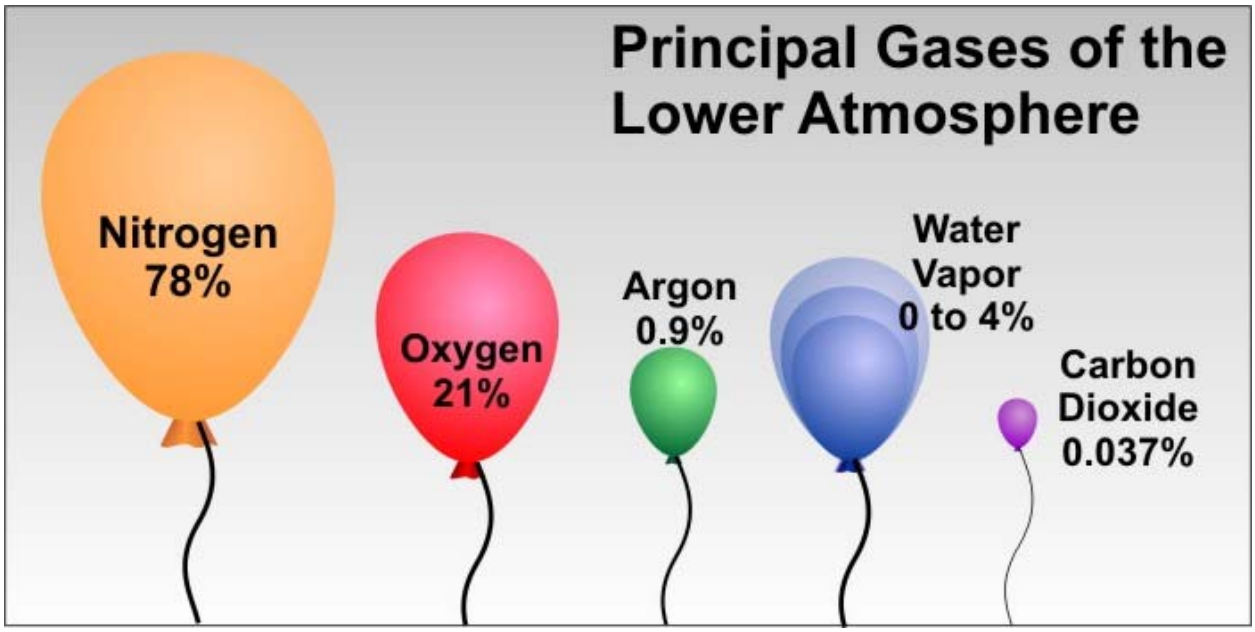
GASES

Learning Objectives:

I. Atmosphere
II. Kinetic Molecular Theory
III. Gas pressure
IV. Relationship between pressure, volume and Temperature, amount of the gas
V. Combined Gas Law
VI. Ideal gas law
VII. Dalton's law
VIII. Molar volume
IX. Vapor Pressure

I. Atmosphere

On earth, we live under a blanket of air that presses down us and everything else surrounding us. According to weather report, the pressure of atmosphere varies day to day. Atmosphere contains several gases like nitrogen, oxygen, argon etc. Their relative percentages in air are given below.

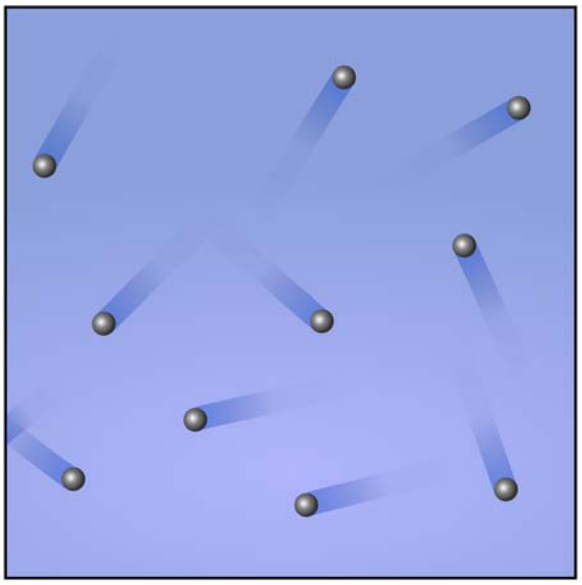


As the height of the air column decreases in higher altitude, the atmospheric pressure decreases. Air pressure is highest at the sea level. Below sea level pressure increases due to water pressure and atmospheric pr.

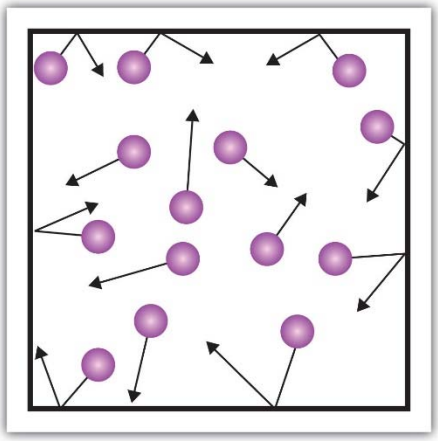
II. Behavior of Gases: Kinetic Molecular Theory

Set of five statements that explain the physical behavior of gaseous system. They are popularly called Kinetic Molecular Theory of Gases.

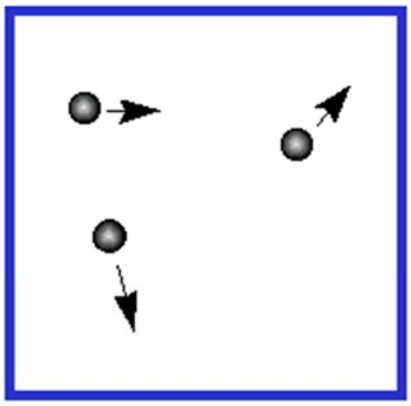
1. A gas consists of small particles (atoms or molecules) that move randomly with high velocities. Below is the molecular view of a gaseous system.



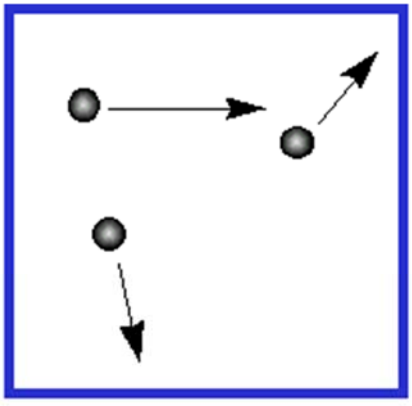
2. gas molecules are constantly moving in straight line motion randomly and colliding with other particles and the walls of the container.



3. At ordinary condition, particles are separated from each other by relatively large distance. They don't experience any attractive-repulsive forces between the molecules.
4. Molecules don't have any volume or mass. The volume of the container is the volume of the gas.
5. The average kinetic energy of the gas molecules is proportional to the Kelvin temperature of the gas molecules.

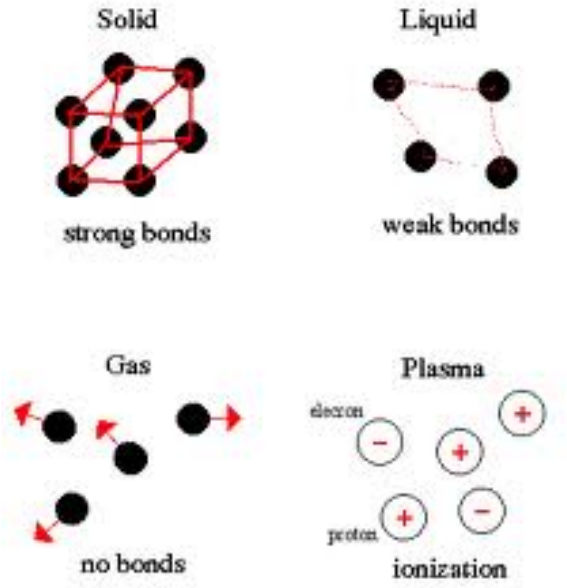


Lower average kinetic energy
Lower absolute temperature



Higher average kinetic energy
Higher absolute temperature

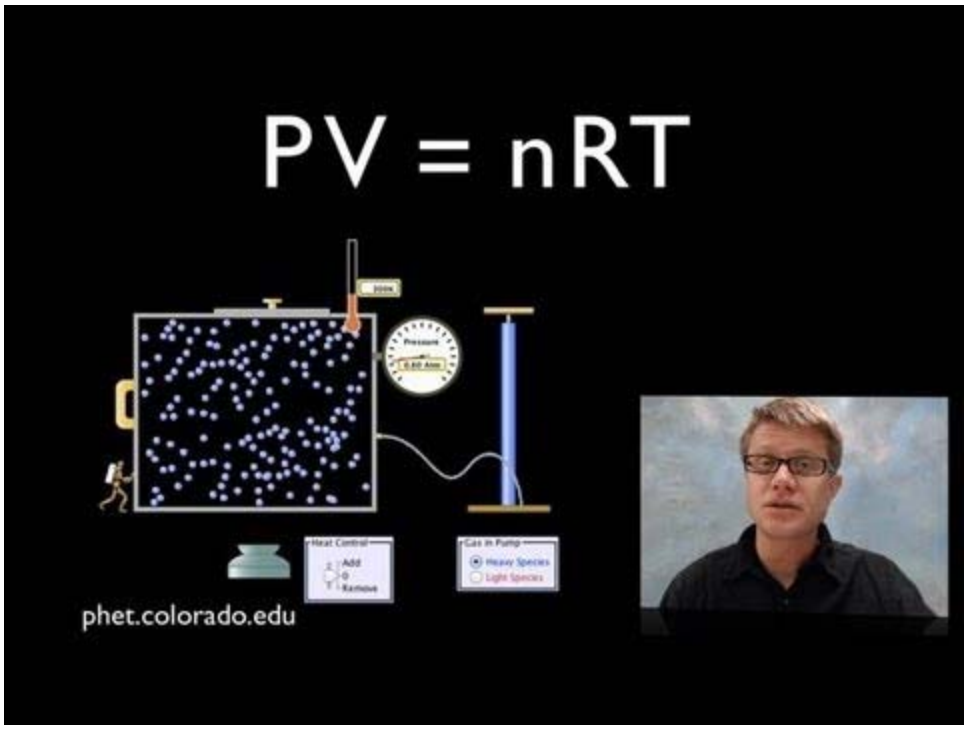
Here is the particulate view of all states of matter including plasma.



This video may help to get a overview of the properties of gases.

https://www.youtube.com/watch?v=o3f_VJ87Df0

https://www.youtube.com/watch?v=gmN2fRlQFp4



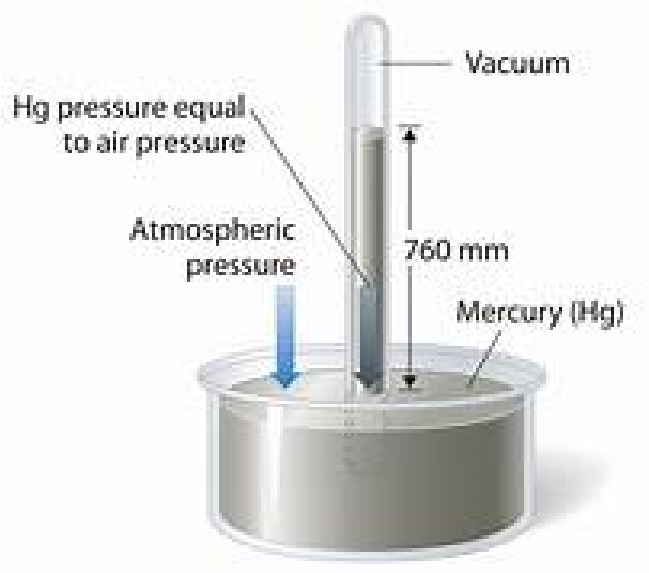
III. Gas pressure

The pressure of a gas is the force exerted when gas particles strike the surface of the walls of the container. The pressure a gas exerts on a surface, such as the walls of a container, results from the continual bombardment on the walls of the container by the rapidly moving gas molecules. We use an instrument called barometer to measure atmospheric pressure. One type of barometer consists of a long glass tube that is completely filled with mercury and then inverted into a pool of mercury in a dish. Because there is no air at the top of the mercury column inside the tube no gas pressure is exerted on the mercury column. The atmosphere, however, exerts its pressure on the mercury in the open dish. The difference in the heights of the two mercury levels is a measure of the atmospheric pressure. Pressure is measured by barometer and units are:

Atmosphere(atm), millimeter of Hg(mm Hg) , torr.

1atm= 760 torr=760 mm of Hg= 14.7 psi= 101,325 Pa

Other units of pressure are pascal, bar etc. All the units can be interconverted.



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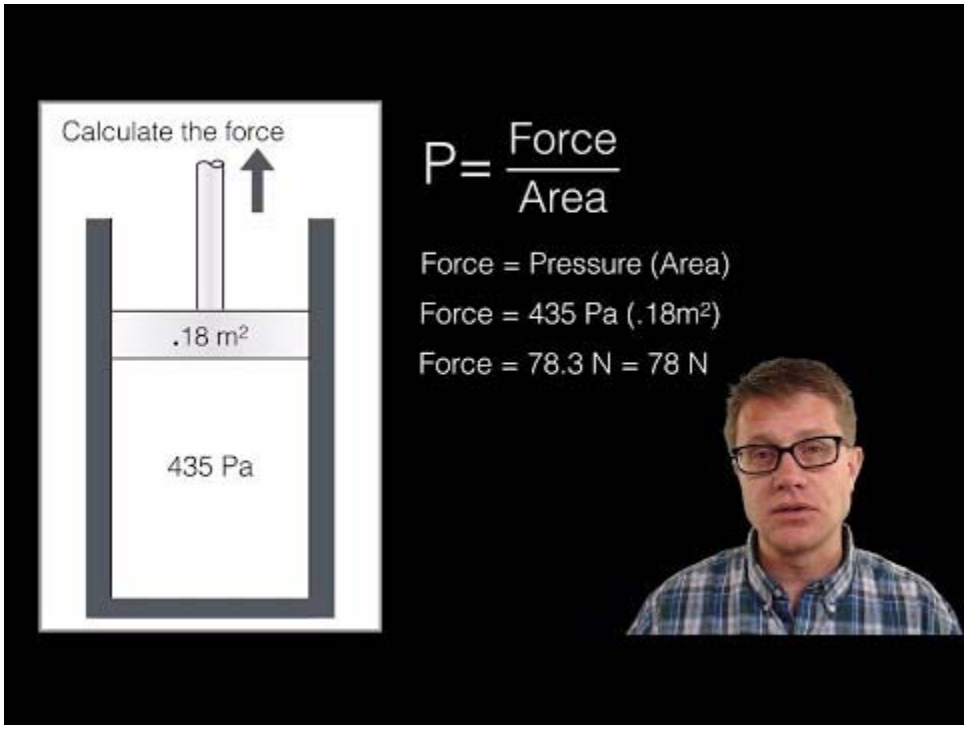


Example: On a dry day, atmospheric pressure is 734 torr. What is the pressure in atmospheric unit?

Ans: 734 torr * $\frac{1\ atm}{760\ torr}$ = 0.966 atm

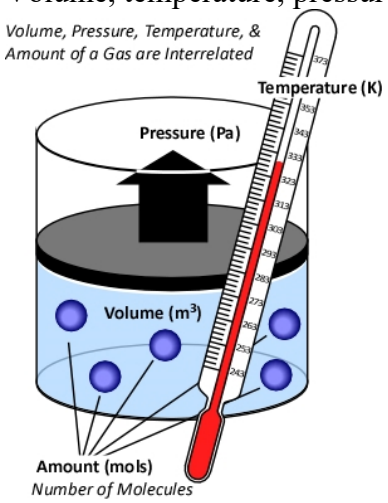
Question:

1. A scuba diver begins diving at 3000. psi. Convert this pressure into a) atm b) mm of Hg.

Ans: a) 204.1 atm b) 155100 mm of Hg

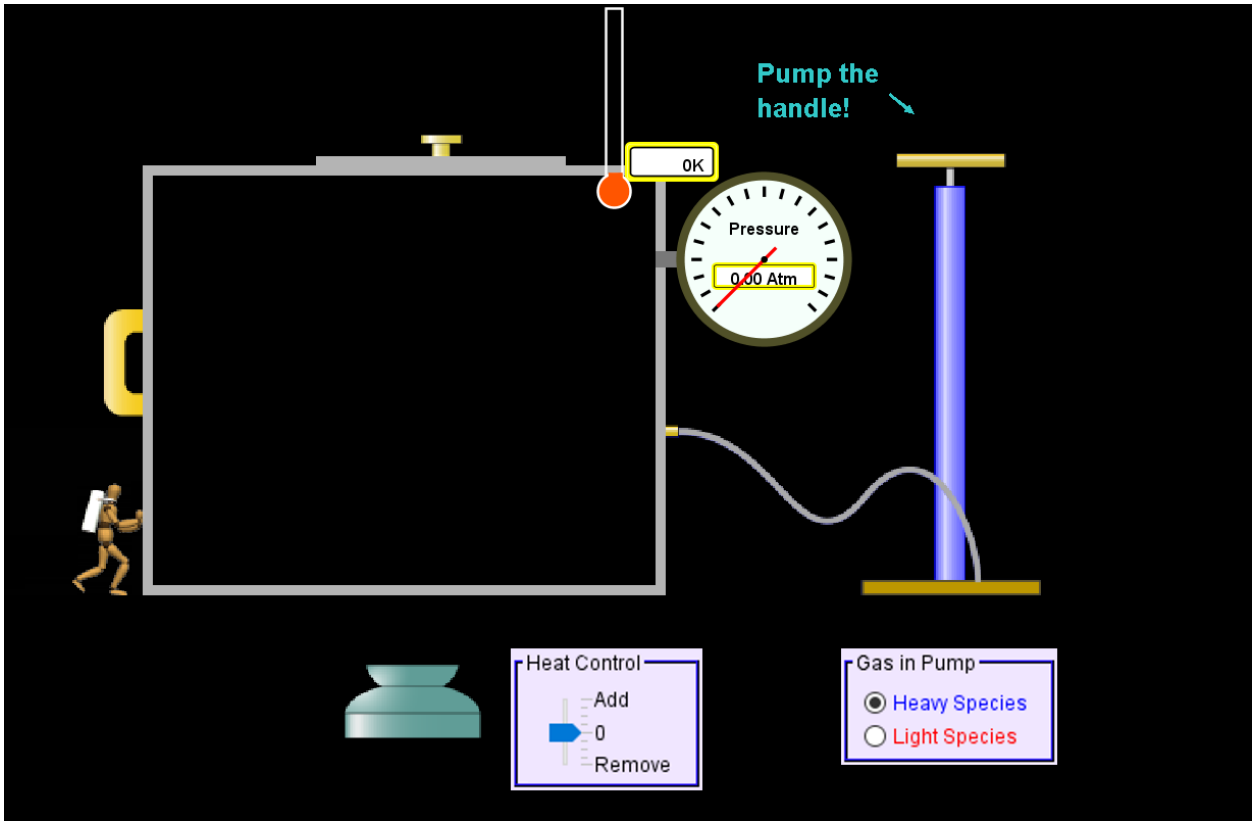
IV. Gas Laws

Volume, temperature, pressure and number of moles are interrelated in gaseous system.



https://phet.colorado.edu/en/simulation/legacy/gas-properties

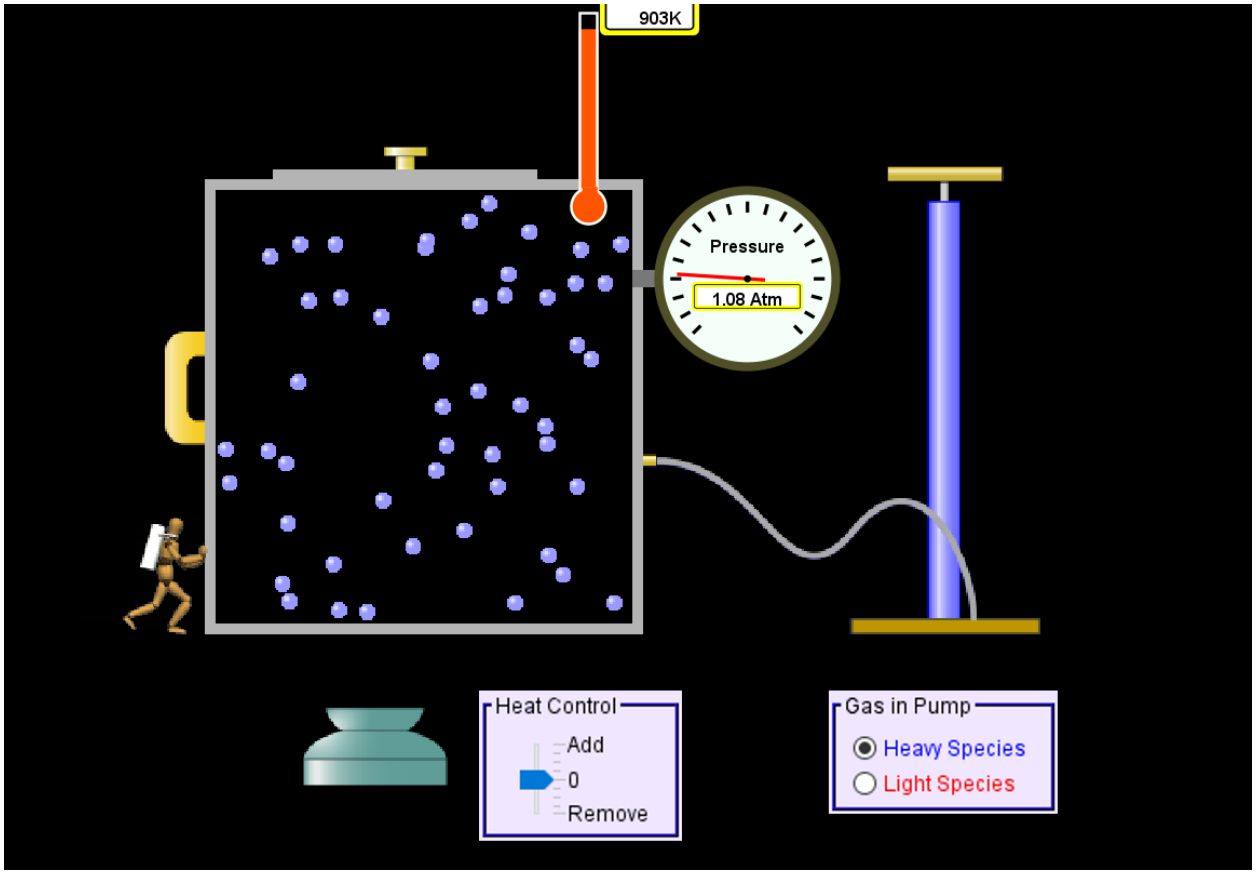
Click on the above simulation and observe the properties of Gas.

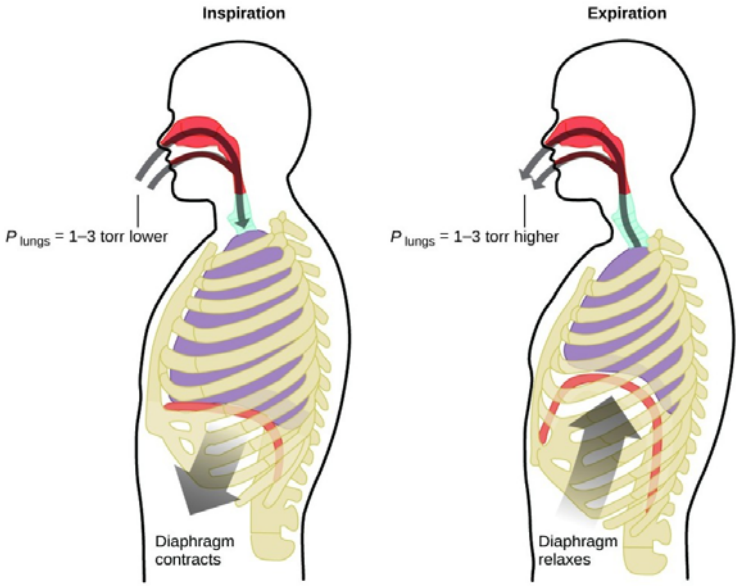


1) Now introduce 50 molecules into the chamber using the handle pump. Slowly decrease the volume of the container using the man symbol. Notice that the pressure monitoring system is giving higher and higher values. This is called Boyle's law.

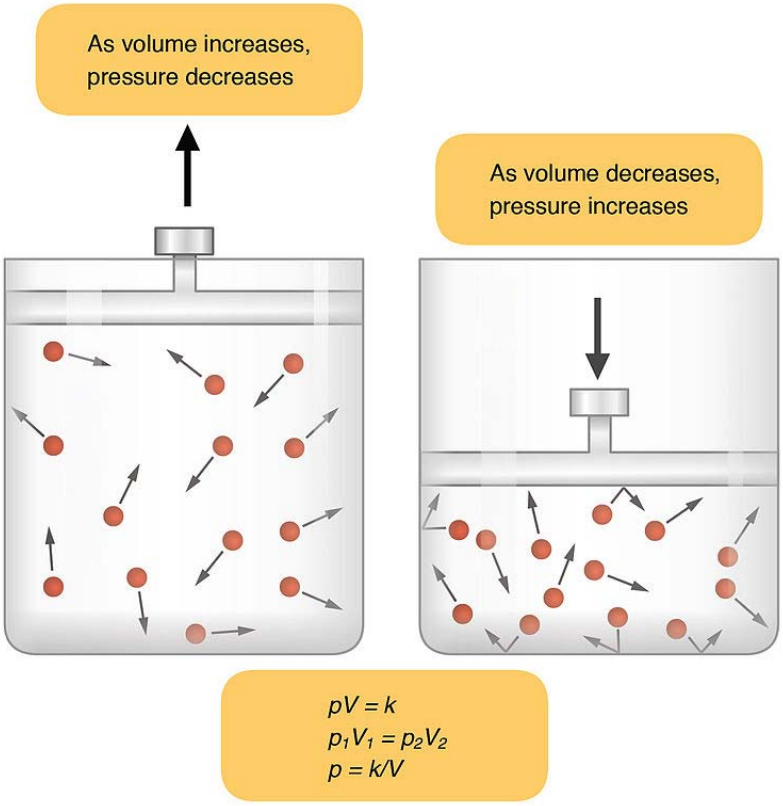
Boyle's law: Volume of a fixed amount of gas is inversely proportional to the pressure applied to the gas if the Temp is kept constant.

Boyle's law has wide application in various fields like scuba diving, human breahing technique.





When a person breathe in, the diaphragm contracts and volume of the lungs get bigger and pressure is low inside the body than outside pressure. Since outside pressure is high, air goes inside the body. When we breathe out, the diaphragm relaxes, volume decreases, high pressure gas comes out of the body.



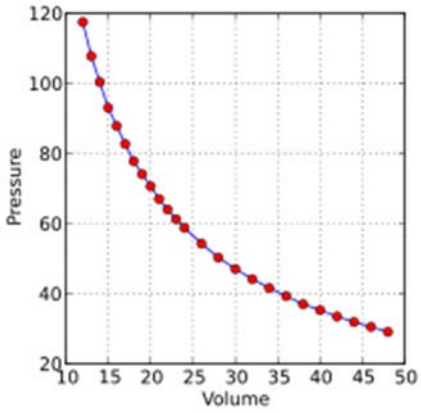
Mathematically we can write,

at constant T,n

$$P_1 V_1 = P_2 V_2$$

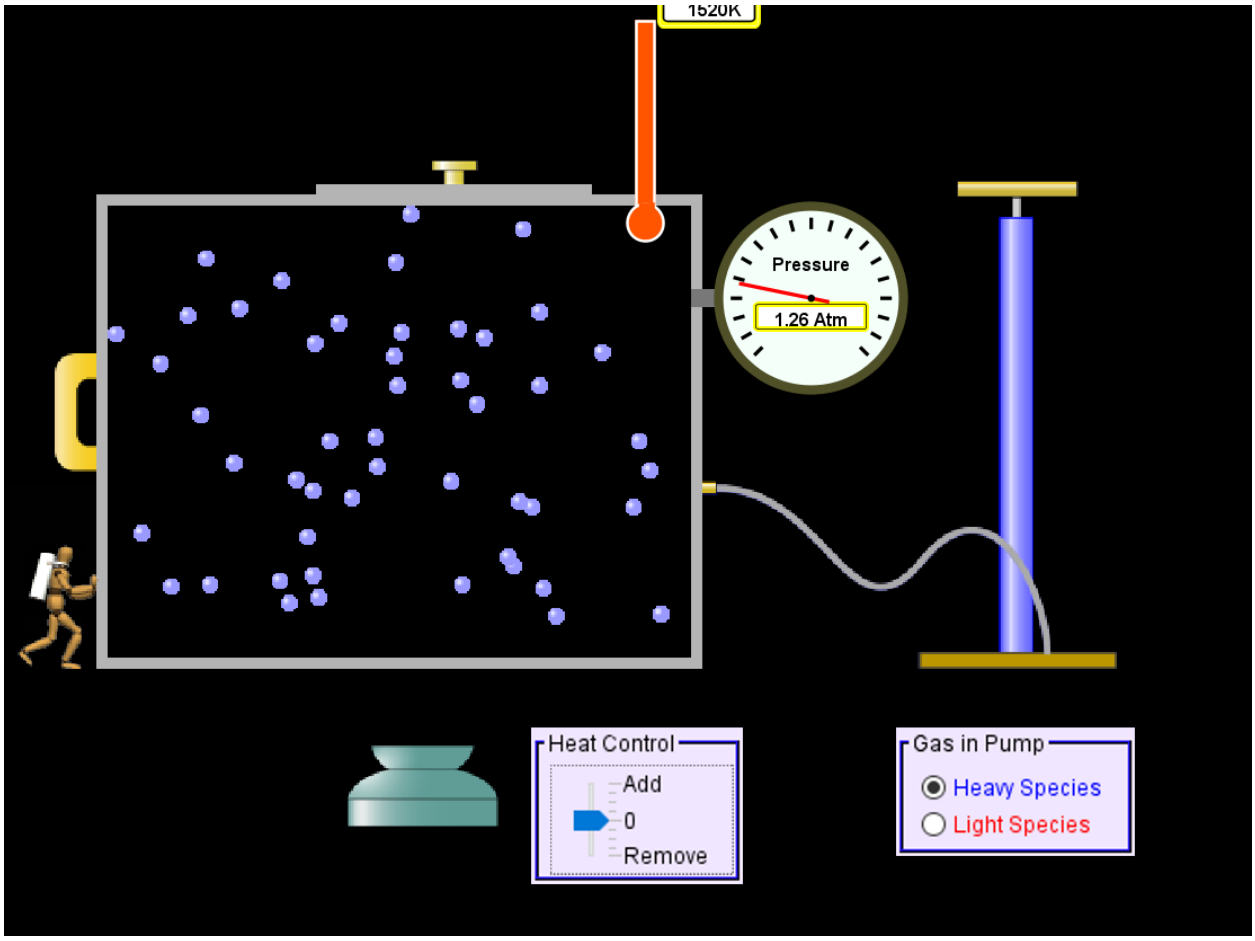
P1= initial pressure, P2= final pressure, T1= initial temp in Kelvin, T2= final temp in Kelvin

If we plot different Pressure vs. Volume for a gaseous system at a constant temperature, the curve will be parabolic in nature.



Example: A 4.0 L container of Helium gas has a pressure of 15.0 atm. What pressure does the gas exert if the volume is increased to 8.0 L?
Ans: since the volume is doubled, pressure must be half of the initial pressure.
New pressure= 15.0/2= 7.50 atm

2) Now introduce heat to the activity: Increase the temp from 400K to 1500K by adding heat keeping the pressure at 1:00atm. On the right top corner of the screen, keep pressure as constant parameter. You will notice that volume of the chamber is increasing. This is called Charles's law.



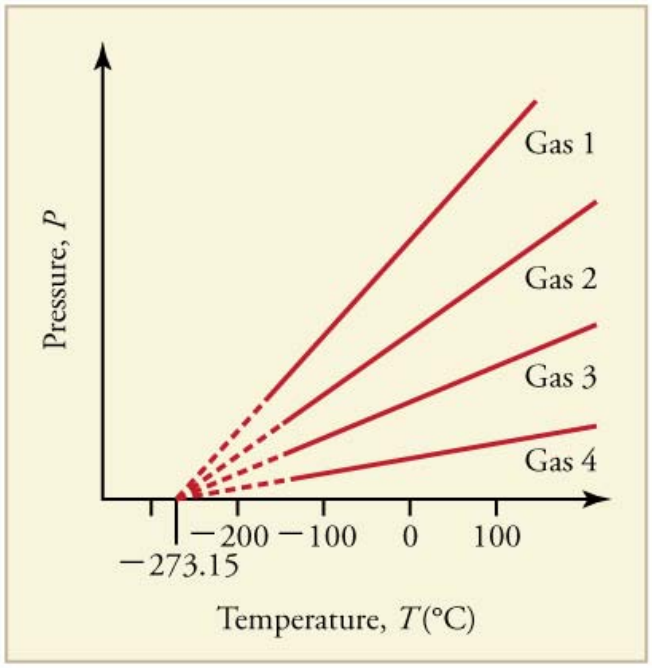
Charles's law: Volume of a fixed amount of gas is directly proportional to the kelvin temp if the pressure is kept constant.
This concept is applied in hot air balloon, where the volume of the gas is expanded by applying heat and once it becomes less dense than air, it can float in air.

Mathematically we can write:

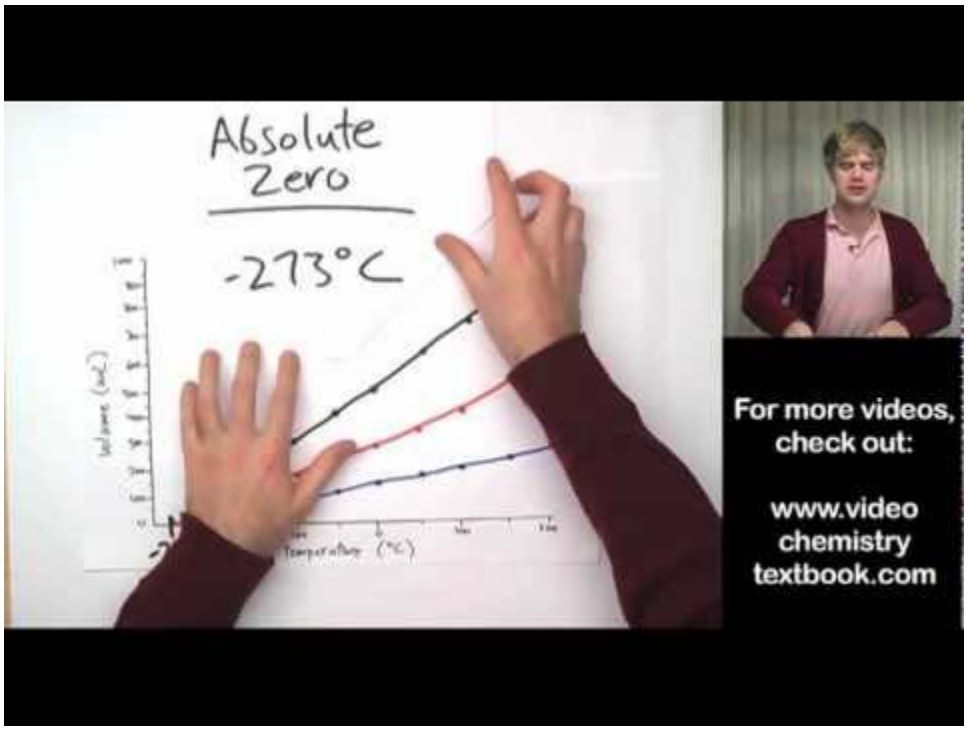
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ **at constant P,n**

V1= initial pressure, V2= final pressure, T1= initial temp in Kelvin, T2= final temp in Kelvin

We can understand the absolute zero temperature from Charles's law. For a sample of gas, when temperature is decreases, volume of the gas molecules decrease. According to the kinetic Molecular theory, the energy of the gas molecules is directly proportional to the kelvin temp. So gas molecules will move slowly as the temperature decreases. Therefore, hypothetically if the absolute temperature of a gaseous system reaches zero i.e. -273^0C, all the gas molecules motion will be ceased and the volume of the gas molecule would be zero. In reality, experiments done at lower temp that show the volume decreases steadily but so far, zero volume hasn't reached.



https://www.youtube.com/watch?v=JHXxPnmyDbk

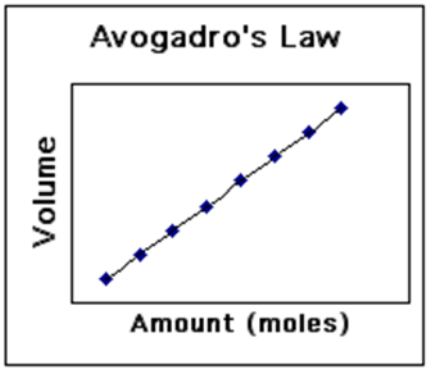


Example: A volume of 1.00L of gas at 37^0C is expelled from the lungs to cold outside at temperature -5^0C. What is the volume of the air at that temperature?

Ans: V2 is unknown.

1.00/(37+ 273) = V2/(-5+ 273) , 1/310=V2/268 or V2= 0.865 L

3) Avogadro's law: Increase the number of molecules from 50 to 100 in the simulation system keeping the pressure and Temperature constant. You may notice that volume of the container is increasing. This is Avogadro's law.
Avogadro's law: Volume of a of gas is directly proportional to the number of moles of gas if the pressure and Temp are kept constant.



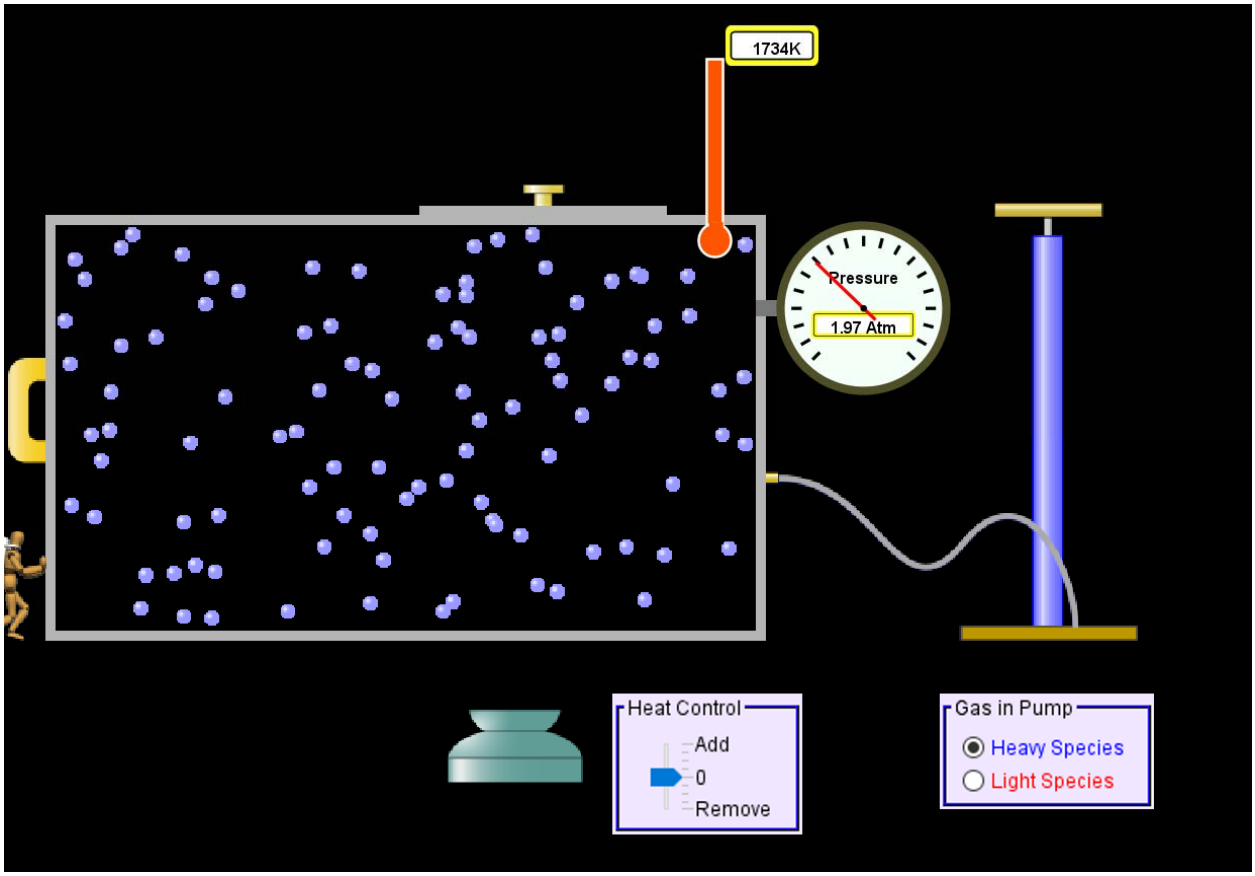
$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad \text{at constant } P \text{ and } T$$

V1= initial volume P2= final volume, n1= initial moles n2= final moles

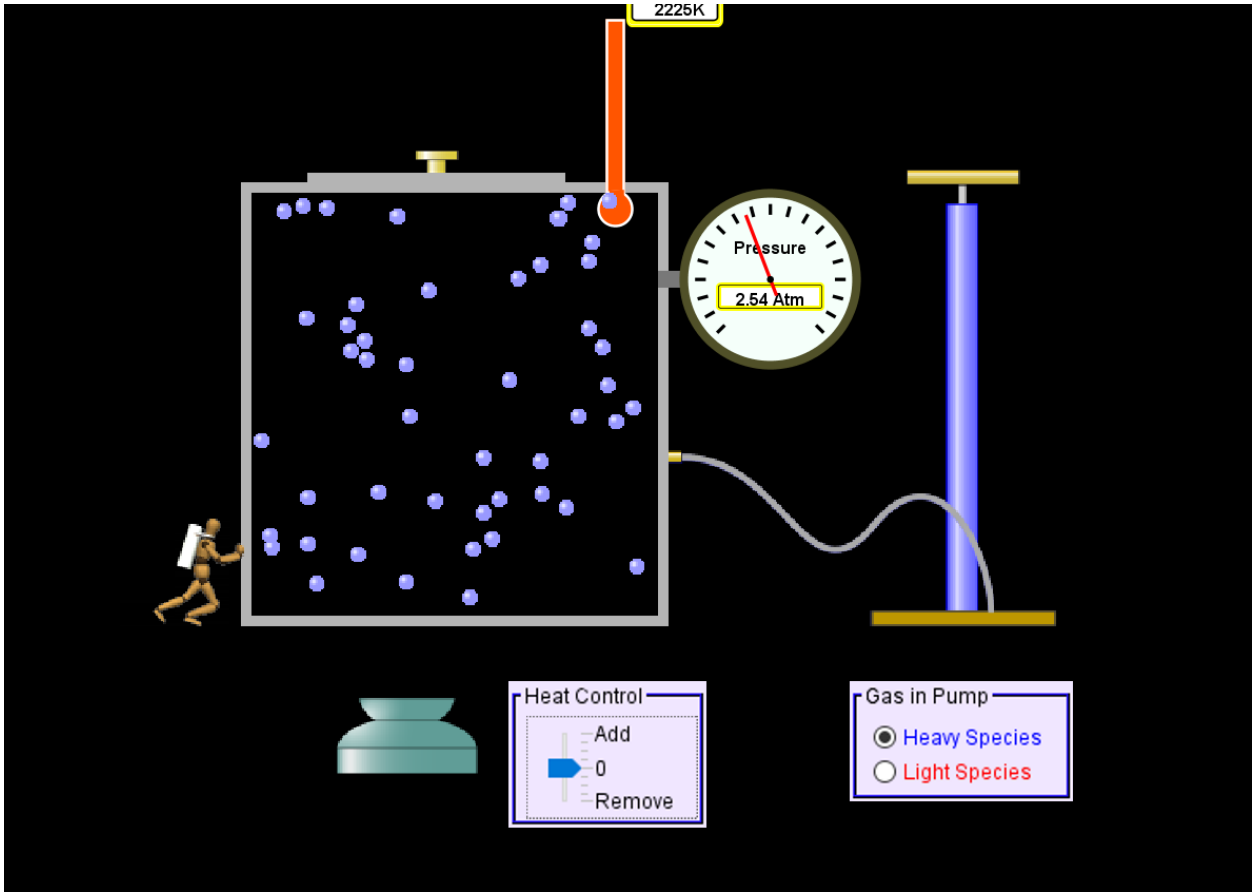
Example: The lungs of an average male holds 0.25 mol of air in a volume of 5.5 L. How many mole sof air do the lungs of an average female hold if the volume is 4.5 L?

Ans: n2 is unknown.

5.5/0.25= 4.5/n2, 22= 4.5/n2 or n2= 0.205 mol or 0.20 mols

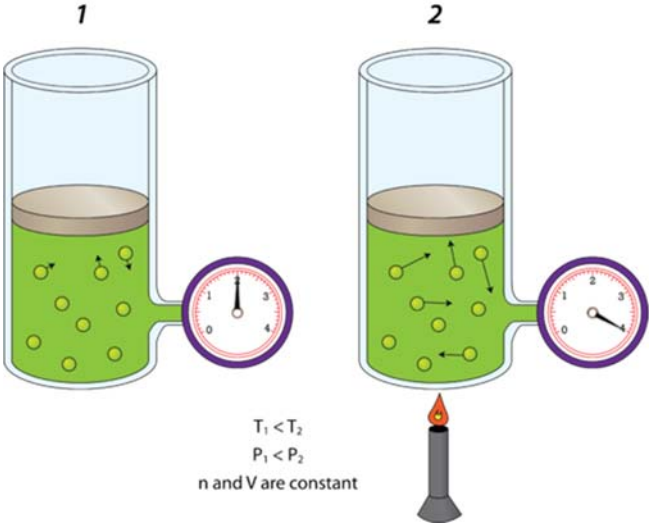


4) Gay Lusaac's law or Amonton's law: With volume remaining constant, the pressure of a gas molecule is directly proportional to its absolute temperature. According to KMT theory, when temperature increases, the gas molecules possess high kinetic energy. They collide with other molecules and with the walls of the container with high speed and try to expand. If the volume is kept constant, they collide each other more frequently and gas pressure increases.



$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \text{at constant } V \text{ and } n$$

P1= initial pressure, P2= final pressure, T1= initial temp, T2= final temp



Gay Lusaac's law can also be observed the above diagram, where application of heat to a gaseous system increases the pressure of the gas.

Example: The tire on a bicycle in a cool garage is stored at 20^0C and 80. Psi. What is the pressure inside the tire after riding the bike at 43^0C?

Ans: P2 is unknown, 80/(20+273)= P2/(43+ 273)

0.273= P2/316 or P2= 0.273*316= 86.3 psi or 86 psi.

The following activity has been taken from AACT (American association of chemical teachers)

https://teachchemistry.org/periodical/issues/november-2015/gas-laws

In this investigation you will examine three gas laws including Boyle's Law, Charles' Law and Gay-Lussac's Law. You will explore how manipulating the variables of volume (L), pressure (atm) and temperature (K) can affect a sample of gas. The formula for each of the gas laws are:

Boyle's Law:	Charles' Law:	Gay-Lussac's Law:
$P_1V_1 = P_2V_2$	$\frac{V_1}{} = \frac{V_2}{}$	$\frac{P_1}{} = \frac{P_2}{}$

Prelab Questions

1. Solve for "*x*" in the following algebraic equations and report your final answer with the correct number of significant digits:

   a. $(1.34)(5.46) = (1.76)(x)$

   b. $\frac{4.38}{332} = \frac{x}{267}$

   c. $\frac{2.25}{295} = \frac{4.85}{x}$

2. Briefly describe, in your own words the meaning of each of the following variables, and common units of measurement associated with each:

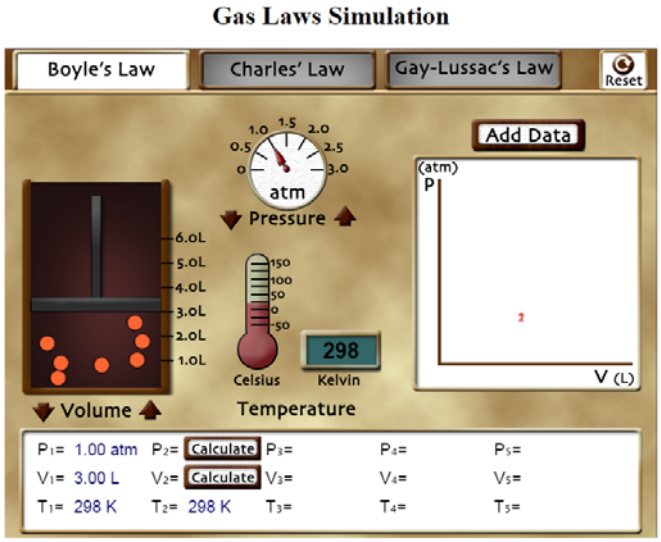
    a. Volume

    b. Pressure

    c. Temperature

Procedure

Visit http://www.teachchemistry.org/gaslaws. Make sure that you select the "Boyle's Law" tab to begin; it will be shown in white. You should see the picture below on your screen.



Boyle's Law

1. Which one of the three variables: Pressure, Volume or Temperature cannot be changed in Boyle's Law? This variable is considered a constant.

2. Using the volume control arrows, reduce the volume of the gas to 1.70L.
    a. In the space below record your observations regarding the behavior of the particles in the gas sample as the volume is reduced. Make certain to discuss *collisions* in your comments.
    a. Calculate the new pressure value for the gas, showing all of your work.
    b. Check your final answer for part b by clicking the *calculate* button next to P_2.

a. Observations when Volume is *reduced*:	b. Calculation
	$P_1V_1 = P_2V_2$

3. Press the *reset* button at the top right of the screen.
   Using the pressure control arrows, reduce the pressure of the gas to 0.700atm.

    a. In the space below record your observations regarding the behavior of the particles in the gas sample as the pressure is reduced.
    b. In the space below calculate the new volume value for the gas.
    c. Check your final answer for part b by clicking the *calculate* button next to V_2.

a. Observations when Pressure is *reduced*:	b. Calculation
	$P_1V_1 = P_2V_2$

4. Press the *reset* button at the top right of the screen.
    a. Using the pressure control arrows, increase the pressure value to 1.50 atm, and fill in the corresponding V_2 value in the data table below.
    b. Press the *Add Data* button. Using the pressure control arrows, increase the pressure to 2.00atm and fill in the corresponding V_3 value in the data table below.
    c. Repeat step b for pressure values of 2.50atm and 2.90atm.

$P_1 = 1.00$atm	$P_2 = 1.50$atm	$P_3 = 2.00$atm	$P_4 = 2.50$atm	$P_5 = 2.90$atm
$V_1 =$	$V_2 =$	$V_3 =$	$V_4 =$	$V_5 =$

    d. Based on the data collected in the table above, what trend can be observed for volume of a gas when the pressure of the gas is increased?

Important Terms

Direct relationship: A relationship between two variables, where a change in one variable results in the same change in the other variable. For example, if one variable is increased, then the other variable will also increase.

Indirect relationship: A relationship between two variables, where a change in one variable results in the opposite change in the other variable. For example, if one variable is increased, then the other variable will decrease.

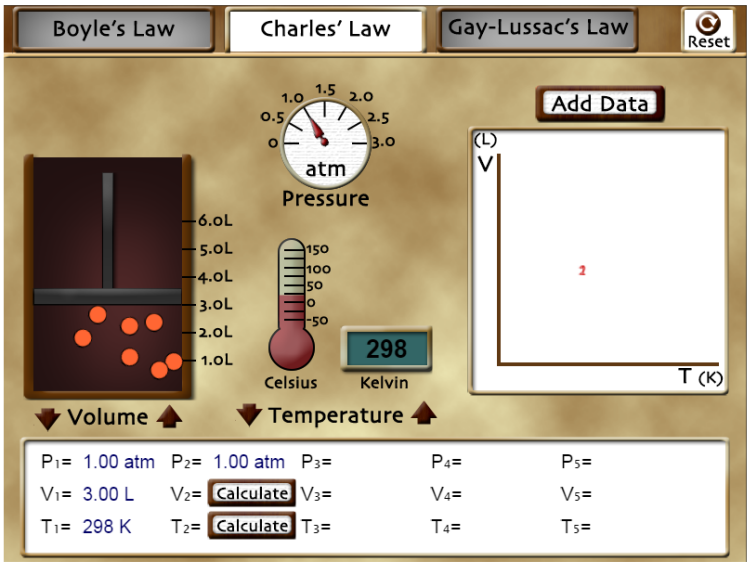
e. Considering the terms described above, do the variables of pressure and volume have a *direct* or an *indirect* relationship in Boyle's Law? Justify your answer with data.

f. Considering what you now know about Boyle's law, make a prediction based on the following situation: What would happen to the pressure of a gas inside a sealed bottle, if the bottle was squeezed tightly, reducing the volume of the gas by half? Explain your thoughts.

Charles' Law

Change the simulation to "Charles' Law" by clicking the tab at the top of the screen it will be shown in white. You should see the picture below on your screen.

Gas Laws Simulation



1. Which one of the three variables: Pressure, Volume or Temperature cannot be changed in Charles' Law? This variable is considered a constant.

2. a. Using the Temperature controls, increase the temperature of the gas. What changes do you observe in the behavior of the particles of the gas while the temperature is increased?

   b. Continue to increase the temperature value until $T_2 = 443K$. Using the equation for Charles' law, calculate the volume of the gas at this increased temperature. Check your final answer for part b by clicking the *calculate* button next to V_2:

   $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

   c. Based on the final value calculated in part b) is Charles' law considered a direct or an indirect relationship between the variables? Explain your choice with reasoning.

3. Press the *reset* button at the top right of the screen.
   Using the volume control arrows, reduce the volume of the gas to 1.86L.

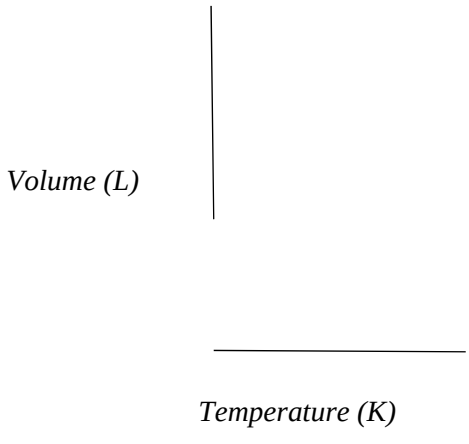
   a. In the space below record your observations regarding the behavior of the particles in the gas sample as the volume is reduced.
   b. In the space below calculate the new temperature value for the gas.
   c. Check your final answer for part b by clicking the *calculate* button next to T_2.

a. Observations when Volume is *reduced*:	b. Calculation
	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

   d. Convert the final value for T_2 into Celsius units.

4. Press the *reset* button at the top right of the screen.
   - Using the pressure control arrows, increase the temperature value to a measurement of your choosing. Then press *Add Data*. This will fix a data point on the graph for T_2.
   - Increase the temperature three additional times; select *Add Data* for each data point: T_3, T_4, and T_5.

   a. Plot these points on the graph below, estimating the five data points created:

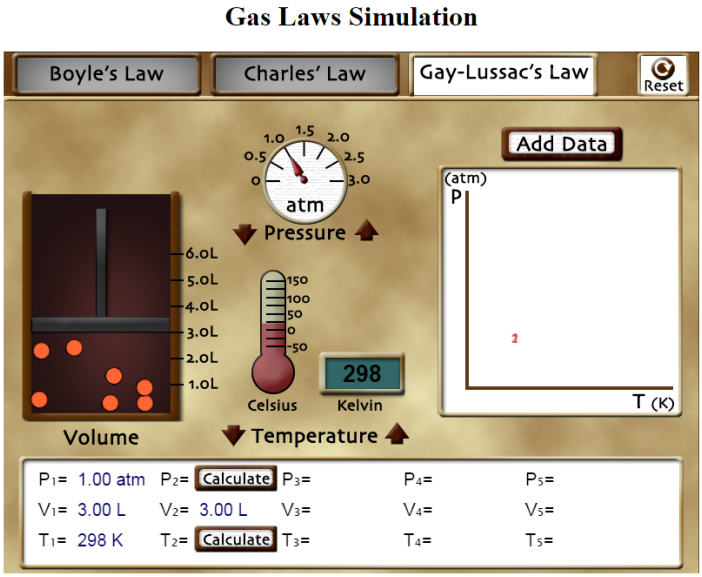


b. Based on the data points collected on the graph, make a statement about the trend that can be observed between the volume and temperature of a gas.

5. Considering what you now know about Charles' law, make a prediction based on the following situation: What would happen to the volume of a gas inside a sealed bottle, if the bottle was heated to double its original temperature? Explain your thoughts.

Gay-Lussac's Law

Change the simulation to "Gay-Lussac's Law" by clicking the tab at the top of the screen it will be shown in white. You should see the picture below on your screen.



$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

2. a. The equation for Gay-Lussac's law is does it look most similar to the equation for Boyle's Law or the equation for Charles' law?

b. What variable is held constant in Gay Lussac's law?

c. Based on your answer to part a) what prediction can you make about the relationship between the variables of Pressure and Temperature of a gas?

3. a. Using the pressure control arrows, increase the pressure value to 1.50atm, and fill in the corresponding T_2 value in the data table below.
   b. Press the *Add Data* button. Using the pressure control arrows, increase the pressure to 2.00atm and fill in the corresponding T_3 value in the data table below.
   c. Repeat step b for pressure values of 2.50atm and 2.90atm.

$P_1 = 1.00$atm	$P_2 = 1.50$atm	$P_3 = 2.00$atm	$P_4 = 2.50$atm	$P_5 = 2.90$atm
$T_1 =$	$T_2 =$	$T_3 =$	$T_4 =$	$T_5 =$

   d. Based on the data collected in the table above, what trend can be observed for temperature of a gas when the pressure of the gas is increased? Is this considered a direct or an indirect relationship between the variables?

4. Press the *reset* button at the top right of the screen.
   Using the temperature control arrows, reduce the temperature of the gas to 158K.

   a. In the space below record your observations regarding the behavior of the particles in the gas sample as the temperature is reduced. Make certain to discuss *collisions* in your comments.
   b. In the space below calculate the new pressure value for the gas.
   c. Check your final answer for part b by clicking the *calculate* button next to P_2.

a. Observations when Volume is *reduced*:	b. Calculation
	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

5. Considering what you now know about Gay-Lussac's law, make a prediction based on the following situation: What would happen to the pressure of a gas inside a sealed bottle, if the bottle was cooled to half of its original temperature? Explain your thoughts.

Checking Comprehension

Please create a list of the variable given in each problem and show all your work required to complete the calculation.

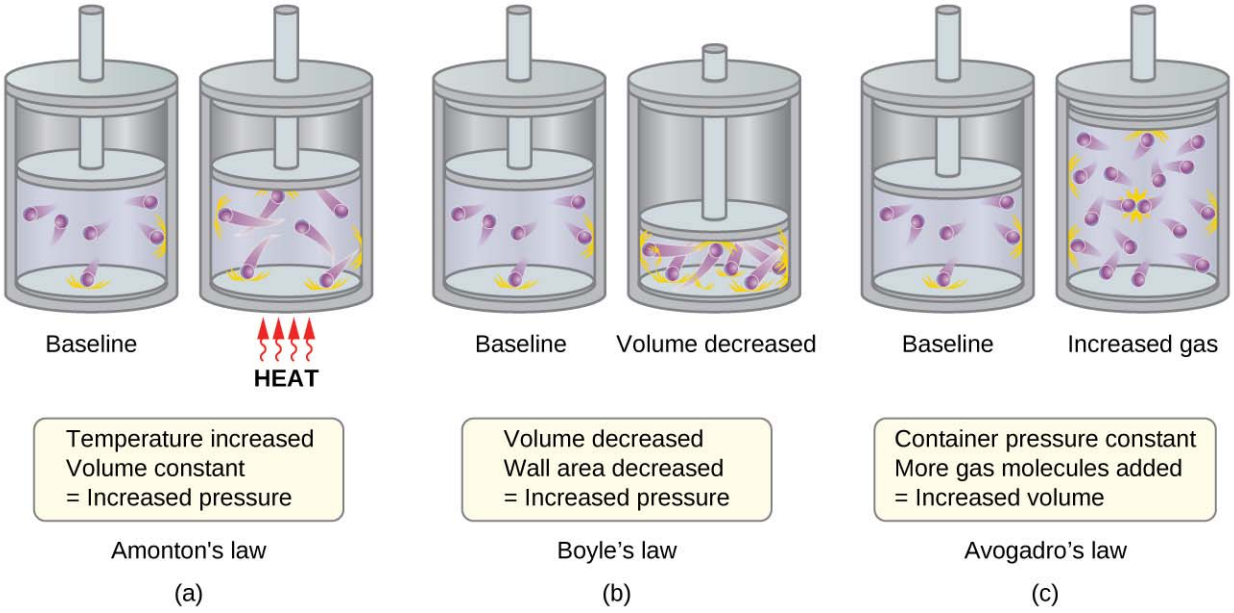
1. Calculate the temperature of a gas when it is expanded to 5.25L. The gas originally occupies 3.45L of space at 282K.

2. The temperature of a gas is increased from 125ºC to 182ºC inside of a rigid container. The original pressure of the gas was 1.22atm, what will the pressure of the gas be after the temperature change?

3. The volume of gas in a container was originally 3.24L, while at standard pressure, 1.00atm. What will the volume be if the pressure is increased to 1.20atm?

V. Combined Gas Law

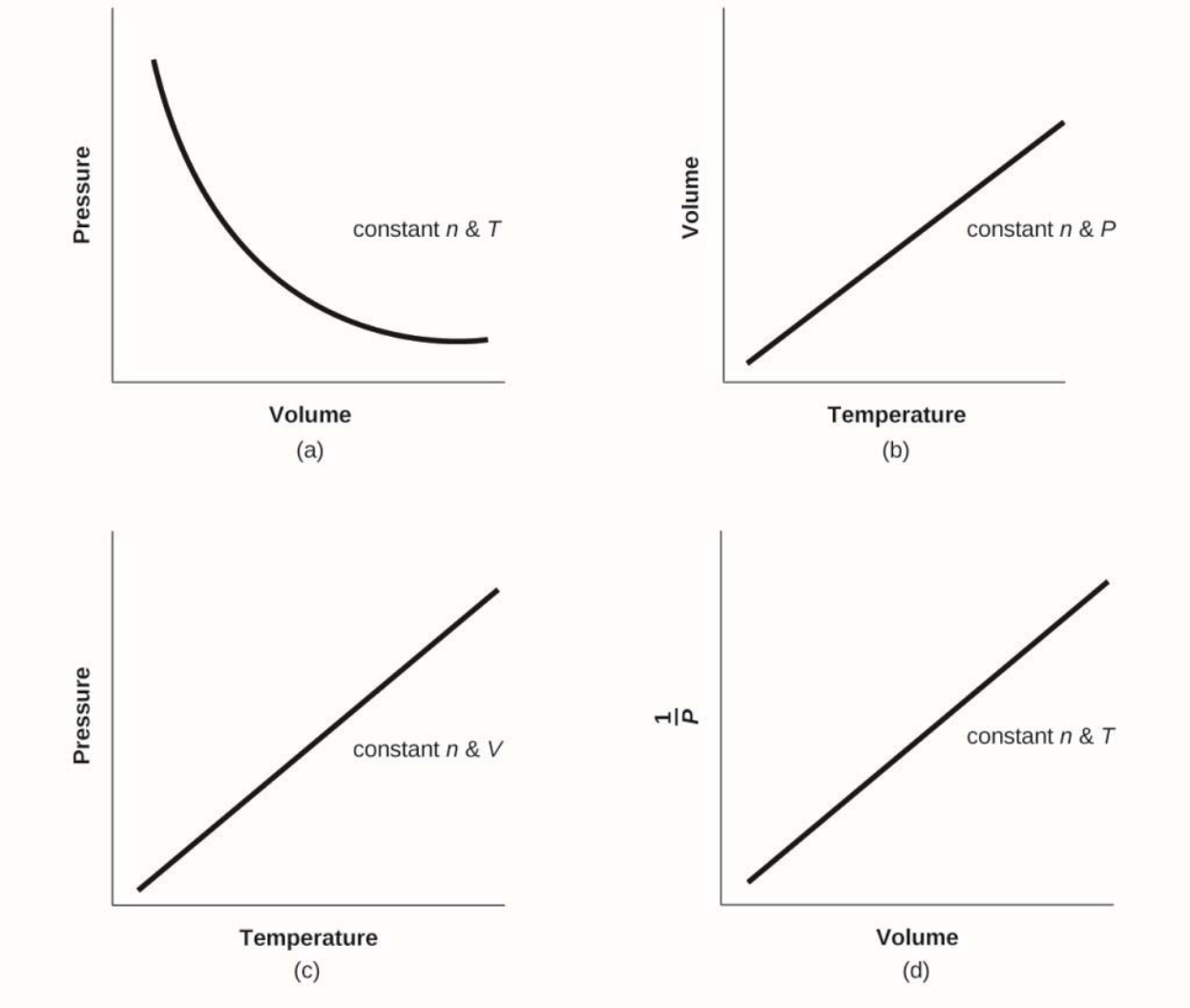
A: The combined gas law is an expression obtained mathematically combining Boyle's and Charle's laws. A change in pressure, temperature or volume that is brought about by changes in the other two variables can be calculated by using this law.



Mathematically we can write, when amount of gas (n) is constant,

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Here is the graphical relationship between pressure, volume and temperature of a gaseous system.

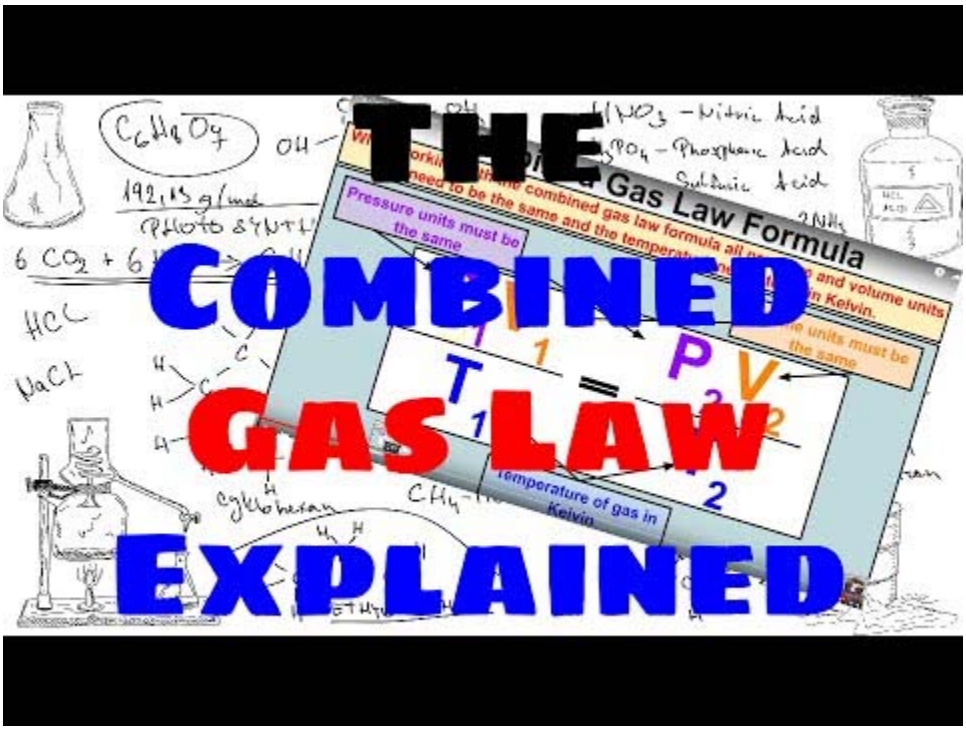


Example: A balloon contains 222 L of Helium at 25.^{0}C and 760 mm of Hg. What is the volume of the balloon when it reaches to an altitude where the temperature is -40^{0}C and the pressure is 540 mm of Hg?

Ans: V2 is unknown.

222* 760/(25+ 273)= 566.17= V2*540/(-40+ 273) , V2= 244.3 L or 244 L.

https://www.youtube.com/watch?v=FSdU6MIjPlo



Questions:

1. The pressure inside a 1.0 L balloon at 25^0C was 750 mm of Hg. What is the pressure inside the balloon when it is cooled to -40^0C and expands to 5.0 L volume?

Ans: 117 mm of Hg

VI. Ideal Gas Law

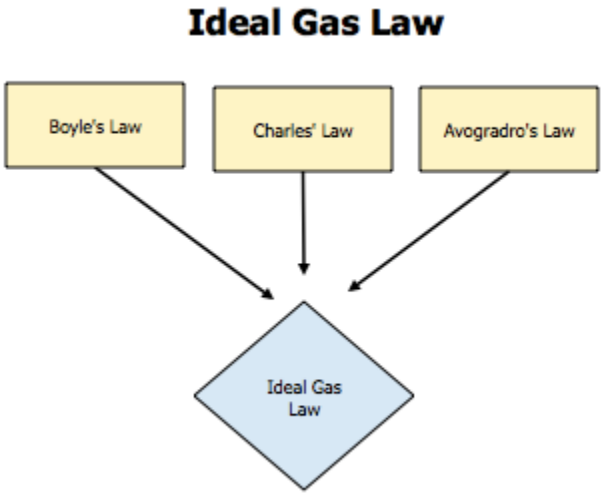
The ideal gas law holds for all ideal gases at any temperature, pressure, and volume. But the only gases we have around us in the real world are real gases. Real gases behave most like ideal gases at low pressures (atm or less) and high temperatures (K or higher). It combines all the gas laws variable into one condition form.

Based on Boyle's law: P/V = constant

Based on Charles's law: V/T = constant

Based on Avogadro's law: V/n= constant

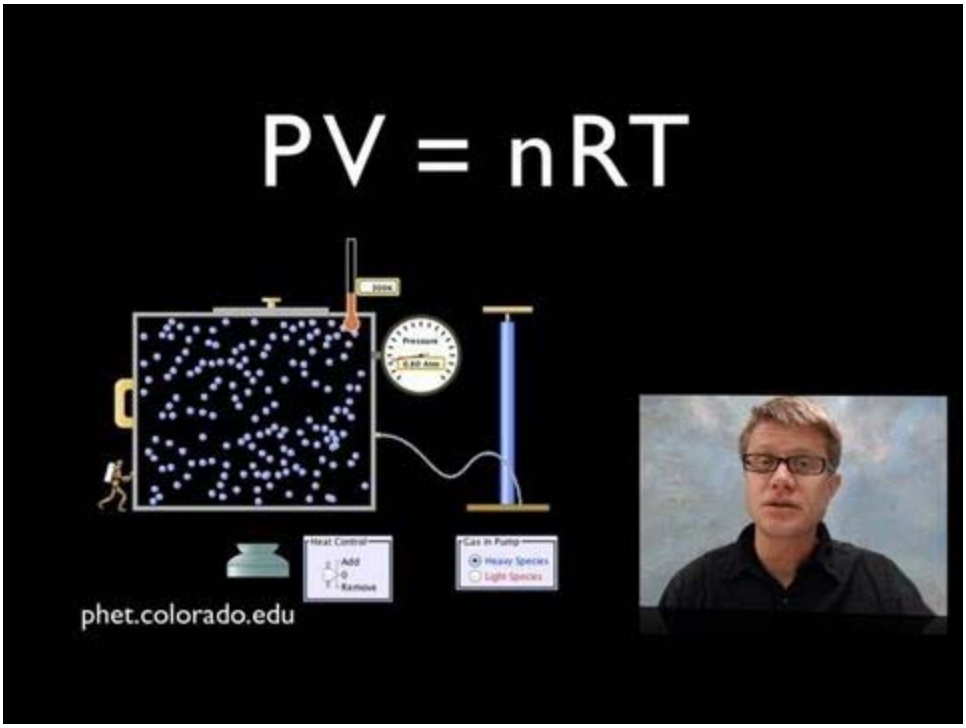
Combining all, PV/n= constant. This constant is symbolized as R and called universal gas constant.



The ideal gas law has the form PV=nRT, where R= Ideal gas Constant (0.08206 L-atm/mol-K). With this equation, any one of the characteristics gas properties (P, V, T or n) can be calculated given the other three.

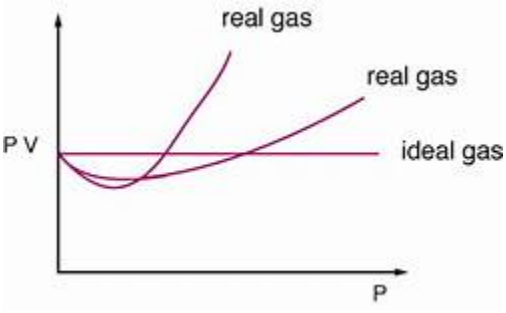
$$R = 8.314\frac{J}{mol \cdot K} = 8.314\frac{L \cdot kPa}{mol \cdot K} = 0.082057\frac{L \cdot atm}{mol \cdot K} = 62.364\frac{L \cdot mmHg}{mol \cdot K}$$

$$\frac{PV}{nT} = R$$



https://www.youtube.com/watch?v=TqLlfHBFY08&t=2s

Ideal gas law follows al the assumptions of kinetic molecular theory. That is why it is called ideal gas law. In real world gas molecules behave differently. Below is the graph that shows how real molecules deviate from ideal gas law. Ideal gas law indicates that plot and PV vs. P should be a constant because PV= constant when temperature is a constant. Real molecules only behave ideally at low pressure and high temperature.



Here is another video to solve problems using ideal gas laws:

https://www.youtube.com/watch?v=oL9XzBcDfF0&t=29s

Example: How many moles of gas are in a typical human breath that takes in 0.50L of air at 1.0 atm pressure and 35^0C?

Number of moles n is unknown. T= 35+ 273= 308K

n= PV/RT i.e. 1.0 * 0.50/(0.0821* 308) n= 0.0198 mol or 0.020 mol

We can determine the mass of a gas from moles if the identity or molar mass of the gas is known. Moles= mass/molar mass.

Questions:

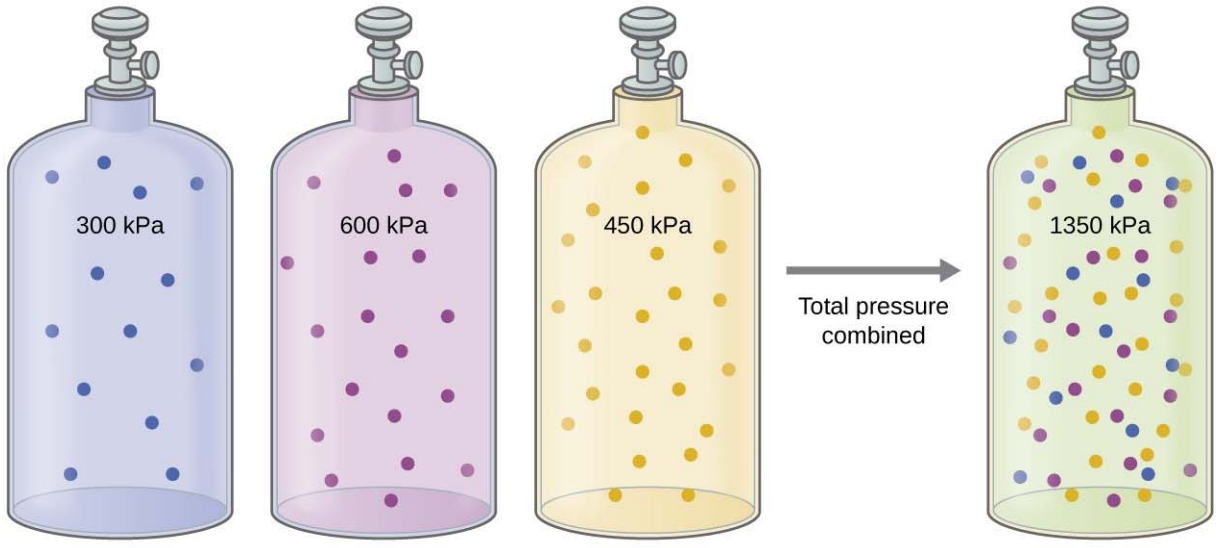
1. How many moles of oxygen are contained in a 5.0 L cylinder that has a pressure of 175 atm and temperature 20.0 ^{0}C?
2. A person exhales 25.0 g of CO_2 in an hour. What volume does it occur at 1.00 atm and 25.0 ^{0}C?

Ans: 1. 36.4 13mol

2.13.9 L

VII. Dalton's Law

In a mixture of gases, each molecule acts independently of all the others, provided that the gases behave as ideal gases and do not interact with each other in any way.

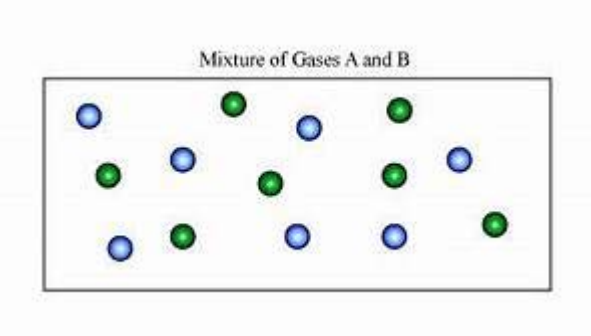


Dalton's law of partial pressures states that the total pressure exerted by a mixture of gases is the sum of the partial pressures of the individual gases.

Mathematically we can write,

$$P_{total} = P_1 + P_2 + P_3 + ... + P_n \equiv \sum_{i=1}^{n} P_i$$

Partial pressure of a gas can be calculated using mol fraction of a gas in a gas mixture and total pressure.



Total pressure = 1 atm

For example: in the above diagram, total number of gas molecules =14. Number of A (blue) gas molecules= 7, number of B (green) gas molecule= 7.

Mole fraction gas A= 7/14= 0.5

Mole fraction of B= 7/14= 0.5

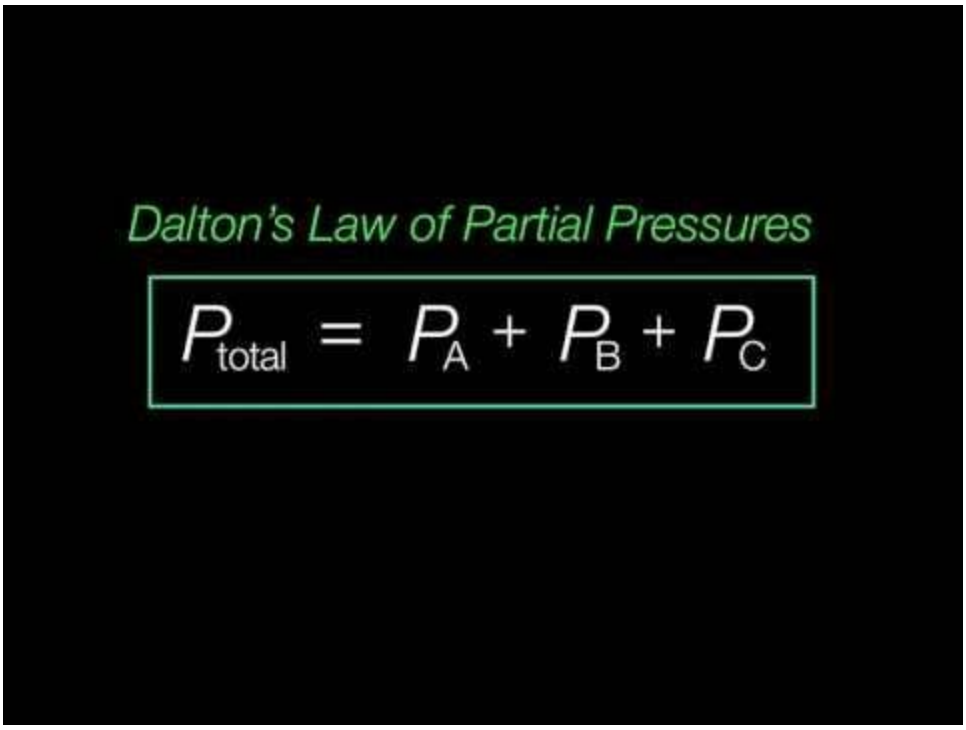
If the total pressure of the gas molecule= 1 aim.

Partial pressure of A= 0.5*1= 0.5 atm

Partial pressure of B= 0.5*1= 0.5 atm

The following videdo might help you to understand the concept.

https://www.youtube.com/watch?v=RqffPYOoxd8



Questions:

1. CO_2 is added to a container containing 2.5 atm of O_2 to give total pressure 4.0 atm of the gas. What is the partial pressure of CO_2 in the final mixture?

Ans: 1.5 atm

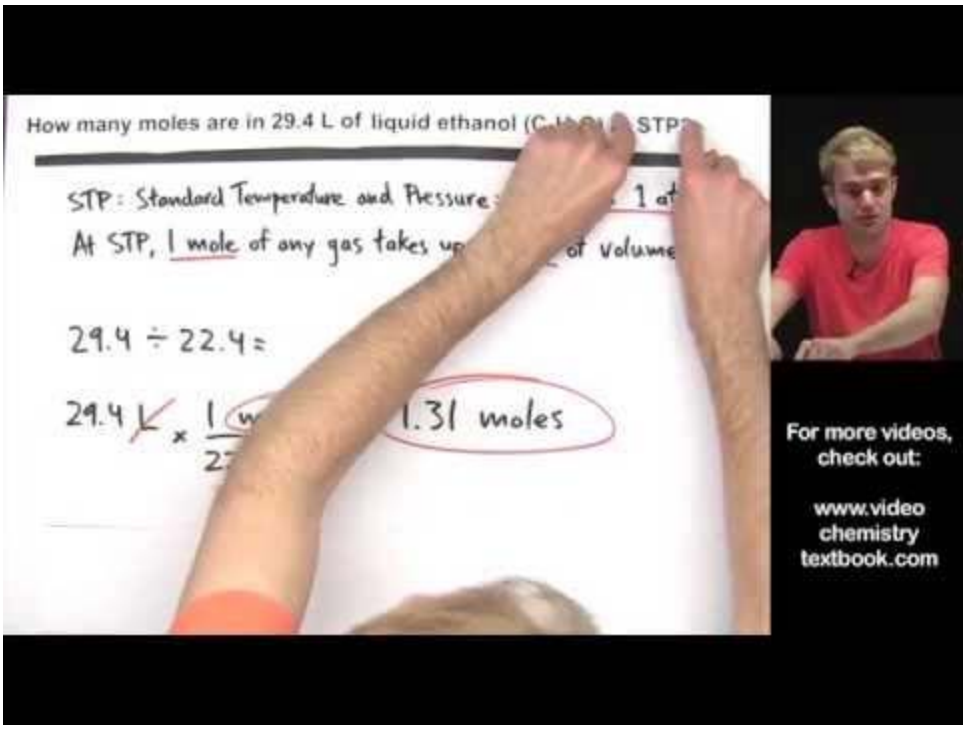
VIII. STP

Avogadro's law allows us to compare the amount of any two gases by comparing their volumes. Often amounts of gas are compared at a set of standard conditins of temperature and pressure called STP.

STP conditions are: 1 atm (760 mm of Pr) and 273 K ((0^0C)

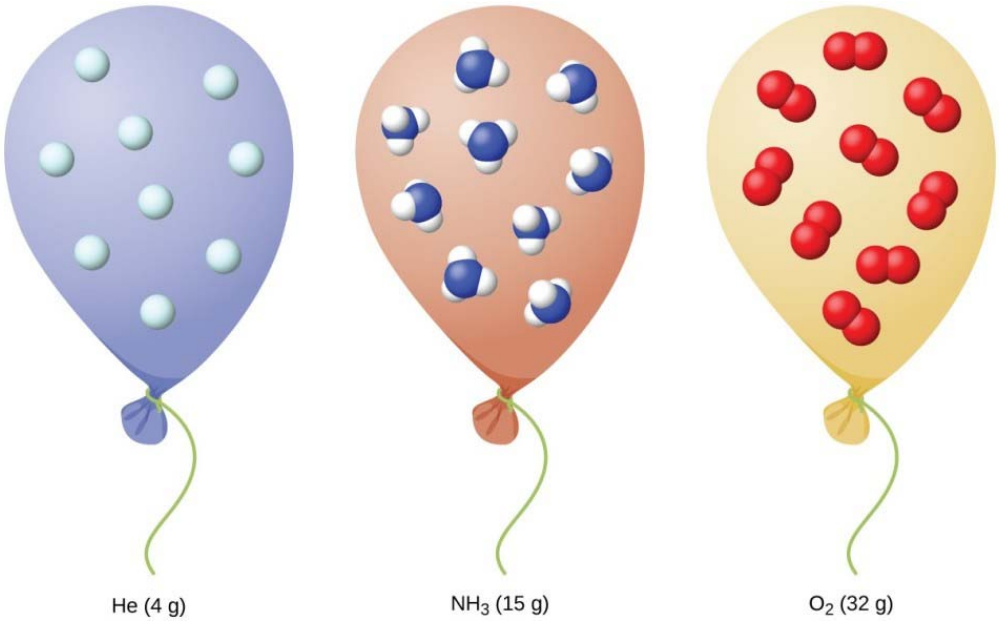
At STP, one mole of any gas has the same volume 22.4 L called the standard molar volume.

https://www.youtube.com/watch?v=Y8e7T09SKZ0&t=14s



Example:
1mol= 22.4 L
Q: How many mols are present Moles of 5.00 L of O_2 at STP?

$\frac{1\text{mol}}{22.4\text{ L}} = \frac{x\text{ mol}}{5.00\text{L}}$ x= 0.223 mols



At STP all different gases occupy same volume.

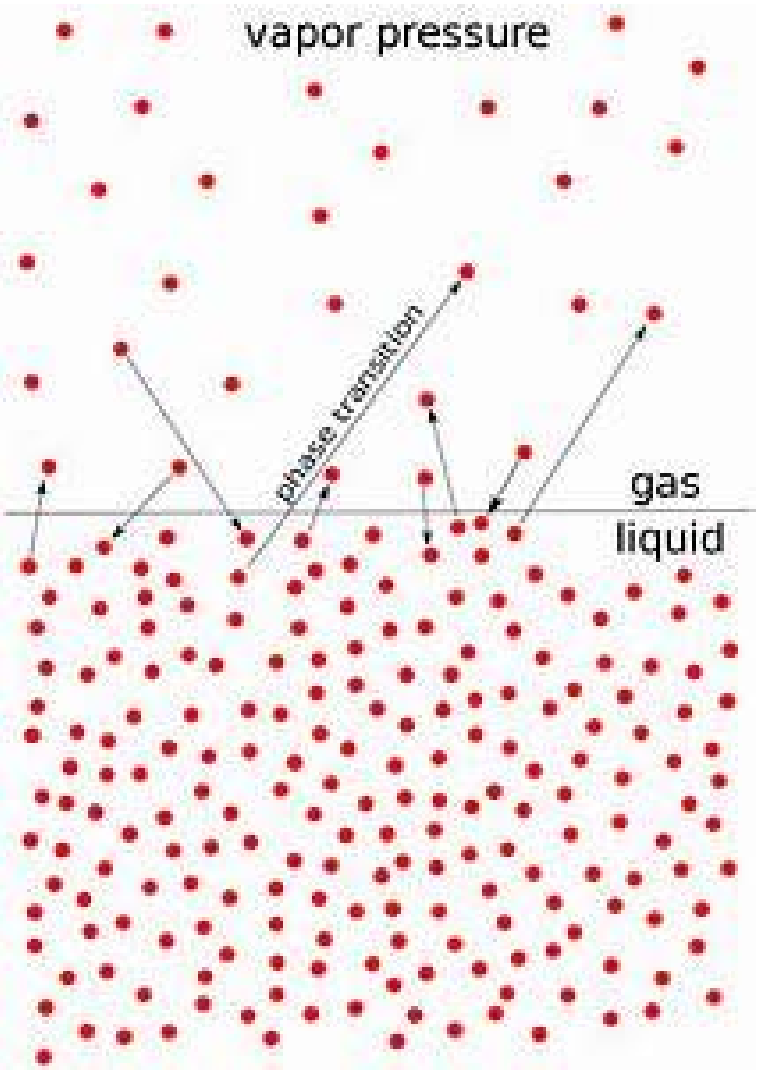
Questions:

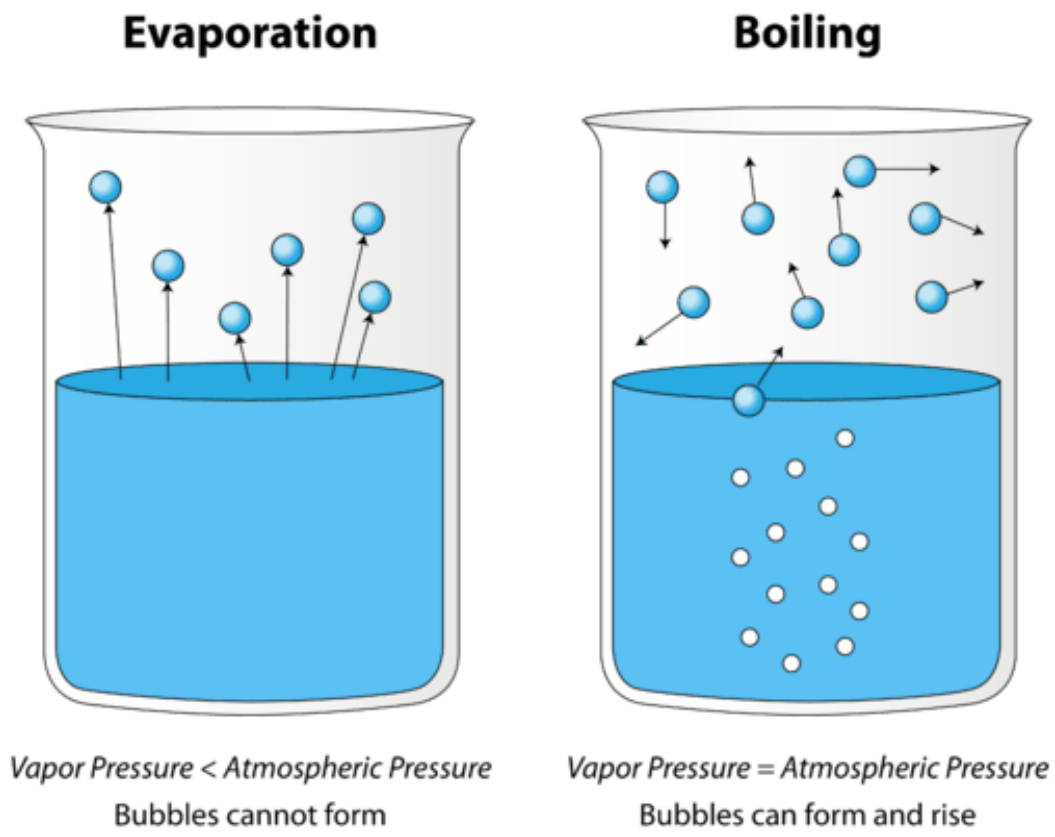
1. Burning 1mol of propane in a gas grill occupies 150. grams of CO_2. What volume of CO_2 does it occupy at STP?

Ans: 76.3L

IX. Vapor Pressure

When a liquid is placed in an open container, liquid molecules near the surface that have enough kinetic energy to overcome the intermolecular forces escape to the gas phase. This process is called evaporation and it is an endothermic process. The opposite process is called condensation which is an endothermic process, where gas molecules lose energy and go back to the liquid phase. Vapor pressure is the pressure of the gas molecules above a liquid in equilibrium in a closed container. The vapor pressure increases with increasing temperature. When the vapor pressure of the gas molecules is equal to the external pressure (1 atm). The liquid boils.


vapor pressure
phase transition
gas
liquid




boiling water

Practice Questions: Chapter 6

Indicate the answer choice that best completes the statement or answers the question.

1. Which of the following molecules cannot engage in hydrogen bonding?
   a. SiH_4 b. PH_3
   c. H_2S d. all of these

2. At what point is the vapor pressure of a liquid measured?
   a. When molecules escape from the liquid more rapidly than they are recaptured by the liquid.
   b. When molecules are recaptured by the liquid more rapidly than they escape from the liquid.
   c. When molecules escape and are recaptured at the same rate.
   d. When the liquid has been totally converted to vapor.

3. Which of the following pairs engage in hydrogen bonding?
   a. water with acetone (CH_3COCH_3)
   b. water with butane ($CH_3CH_2CH_2CH_3$)
   c. both a and b
   d. neither a nor b

4. Which of the following exerts the greatest pressure?
   a. a 40 gram object on a surface of 2.0 cm^2
   b. a 60 gram object on a surface of 3.0 cm^2
   c. a 80 gram object on a surface of 4.0 cm^2
   d. None, they all exert the same pressure.

5. What temperature scale should be used if we wish to express Charles's Law as a simple direct proportionality?
   a. Fahrenheit b. Celsius
   c. Kelvin d. It makes no difference.

6. Which law relates the volume and pressure of a gas under conditions of constant temperature?
   a. Avogadro's law b. Boyle's law
   c. Charles's law d. Dalton's law

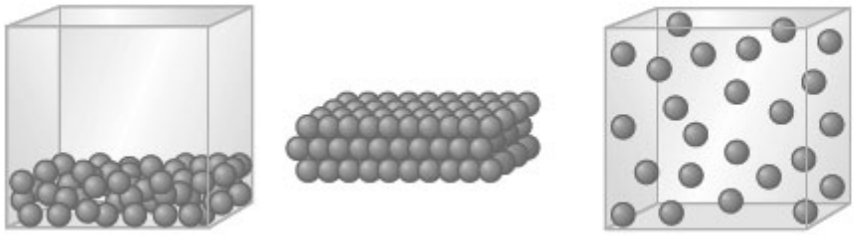
7. The term "vapor pressure of a liquid" means which of the following?

a. the pressure exerted by a liquid
b. the partial pressure exerted by a gas in equilibrium with its liquid
c. both a and b
d. neither a nor b

8. According to the kinetic molecular theory, which of the following is not true?
a. The average kinetic energy of gas particles is proportional to the Kelvin temperature.
b. Gas molecules are assumed to have no volume.
c. Gas pressure is caused by collisions between gas molecules and the container walls.
d. None, all of the above are true.

9. A closed flask contains a 0.25 moles of O_2 which exerts a pressure of 0.50 atm. If 0.75 moles of CO_2 is added to the container what is the total pressure in the flask?
a. 0.50 atm b. 1.0 atm
c. 1.5 atm d. 2.0 atm

10. Consider a substance as represented by the following models.



A B C

When sugar is heated it forms a mass called caramel. Based on this information sugar does not normally exist as shown in which model?
a. A
b. B
c. C
d. either A or C

11. The substance shown in the image is dry ice (solid CO_2) which is composed of molecules in the crystal lattice.

What type of intermolecular force holds the molecules together in the crystal?

a. London dispersion forces
b. dipole-dipole interactions
c. hydrogen bonding
d. More than one of the above may be present.

12. Which of the following is a mathematical statement of the combined gas law?

a. $P_1V_2T_1 = P_2V_1T_2$ b. $P_1V_2T_2 = P_2V_1T_1$
c. $P_1V_1T_2 = P_2V_2T_1$ d. $P_1V_1T_1 = P_2V_2T_2$

13. Which law relates the volume and number of molecules of a gas under conditions of constant temperature and pressure?

a. Avogadro's law b. Boyle's law
c. Charles's law d. Dalton's law

14. The normal boiling point of acetic acid is 117.9°C. Which of the following is true?

a. The vapor pressure of acetic acid at 100°C is greater than 760 torr.
b. The vapor pressure of acetic acid at 100°C is equal to 760 torr.
c. The vapor pressure of acetic acid at 100°C is less than 760 torr.
d. There is insufficient information to answer the question.

15. A certain quantity of neon gas is under 1.05 atm pressure at 303 K in a 10.0 L vessel. How many moles of neon are present?

a. 0.222 mol b. 0.402 mol
c. 0.422 mol d. 2.37 mol

16. Which of the following will occur if the temperature of a gas is increased from 20°C to 40°C at constant pressure?

a. The volume will double.
b. The volume will be halved.
c. The volume will decrease slightly.
d. The volume will increase slightly.

17. Which of the following will occur if the temperature of a gas is decreased from 60°C to 30°C at constant pressure?

a. The volume will double.

b. The volume will be halved.

c. The volume will decrease slightly.

d. The volume will increase slightly.

18. Which of the following increases as temperature increases?

a. kinetic energy b. nuclear forces

c. potential energy d. none of these

19. At constant temperature the pressure on a 10.0 L sample of gas is changed from 1140 torr to 1.00 atm. What is the new volume of the gas sample?

a. 0.00877 L b. 6.67 L

c. 15.0 L d. 114 L

20. What is the volume occupied by an 8.00 gram sample of molecular oxygen at STP?

a. 5.60 L b. 11.2 L

c. 22.4 L d. 44.8 L

21. Which of the following instruments is used to measure atmospheric pressure?

a. an altimeter b. a barometer

c. a manometer d. an odometer

22. A sample of carbon dioxide occupies 22.4 L at STP. Which of the following statements apply to the sample?

a. The sample contains 6.02×10^{23} carbon atoms.

b. The sample contains 6.02×10^{23} molecules.

c. Both a and b are correct.

d. Neither a nor b is correct.

23. Chloroform has a normal boiling point of 61.7°C. Which of the following is true?

a. At any temperature the vapor pressure of chloroform is less than that of water.

b. Chloroform is more volatile than water.

c. Both a and b are correct.

d. Neither a nor b is correct.

24. Which of the following is true of London dispersion forces?

a. They increase as the number of electrons in a molecule increases.

b. They are only present in some molecules.

c. Both a and b are correct.

d. Neither a nor b is correct.

25. Which of the following pairs do not engage in hydrogen bonding?
    a. H_2O with NH_3
    b. H_2O with H_2O
    c. NH_3 with NH_3
    d. None, they all engage in hydrogen bonding.

26. Which of the following is a mathematical statement of the ideal gas law?
    a. $PV = n/RT$ b. $PV = nRT$
    c. $V = nP/RT$ d. $PV = RT/n$

27. Which of the following molecules can engage in hydrogen bonding?
    a. HF b. HCl
    c. HBr d. HI

28. Which of the following is a mathematical statement of the ideal gas law?
    a. $PVRT = n$ b. $PV/RT = n$
    c. $VRT/P = n$ d. $n = RT/PV$

29. Which of the following is a mathematical statement of Boyle's Law?
    a. $P_1V_2 = P_2V_1$ b. $P_1V_1 = P_2V_2$
    c. $P_1/T_2 = P_2/T_1$ d. $P_1/T_1 = P_2/T_2$

30. Suppose a balloon is filled so that its volume is 2.00 L when the pressure is 1.10 atm and the temperature is 300 K. What volume will it occupy if it rises to an elevation where the pressure is 418 mm Hg and the temperature is 200 K?
    a. 3.30 L b. 2.67 L
    c. 0.375 L d. 0.303 L

31. According to the kinetic molecular theory, which of the following is not true?
    a. Gas molecules are assumed to have no volume.
    b. Gas pressure is caused by collisions between gas molecules and the container walls.
    c. When gas molecules collide they stick together.
    d. None, all of the above are true.

32. Which of the following phase changes does not involve a liquid?
    a. evaporation b. melting
    c. sublimation d. None, they all involve a liquid.

33. Dry air is 78.08% nitrogen, 20.95% oxygen and 0.93% argon with the 0.04% being other gases. If the atmospheric pressure is 760.0 torr, what is the partial pressure of nitrogen in dry air?

a. 78.08 torr b. 166.6 torr

c. 593.4 torr d. 760.0 torr

34. Which law applies only to mixtures of gases?

a. Avogadro's law b. Boyle's law

c. Charles's law d. Dalton's law

Answer Key

1. d

2. c

3. a

4. d

5. c

6. b

7. b

8. d

9. d

10. d

11. a

12. c

13. a

14. c

15. c

16. d

17. c

18. a

19. c

20. a

21. b

22. c

23. b

24. a

25. d

26. b

27. a

28. b

29. b

30. b

31. c

32. c

33. c

34. d