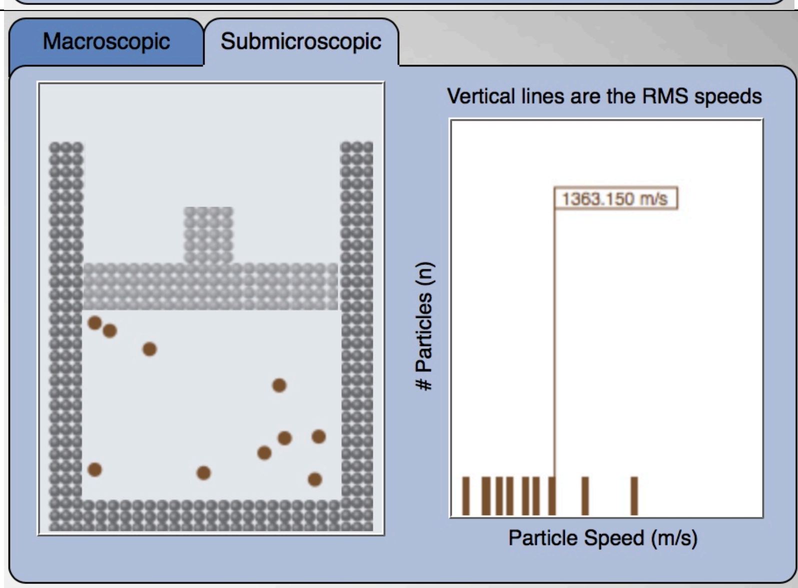
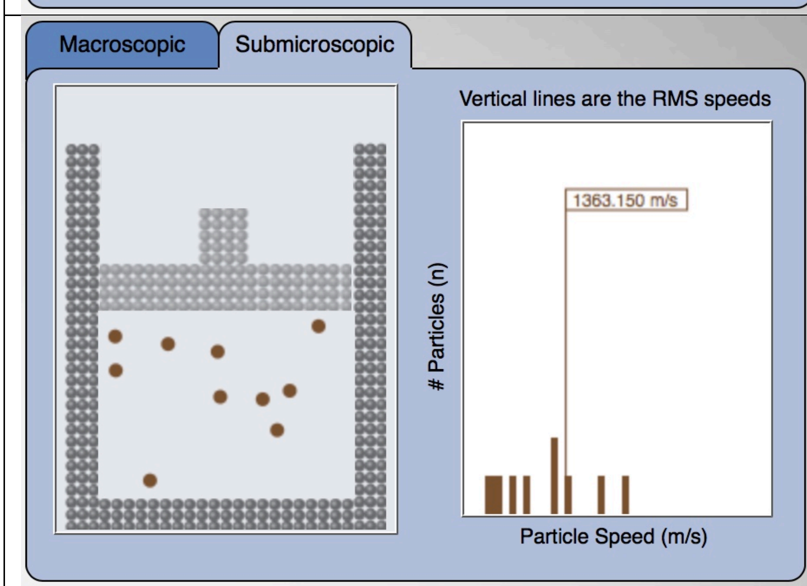
D. Observe fluctuating bars of the particle speeds graph. Relate what you see with the behavior of the particles in the submicroscopic view.



In the window on the right, bars are used to represent the different velocities of all of the particles in the sample. The velocity of 1363.150 m/s is the root-mean-square (RMS) velocity of all of the particles in the sample. The velocity of 670.718 m/s is the speed of the particle being tracked in the gas sample. When particles collide their velocity change, so the bars fluctuate in height and in position along the x-axis. When the height decreases that means a particle no longer has that velocity (it has collided with another particle). If the height increases that means a particle now has that velocity after colliding with a particle. Along the x-axis are different velocities, so the bar for a particular particle will move from different velocity value to a new velocity value after every collision with another particle. It is interesting to note that with ten particles in the container there are usually 7 to 10 different bars representing 7 to 10 different velocities. So particles of a gas do not have the exact same velocity at all times, the velocity of a sample of gas particles has a range, with some particles moving slowly and other particles moving rapidly.

Click the Pause button and sketch and label the graph in the space below.

Watching the Velocity Window, the bars are constantly changing indicating that the distribution of the particles velocities is constantly changing in the sample. Each change occurs when particles collide with each other. A particle's velocity remains constant until it collides with another particle.

	**In this sketch notice there are nine different velocities. The bar with twice the height on the right means two particles have that same velocity.** **Now look at the next sketch below.**
	**Notice in this sketch there are ten different velocities, but most of the velocities are different from the ones in the sketch above. Also notice the RMS velocity of the sample of particles is the same, in all three of these images.**
	**In this third sketch there are nine different velocities, again different from the velocities in the two sketches above. Also in this sketch there appears to be one pair of particles with the same velocity.**

E. Using the slidebars for the variable Pressure and Volume, fix Pressure as a dependent variable by moving the button. Change the volume of the container using the Volume slider bar and observe what happens to the pressure, as well as what happens in the submicroscopic view, of the system as the number of moles of gas and temperature of the gas are held constant.

i) Describe your observation about the relationship of pressure and volume. Also describe the behavior of the particles in the container as you change the Volume slidebar.

As the volume sliderbar moves to the right the volume increases and the pressure decreases. As the volume sliderbar moves to the left the volume decreases and the pressure increases. Particles continue to collide with the walls of the container and with each other.

ii) While changing the Volume sliderbar how is the average speed of the particles in the container affected? (Answer in a complete sentence.)

The average speed of the particles does not change when the volume slidebar is adjusted.

iii) While changing the Volume sliderbar does the temperature of the contents of the container change? (Answer in a complete sentence.)

The temperature of the container does not change when the volume slidebar is adjusted.

iv) Provide an explanation, in terms of the particles and their behavior, that explains why the pressure changes as a result of changing the volume of the container.

When the volume is increased the particles have a greater distance to travel before colliding with the walls of the container, so at higher volumes the number of the collisions with the walls of the container decreases and the pressure inside the container decreases. When the volume is decreased the particles have a shorter distance to travel before colliding with the walls of the container, so at lower volumes the number of the collisions with the walls of the container increases and the pressure inside the container increases.

F. Collect five additional observations of volume/pressure relationships and record all of your data in the following table.

Data Table
(mol_{He} = 0.05 and T (K) = 298 K)

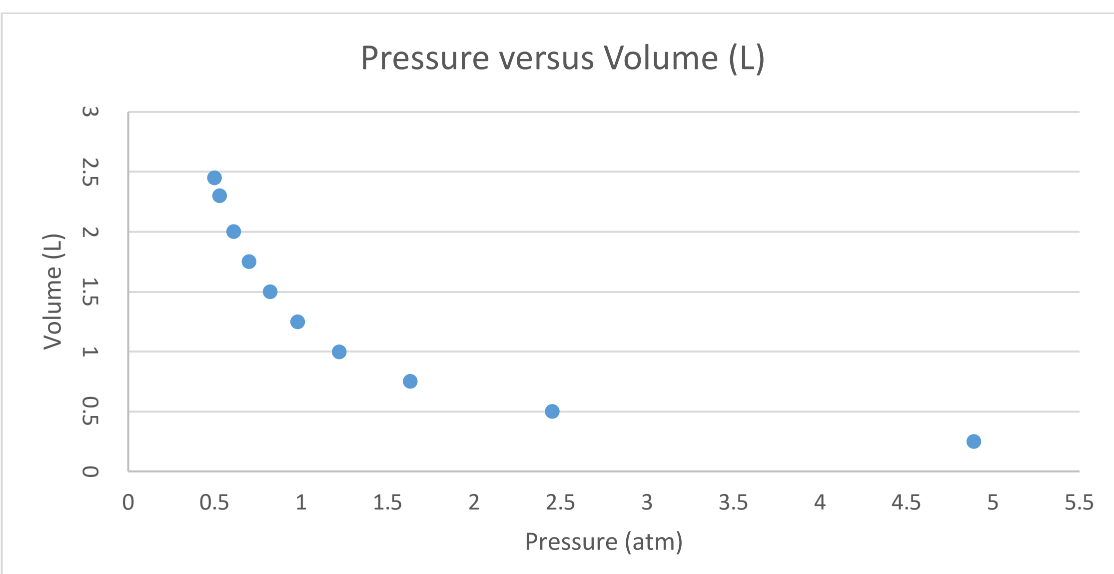
Pressure (atm)	Volume (L)
0.50	2.45
0.53	2.30
0.61	2.00
0.70	1.75
0.82	1.50
0.98	1.25
1.22	1.00
1.63	0.75
2.45	0.50
4.89	0.25

II. Data Analysis:

What patterns are shown in these data? It might be helpful to graph the data. Try to come up with an algebraic equation that expresses the pattern you found.

The pattern in the data shows that as the volume decreases the pressure increases. There is an inverse relationship between pressure and volume. Below is a graph of pressure versus volume for the data above.

Mathematically we can summarize the relationship as P·V = constant (when T and moles are constant.)



Pressure (atm)	Volume (L)	Constant (L·atm)
0.50	**2.45**	**22.8**
0.53	**2.30**	**22.5**
0.61	**2.00**	**22.7**
0.70	**1.75**	**22.6**
0.82	**1.50**	**22.7**
0.98	**1.25**	**22.6**
1.22	**1.00**	**22.7**
1.63	**0.75**	
2.45	**0.50**	
4.89	**0.25**	

The average for the constant is 22.7 L·atm

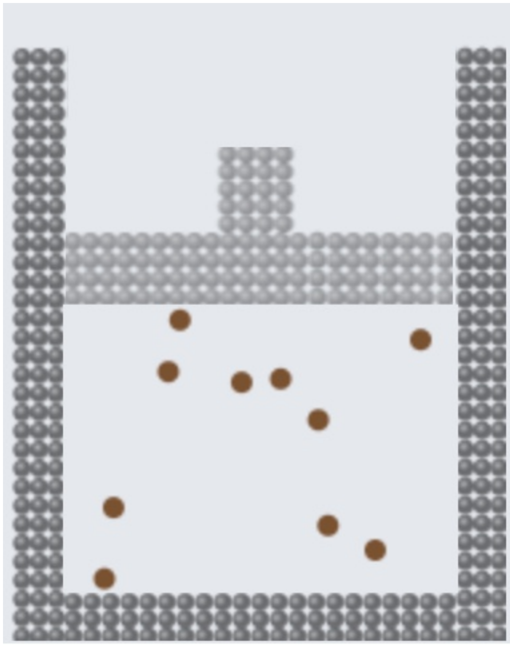
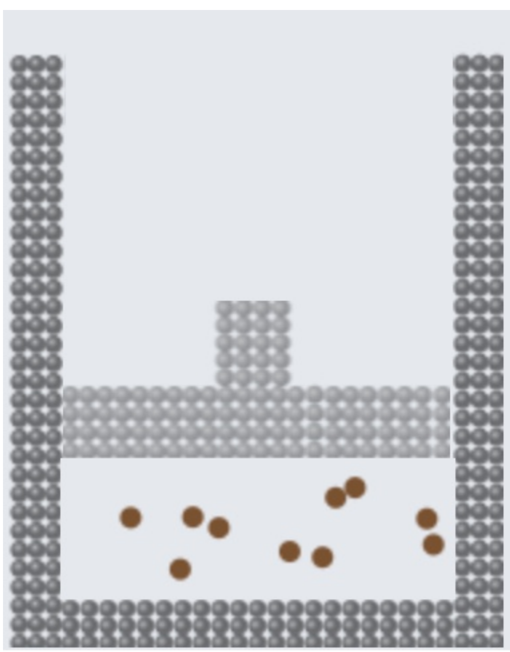
III. Interpretation and Conclusions:

A. How are the pressure and volume of a gas sample related?

Pressure is inversely related to the volume of a gas. As the volume of a container decreases the pressure increases, while the temperature and moles of gas remain constant. As shown in the table above,

$$\mathbf{P \cdot V = constant}$$

B. Mental Model - Draw a picture(s) that explains how the pressure and volume of a gas sample are related at the level of atoms and molecules, and that illustrates the observations you made in the experiment. In words, explain how your picture(s) illustrate(s) this relationship.

	**In this first diagram the volume of the container is 2.45 L and the pressure is 1.00 atm for 0.10 moles of helium at 298 K. In the second container, below, the volume is 1.20 L and the pressure is 2.04 atm for 0.10 moles of helium at 298 K.** **As the volume is reduced the pressure increases. When we look at the two diagrams we can understand that the pressure goes up when the volume goes down because in the container with the smaller volume the distance the particles must travel is smaller than in the container with the higher volume.** **If particles travel a shorter distance between collisions with the walls of the container**
	**Then there are more collisions with the walls of the container when the volume is smaller. More collisions produces higher force against the walls of the container, which means higher pressure.**

C. Using your data, predict the pressure of a gas sample at a volume of 100L. Show how you made your prediction.

From Part II. We concluded that P·V = 22.7 L·atm, so if we have a container at the same temperature and number of moles of gas as was in the container that we made our measurements in I. F.

$$\mathbf{P \cdot 100\ L = 22.7\ L\ atm}$$

$$\mathbf{P = \frac{22.7\ L\ atm}{100\ L} = 0.227\ atm}$$