Kinetic Molecular Theory

Information:

The **macroscopic** behavior or properties of gases can be explained by the **microscopic** behavior of the particles of a gas. This is known as the Kinetic Molecular Theory of Gases.

The Kinetic Molecular Theory postulates that ideal gases are governed by the following rules:

1. The particles of a gas move in constant, random, straight-line motion and follow Newton's laws
2. The particles of a gas are solid, spherical and have relatively negligible volume
3. Gas particles move independently of each other and experience no attractive or repulsive forces between each other or the walls of the container
4. Collisions are elastic i.e. no energy loss occurs during collisions between particles or the walls of the container
5. Pressure is a result of collisions between particles and the walls of the container

Kinetic Energy is the energy of motion of a particle and is a product of its mass and speed

Procedure:

Go to the following web address and click on **Run Now**

http://phet.colorado.edu/simulations/sims.php?sim=Gas_Properties

Click on measurement tools and select ruler and species information. The ruler can be moved and used to measure the length of the chamber and the species information indicates the number of molecules and their average speed. Make a note of the initial conditions of the pressure, temperature and length (nm) of the gas chamber.

Initial Conditions: Temp_________ Pressure _________ Length____________

The idea of pressure resulting from collisions between gas particles and the walls of the container can be illustrated by the following:

1. Add 100 heavy molecules to the chamber by typing in the input box or clicking on the arrows next to Heavy Species in the Gas in Chamber section. After allowing the chamber to stabilize, record the average speed, temperature, length of the container and pressure in the data field below.
2. Click Reset and then add 100 light molecules and record the same information after again allowing the chamber to stabilize.
3. Click Reset again and add 50 heavy and 50 light molecules and record the same information after allowing the chamber to stabilize. You will need to calculate the average speed.
4. Click Reset again and add 50 heavy molecules and record the same information after allowing the chamber to stabilize.

5. Click Reset again and add 50 light molecules and record the same information after allowing the chamber to stabilize.
6. Click Reset again and add 10 heavy molecules and record the same information after allowing the chamber to stabilize.
7. Click Reset again and add 10 light molecules and record the same information after allowing the chamber to stabilize.

Species Type and number	Total n	Average speed	Pressure	Temperature	Length
100 Heavy	100				
100 Light	100				
50 Heavy and 50 Light	100				
50 Heavy	50				
50 Light	50				
10 Heavy	10				
10 Light	10				

Questions:

1. What is the relationship between the mass of the molecules of a gas and the average speed of the molecules when the temperature and volume of the chamber are constant?

2. What is the relationship between the mass of the molecules of a gas and the amount of pressure it exerts when the temperature and volume of the chamber are constant?

3. What is the relationship between the number of gas molecules and the number of collisions with the walls of the container that result in a time period? Why?

4. What would happen to the number of collisions in a time period if the speed of the molecules were increased? Why?

5. What is the relationship between the number of molecules of a gas and the amount of pressure it exerts when the temperature and volume of the chamber are constant? Why?

The Ideal Gas Law

Information:

The properties of gases, pressure, volume, and temperature, are expressed by the ideal gas law equation:

$$PV=nRT$$

Where P = pressure in kilopascals or atmospheres

V = volume in liters

n = amount of gas in moles

T = temperature in Kelvin

R = gas constant = 8.314 L* kPa / mol * K or .08206 L* atm / mol * K

Examine the ideal gas law equation and rearrange it to solve for each of the variables.

P=

V=

T=

n=

Calculate the volume of 1.50 moles of a gas at 115 kPA and a temperature of 298 K.

Questions:

Use the Ideal Gas Equation to answer the following questions.

1. If the number of moles and the temperature of a sample of gas are kept constant, what would happen to P if V increases?
2. If the number of moles and the pressure of a sample of gas are kept constant, what would happen to V if T decreases?
3. If the number of moles and the volume of a sample of gas are kept constant, what would happen to P if T increases?

Boyle's Law

$P_1V_1 = P_2V_2$

Boyle's Law relates pressure and volume keeping temperature constant where **P_1 and V_1 are the initial state** of the gas and **P_2 and V_2 are the final state** of the gas.

Examine Boyle's Law and rearrange the equation to solve for each of the variables

P_1 =

V_1 =

P_2 =

V_2 =

Procedure:
Click Reset.
Click on measurement tools and select ruler.
Select Temperature in the Constant Parameter section to make it a constant.

1. Use the handle on the side of the chamber to adjust the volume of the chamber until it is 6.4 nm wide.
2. Add 100 total molecules of your choice in any combination to the chamber.
3. Record the Temperature and the ***initial volume*** and ***initial pressure*** after allowing the system to stabilize.
4. Use the handle on the side of the chamber to adjust the volume of the chamber until it is 3.2 nm wide. Note any other activity on the screen.

5. Record the temperature and the ***final volume*** and ***final pressure*** after allowing the system to stabilize.

Species Type and Number					
	Length	Height	Total Volume	Pressure	Temp
Initial		5.2			
Final		5.2			

Try adding more molecules and removing some molecules and note the effect it has on the pressure. Molecules can be removed by sliding the lid on top over and allowing them to escape.

Questions:

1. Examine the equation for Boyle's Law. Should the value of P_2 increase or decrease if V_2 is decreased?

2. Did this happen when you reduced the volume of the chamber?

3. Is the relationship between pressure and volume directly or inversely proportional?

4. What other activity did you notice happening on the screen while you reduced the volume of the chamber? Explain why you think this may have occurred.

5. Using Boyle's Law, calculate the final pressure of a gas if the initial volume was 500ml at a pressure of 1.00 atm and the final volume was 750 mL?

6. Find the initial volume of a gas in mL if the initial pressure was 125 kPa and the final volume and pressure were .250 L and 175 kPa respectively.

7. Explain why the pressure increases in an air pump as you push down on the handle.

Charles' Law

$$V_1 / T_1 = V_2 / T_2$$

Charles' law relates volume and temperature keeping pressure constant where **V_1 and T_1 are the initial state** of the gas and **V_2 and T_2 are the final state** of the gas.

Examine Charles' Law and rearrange the equation to solve for each of the variables

V_1 =

T_1 =

V_2 =

T_2 =

Procedure:
Click Reset.
Click on measurement tools and select ruler.
Make sure the Constant Parameter is set to none before beginning.

1. Use the handle on the side of the chamber to adjust the volume of the chamber until it is 4.0 nm wide.
2. Add 100 total molecules of your choice in any combination to the chamber.
3. Select Pressure in the Constant Parameter section to make it a constant.
4. Record the pressure and the ***initial volume*** and ***initial temperature*** after allowing the system to stabilize.
5. Use the heat control to add heat by clicking and dragging the button. Add enough heat to bring the temperature to a little over 500 degrees K and record the ***final volume*** and ***final temperature*** in the > 500 degree row after allowing some time for the system to stabilize. Note any other activity on the screen.

6. Use the heat control to remove heat by clicking and dragging the button. Remove enough heat to bring the temperature to a little under 200 degrees K and record the ***final volume*** and ***final temperature*** in the < 200 degree row after allowing some time for the system to stabilize. Note any other activity on the screen

Species Type and Number					
	Length	Height	Total Volume	Temp	Pressure
Initial		5.2			
> 500 degrees		5.2			
< 200 degrees		5.2			

Questions:

1. Examine the equation for Charles' Law. Should the value of V_2 increase or decrease if T_2 is increased? If T_2 is decreased?

2. Did this happen when you increased the temperature of the gas in the chamber? Decreased the temperature?

3. Is the relationship between volume and temperature directly or inversely proportional?

4. What other activity did you notice on the screen while you increased and reduced the temperature of the gas in the chamber? Explain why you think this may have occurred.

5. Using Charles' Law, calculate the final temperature of a gas if the initial volume was 250 ml at a temperature of 300 degrees K and the final volume was 750 mL?

6. Find the initial temperature of a gas if the initial volume was 125 mL and the final volume and temperature were .500 L and 175 K respectively.

7. Using Charles' Law explain why a balloon you purchased at the store deflates when you take it outside on a cold winter day.

Gay-Lussac's law

$$P_1 / T_1 = P_2 / T_2$$

Gay-Lussac's law relates pressure and temperature keeping volume constant where **P_1 and T_1 are the initial state** of the gas and **P_2 and T_2 are the final state** of the gas.

Examine Gay-Lussac's and rearrange the equation to solve for each of the variables

P_1 =

T_1 =

P_2 =

T_2 =

Procedure:

Click Reset.

Click on measurement tools and select ruler.

Make sure the Constant Parameter is set to none before beginning.

1. Use the handle on the side of the chamber to adjust the volume of the chamber until it is 5.0 nm wide.
2. Add 150 – 170 total molecules of your choice in any combination to the chamber.
3. Select Volume in the Constant Parameter section to make it a constant.
4. Record the ***initial pressure*** and ***initial temperature*** after allowing the system to stabilize.
5. Use the heat control to add heat by clicking and dragging the button. Add enough heat to bring the temperature to about 500 degrees K and record the ***final pressure*** and ***final temperature*** in the 500 degree row after allowing some time for the system to stabilize. Note any other activity on the screen.

6. Use the heat control to remove heat by clicking and dragging the button. Remove enough heat to bring the temperature to about 50 degrees K and record the ***final pressure*** and ***final temperature*** in the 50 degree row after allowing some time for the system to stabilize. Note any other activity on the screen.

7. Increase the temperature to about 1600 degrees K and then add heat slowly. Record what happens here.

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Species Type and Number					
	Length	Height	Total Volume	Temp	Pressure
Initial	5.0	5.2	26 nm^2		
500 degrees	5.0	5.2	26 nm^2		
50 degrees	5.0	5.2	26 nm^2		

Questions:

1. Examine the equation for Gay-Lussac's Law. Should the value of P_2 increase or decrease if T_2 is increased? If T_2 is decreased?

2. Did this happen when you increased the temperature of the gas in the chamber? Decreased the temperature?

3. Is the relationship between pressure and temperature directly or inversely proportional?

4. What other activity did you notice happening on the screen while you increased and reduced the temperature of the gas in the chamber? Explain why this occurred.

5. Using Gay-Lussac's Law, calculate the final temperature of a gas if the initial pressure was 255 kPa at a temperature of 500 degrees K and the final pressure was 67.5 kPa?

6. Find the initial pressure of a gas if the final pressure was 125 kPa at a temperature of 340 degrees K and the initial temperature was 175 degrees K.

7. Using Gay-Lussac's Law explain why a tire you inflated to the recommended proper pressure on a cold day has a pressure higher than recommended on a hot summer day.

8. What happened when the temperature was raised to over 1600 degrees K? Without reducing the temperature, identify two things you could have changed in the system to keep the container lid from coming off.