Gas Pressure and Temperature Relationships

Name_________________________________ Lab Section____________________________

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

http://introchem.chem.okstate.edu/DCICLA/GLHeNeAr.htm

This will load a Particulate Simulation. Once you have the simulation running your screen will look like what is shown in Figure 1 below. If you haven't already done so, read the Particulate Simulation section of the Introduction to MoLEs Activities to learn how to use the simulation.

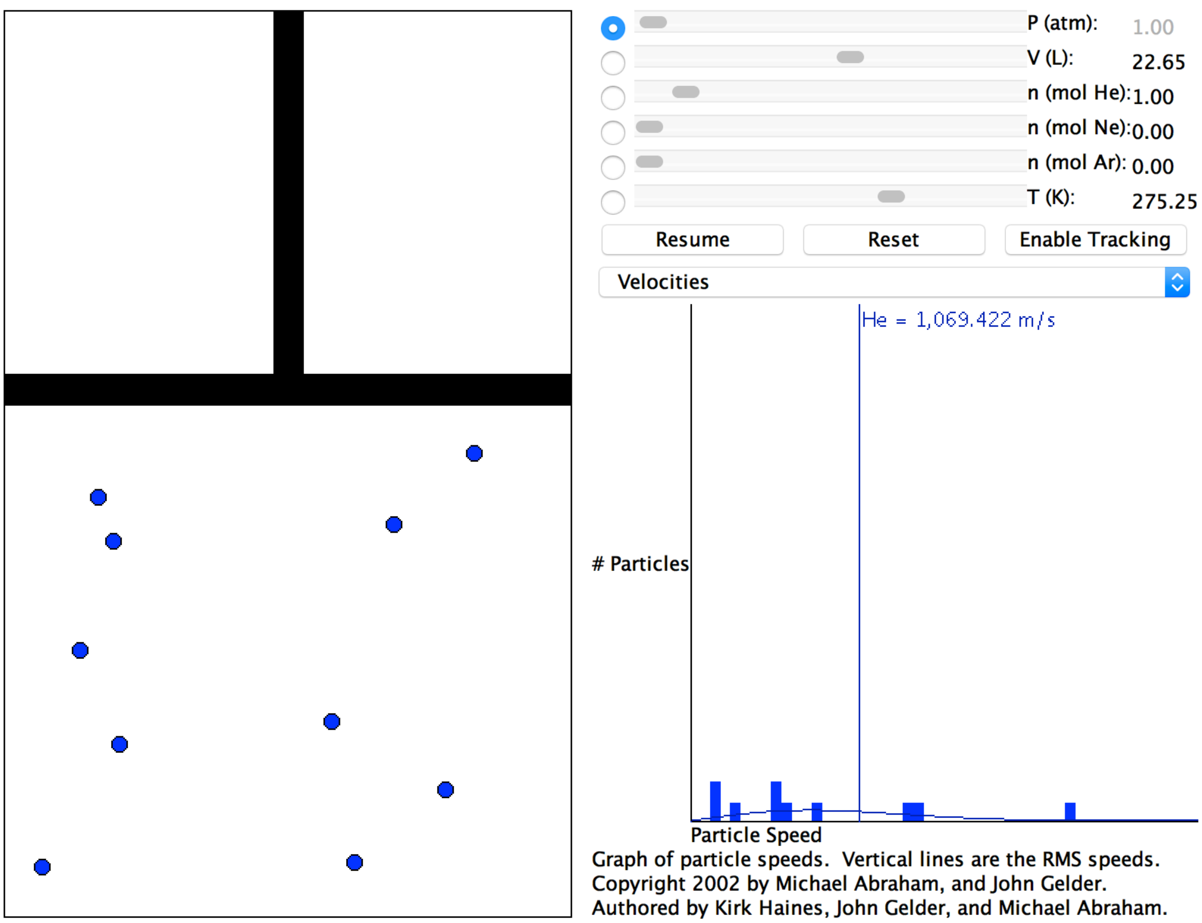


Figure 1.

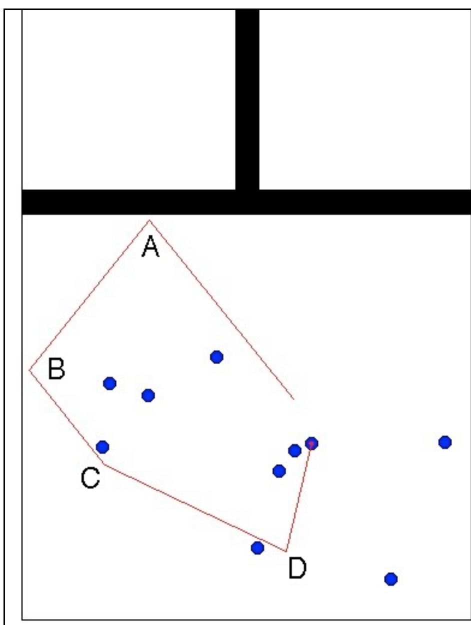
Problem Statement: How are the pressure and temperature of a gas sample related?

I. Data Collection:

A. Open the Gas Law Simulation program and observe and describe, in the space below, the activity in the Gas Sample window. 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 particles change, so the energy changes with collisions between particles, but the total energy is conserved. The force of the collision with the walls of the container accounts for the pressure exerted by the gas.

B. 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.**

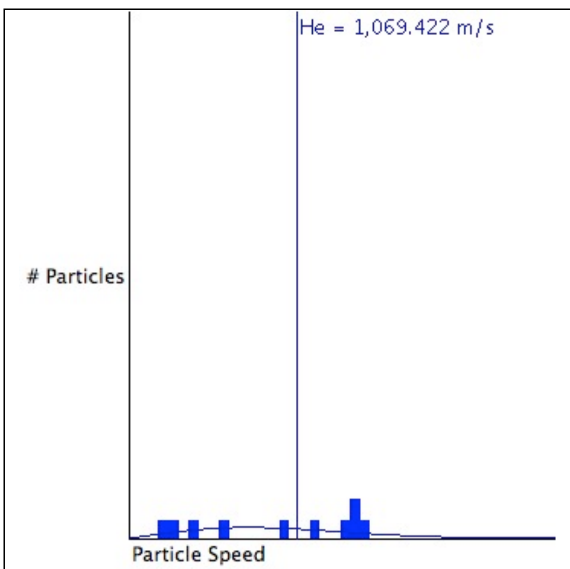
C. Record the values for pressure, volume and temperature on the digital read-outs of the Control Bar window.

After clicking on the Reset button the digital read-outs are:
P(pressure) = 1 atm
V (volume) = 22.65 L
n (mole) = 1 mol (of He)
T (temperature) = 275.25 K

D. Observe the action in the Velocities window. Relate what you see with the behavior of the objects in the Gas Sample window.

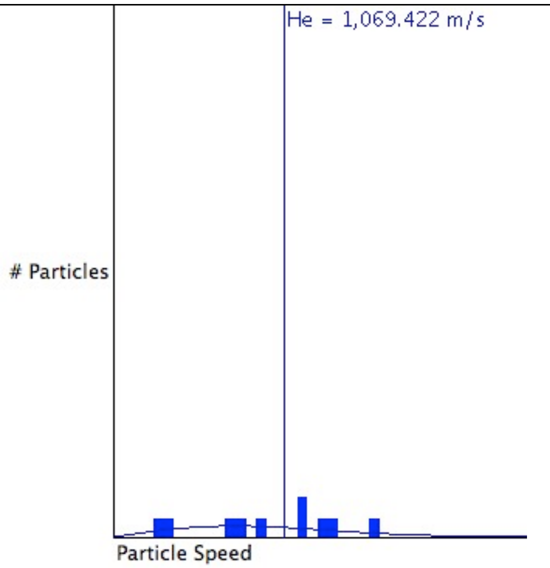
In the Velocities window bars are used to represent the different velocities of all of the particles in the sample. When particles collide their velocity change, so the bars fluctuate in height and in position along the x-axis. When the height decreases that means a particle no longer has that velocity (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.

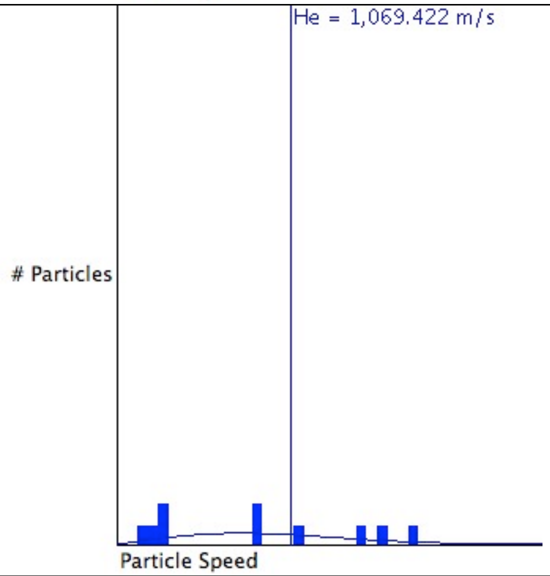
Click the Pause button and sketch and label the graph in the space below.



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.

<table>
<tr>
<td>


</td>
<td>Notice in this sketch there are again nine different velocities, but most of the velocities are different from the ones in the sketch above. Also notice there is one pair of particles with the same velocities.</td>
</tr>
<tr>
<td>


</td>
<td>In this third sketch there are eight different velocities, again different from the velocities in the two sketches above. Also in this sketch there appear to be two pairs of particles each different velocities.</td>
</tr>
</table>

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

E. Using the controls in the Control Bar window, fix Pressure as a dependent variable by clicking on its radio button. Change the temperature of the container using the temperature slider bar and observe what happens to the pressure of the system. Also observe what happens in the Speed Distribution window. Explain how the activity in the Gas Sample window accounts for your observations.

As the temperature is decreased it is observed that in the Velocity Window the distribution

of particle velocities is changing much more slowly. The bars are going up and down and moving left and right more slowly. This is happening because as the temperature of the container is lowered the average velocity of the collection of particles decreases, resulting in the fewer collisions with the walls of the container. Additionally, because the particles are moving more slowly the average force of the collision between the particle and a wall of the container is also smaller. So there are fewer collisions with the walls, and less forceful collisions. This results in the observed drop in pressure in the container. Collisions with other particles cause a change in velocity for each particle we observe that the distribution of velocity changes more slowly. Since the particles are slowing down, the number of particles with lower velocity increases, and the number of particles with high velocity decreases, this produces the observed change in the particle distribution and in the observe drop in the average velocity of the collection of particles.

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

Data Table

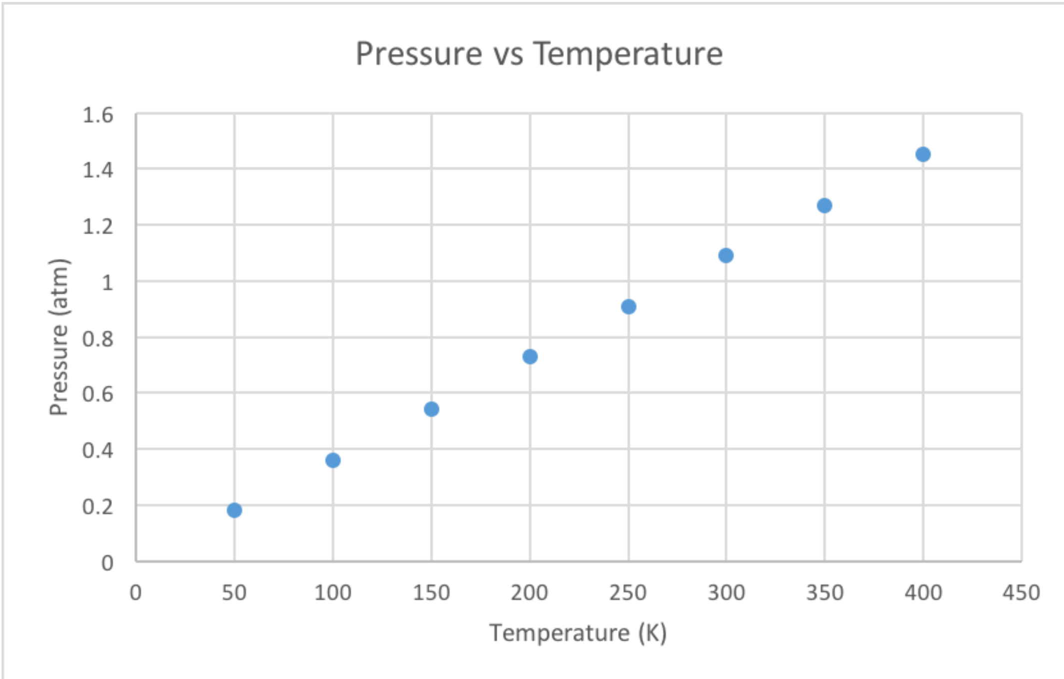
Pressure (atm)	Temperature (K)
0.18	50
0.36	100
0.54	150
0.73	200
0.91	250
1.09	300
1.27	350
1.45	400

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 temperature increases the pressure increases. There is an direct relationship between temperature and pressure. Below is a graph of pressure versus temperature for the data above.

Mathematically we can summarize the relationship as $\frac{P}{T}$ = constant (when volume and moles are constant.)



Pressure (atm)	Temperature (K)	Constant $\frac{P}{T}$
0.18	50	0.0036
0.36	100	0.0036
0.54	150	0.0036
0.73	200	0.0036
0.91	250	0.0036
1.09	300	0.0036
1.27	350	0.0036
1.45	400	0.0036

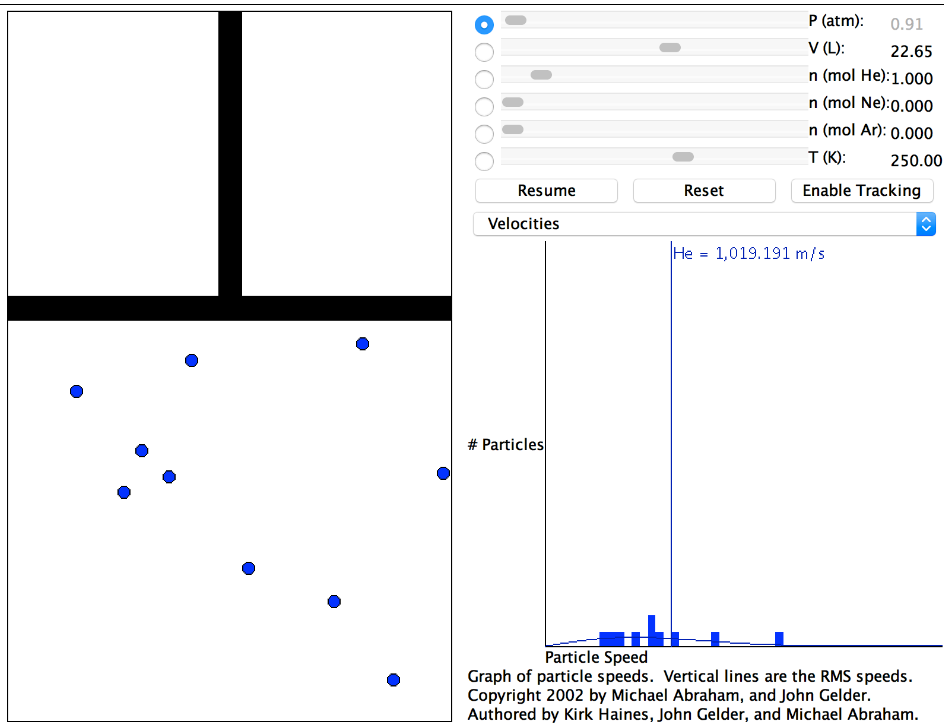
The average for the constant is 0.0036$\frac{atm}{K}$

III. Interpretation and Conclusions:

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

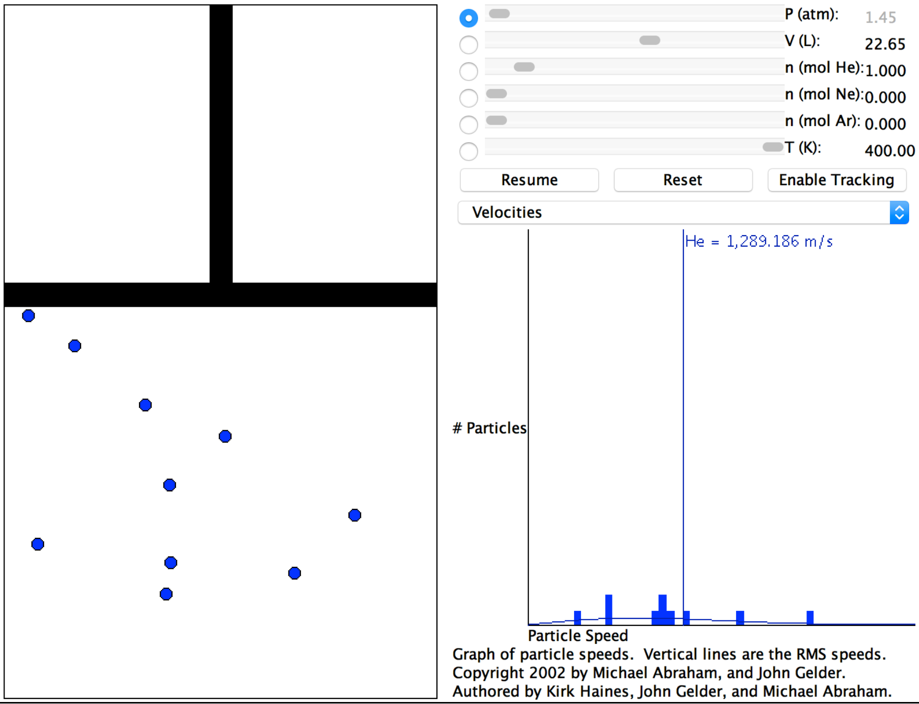
Pressure is directly related to the temperature of a gas. As the temperature of a container increases the pressure increases, while the volume and moles of gas remain constant.

B. Mental Model - Draw a picture(s) that explains how the pressure and temperature 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 temperature of the gas sample is 250 K and the pressure is 0.91 atm. In the second container, below, the temperature is 400 K and the pressure is 1.45 atm.

As the temperature is raised the pressure increases. When we look at the Velocity distribution, in the lower right portion of the image, the average velocity of the particles is 1019 meters sec^{-1}. In the image below, at the higher temperature, the average velocity of the particles is 1289 meters sec^{-1}. The higher velocity of the particles in the container at constant

	**volume and moles of gas mean the particles at 400 K are moving faster, colliding with the walls of the container more often, and collisions are on the average more forceful, causing the pressure exerted in the container to increase.**

C. Using your data, predict the pressure of a gas sample at a temperature of 10 K. Show how you made your prediction.

From Part II. We concluded that $\frac{P}{T} = 0.0036\frac{atm}{K}$, so if we have a container at the same volume and number of moles of gas as was in the container that we made our measurement in I. F.

$$\frac{P}{T} = 0.0036\frac{atm}{K}$$

$$P = 0.0036\,\frac{atm}{K} \cdot 10\ K = 0.036\ atm$$