Unit 11-Gas Laws

The suggested schedule for this unit:
Week of April 13- do all of the notes and the 1st of the Choose your own adventure items
Week of April 20-finish the 2nd Choose your own adventure item, and the Unit 11 Review either in your notebook or online

Mandatory Items: Suggested date for completion and turn in is **Monday, April 27th**		To be turned in to Sanders
Notes and problems 11.1		
Notes and problems 11.2		
Notes and problems 11.3		
Unit 11 Review	Red notebook or digital	**x**
Choose your own adventure-Pick 2 of the following items		**x**
Chapter 13 Questions-textbook	# 1-36 odds (answers in the back of the book)	
11.1 Lab: Popcorn Pressure (data provided)	Red notebook, data posted to google.classroom	
Study Guide: chapter 13-connects with your textbook	Google.classroom link or paper based	
PhET Simulation for gases	Lab paper on google.classroom https://phet.colorado.edu/en/simulation/gases-intro	
Extra Practice-not required or graded		
Khan Academy: Gas Laws	https://www.khanacademy.org/science/chemistry/gases-and-kinetic-molecular-theory	
Crash Course videos	Pick a few of the gas laws videos, there are multiple and they are all interesting https://thecrashcourse.com/courses/chemistry?page=2	

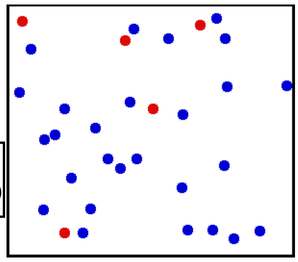
11.1 - Gas Laws

More

What keeps the hot air balloons up?

Gas Particles

Kinetic Molecular Theory - assumes that particles in a gas sample are far apart, so their size has little influence on the volume occupied by the gas (lots of space between them).



Each particle has kinetic energy - energy of motion:

$K = \frac{1}{2}mv^2$	m = mass (kg) v = velocity (m/s)

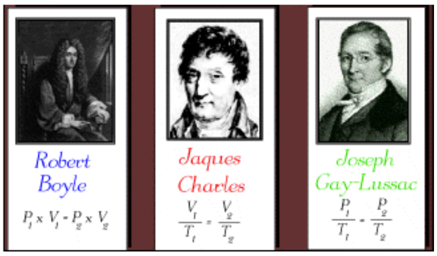
Intro to Gases - 3 Laws

Gases respond predictably to changes in pressure, temperature, volume and number of particles.

For a fixed amount of gas, a change in one variable (pressure, temperature, volume) affects the others.

Meet the Ancient Gas Law Scientists!

Gases were studied extensively in the late 1600's into early 1700's, and the three major Laws were discovered by the following people:



A Note on Temperature

Temperature must be in **Kelvin**!

Kelvin scale is an absolute scale → 0 K is the lowest possible temperature.

At this point, all molecular motion is stopped.

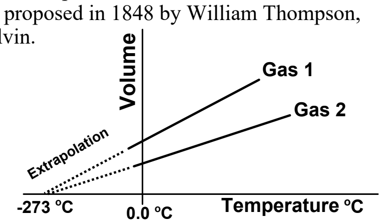
Celsius to Kelvin: $Temp_K = °C + 273$ Kelvin to Celsius: $Temp_{°C} = K - 273$

The Quest for Absolute Zero

The relation of temperature vs. volume originally led to the idea of an absolute lowest temperature.

All gases at temperatures well above their condensation points expanded identically, and extrapolating a Temp. vs Volume graph to 0 volume yielded an approximation of absolute zero.

Original work was done on many gases at 0 °C and 100 °C, due to the ease of achieving these temperatures in a lab, and the first absolute zero value was proposed in 1848 by William Thompson, later known as Lord Kelvin.



Chem Unit 11.1 Notes - Gas Laws

1. Temperature Conversions

A. Convert 245 ºC to Kelvins.

$Temp_K$ = ºC + 273
= 245 ºC + 273
= 518 K

B. Convert 350 K to ºC.

$Temp_{°C}$ = K - 273
= 350 K - 273
= 77 ºC

Pressure:

Definition: force per unit area.

Air Pressure: pressure exerted in all directions from the particles in air.

Unit of pressure (for this class) is the atmosphere (atm).

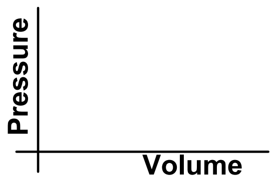
At sea level, 1.0 atm is the average pressure that the air exerts.

Pressure Gauge Exercise

Try This!

Develop a relation between pressure and volume for the construction set syringe system. When you mess with one, what happens to the other?

NEXT: Draw a crude sketch of pressure vs. volume:

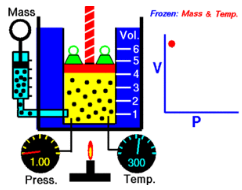


Boyle's Law - Constant Temperature

The volume of a gas is inversely proportional to its pressure at constant temperature.
From condition 1 to condition 2:

Boyle's Law	
$P_1V_1 = P_2V_2$	P = absolute pressure V = volume

A note on units: they can be anything, as long as they're the same!



2. Boyle's Law Example

A gas' volume at 9.9 atm is 300.0 mL. If pressure decreases to 3.4 atm, what is the new volume?

Data:

$P_1 = 9.9\,atm$

$V_1 = 300.0\,mL$

$P_2 = 3.4\,atm$

$V_2 = ?$

$$P_1V_1 = P_2V_2$$

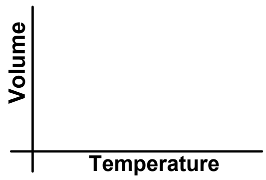
$$V_2 = \frac{P_1 \bullet V_1}{P_2} = \frac{9.9\,atm \bullet 300.0\,ml}{3.4\,atm}$$

$$= 874\,ml$$

Temperature Vs. Volume!

Observe the balloon, as I put the flask into the hot water bath. What happens?
Develop a relation between temperature and volume for this system. When you mess with one, what happens to the other?

NEXT: Draw a crude sketch of temperature vs. volume:



Chem Unit 11.1 Notes - Gas Laws

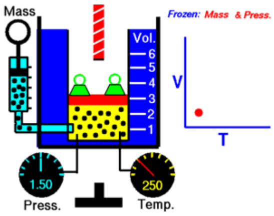
Charles' Law: Constant Pressure

The volume of gas is directly proportional to its Kelvin temperature (constant pressure).

From condition 1 to condition 2:

Charles' Law

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	V = volume T = temperature (Kelvins)

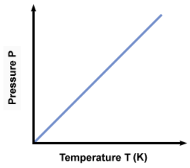


Gay-Lussac's Law: Constant Volume

The pressure of a gas is directly proportional to the Kelvin temperature (constant volume).

Gay-Lussac's Law

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	P = absolute pressure T = temperature (Kelvins)



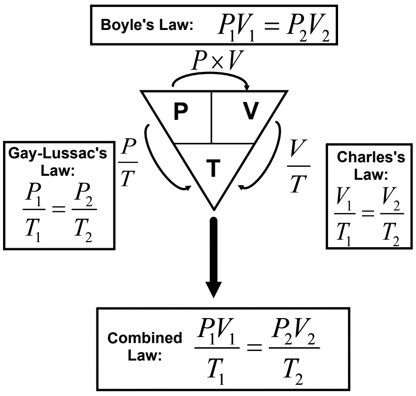
Combined Gas Law

Combined Gas Law: when more than one variable is changed for a fixed amount of gas:

Combined Law: $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Remember: all these laws are for a <u>fixed amount</u> of gas.

Combined Gas Law: Pictorial Aid



3. Which Law?

A <u>rigid</u> steel container holds 1.00 L of methane gas at 6.6 atm when the temperature is 22 ^{o}C.

What's the pressure at 45 ^{o}C?

Which Law is useful? Gay-Lussac's.

Convert Celsius to Kelvin: 22.0 °C = 295 K
45 °C = 318 K.

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

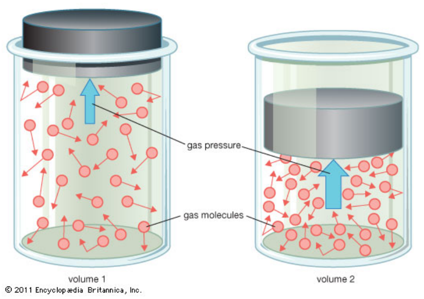
$$P_2 = \frac{P_1 \bullet T_2}{T_1} = \frac{6.6\,atm \bullet 318\,K}{295\,K} = 7.1\,atm$$

Homework:

11.1 Problems
Due: Next Class

Chem Unit 11.2 Notes - The Ideal Gas Law

11.2 - The Ideal Gas Law



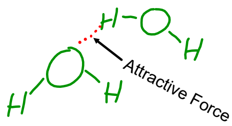
Ideal Gases

Different gases have different expansion properties, depending on how they interact.

At low densities, however, all gases exhibit identical expansion behavior.

Non-interactive gases are called Ideal Gases (a theoretical condition), and are considered to have:

1. no mass,
2. no electrostatic interactions,
3. no volume,
4. no collisions.



Molar Volume and STP

Avogadro's Principle: equal volume of gases at the same temperature and pressure contain equal numbers of particles.

At **S**tandard **T**emperature and **P**ressure (STP) (0 degrees Celsius (273 K), and 1.0 atm pressure), one mole of any gas has the same molar volume, equal to 22.4 liters.

For conversions, use: $\dfrac{22.4L}{1mol}$ or $\dfrac{1mol}{22.4L}$

1. Molar Volume Example

What volume will 2.16 g of krypton gas occupy at STP?

Convert mass to moles:

$$2.16\,g \bullet \frac{1\,mol\,Kr}{83.80\,g\,Kr} = 0.0258\,mol\,Kr$$

$$0.0258\,mol\,Kr \bullet \frac{22.4\,L}{1\,mol} = 0.577\,L$$

Ideal Gas Law

The Ideal Gas Law relates the number of moles to pressure, temperature, and volume.

PV = nRT	P = pressure (atm) V = volume (L) n = number of moles of gas (mol) R = Universal Gas Constant: $0.0821\dfrac{L \bullet atm}{K \bullet mol}$ T = temperature (Kelvins)

The Universal Gas Constant (R) is a factor that ties the four variables together at ANY condition.

2. Ideal Gas Example

If the pressure exerted by a gas at 298 K in a volume of 0.044 L is 3.81 atm, how many moles of gas are present?

Ideal Gas Law:

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{3.81\,atm \bullet 0.044\,L}{0.0821\dfrac{L \cdot atm}{K \cdot mol} \bullet 298\,K} = 0.00685\,moles$$

The Ideal Gas Law and Density

Remember that density equals mass over volume:

$\rho (or\,D) = \frac{m}{V}$	m = mass (g) V = volume (L)

Using molar mass, the equation of gas density is:

$\rho = \frac{MP}{RT}$	M = molar mass (g/mol) P = pressure (atm) R = 0.0821 L atm/K mol T = temperature (K)

Why do we care about density of gases?

Fire Extinguishers! Demo.

3. Density Example

Determine the density of chlorine gas at 22.0 ºC and 1.00 atm.

List known values:

M = 70.90 g/mol
P = 1.00 atm
T = 22.0 ºC = 295 K

$$\rho = \frac{MP}{RT} = \frac{70.90\frac{g}{mol} \bullet 1.00\,atm}{0.0821\frac{L \bullet atm}{K \bullet mol} \bullet 295\,K} = \boxed{2.93\frac{g}{L}Cl_2}$$

Homework:

11.2 Booklet Problems
Due: Next Class

11.3 Gas Stoichiometry

By an extension of Avogadro's Principle, when gases react, coefficients in the balanced equation represent molar amounts AND relative volumes.

Example: $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$

- 2 moles hydrogen gas will react with 1 mole of oxygen gas to produce 2 moles water vapor.
- 2 volumes hydrogen gas will react with 1 volume of oxygen gas to produce 2 volumes water vapor.

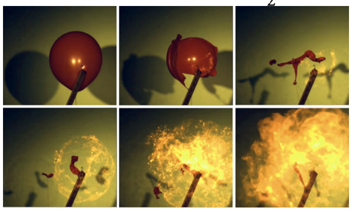
Gas laws can be used to calculate the stoichiometry of reactions where gases are reactants or products.

1. Volume-Volume Example A

How many liters of H_2 gas will react with 5.00 L of O_2 to form water?

$$2\ H_{2(g)} + O_{2(g)} \longrightarrow 2\ H_2O_{(g)}$$

$$5.00\ Liters\ O_2 \bullet \frac{2\ volumes\ H_2}{1\ volume\ O_2} = 10.0\ L\ H_2$$



2. Volume-Volume Example B

How many liters of water will be produced through the combustion of 15.6 L of propane?

$$\_\_\ C_3H_{8(g)} + \underline{5}\ O_{2(g)} \longrightarrow \underline{3}\ CO_{2(g)} + \underline{4}\ H_2O_{(g)}$$

$$15.6\ L\ C_3H_8 \bullet \frac{4\ volumes\ H_2O}{1\ volume\ C_3H_8} = 62.4\ L\ H_2$$

3. Volume-Mass Example (Slide 1)

If 7.00 L of N_2 reacts with H_2 at 298 K (P = 3.00 atm), what mass of ammonia is produced?

$$N_{2(g)} + 3\ H_{2(g)} \longrightarrow 2\ NH_{3(g)}$$

Step 1: Determine liters of gaseous ammonia made from 7.00 L of nitrogen gas.

$$7.00\ L\ N_2 \bullet \frac{2\ volumes\ NH_3}{1\ volumes\ N_2} = 14.0\ L\ NH_3$$

3. Volume-Mass Example (Slide 2)

7.00 L of N_2 produces 14.0 L of ammonia at 298 K and pressure of 3.00 atm.

Step 2: Use Ideal Gas Law to find moles.

Data:

$V_{NH3} = 14.0$ L

P = 3.00 atm

T = 298K

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{(3.00\,atm)(14.0\,L)}{\left(0.0821 \frac{L \bullet atm}{K \bullet mol}\right)(298\,K)}$$

$$= 1.72\ mol\ NH_3$$

3. Volume-Mass Example (Slide 3)

Finally, find ammonia's molar mass, then make a moles to mass conversion.

Molar mass = 17.3 g/mol.

$$1.72\ mol\ NH_3 \bullet \frac{17.04\ g\ NH_3}{1\ mol\ NH_3} = \boxed{29.3\ g\ NH_3}$$

Homework:

11.3 Booklet Problems

Due: Next Class

Unit 11 Review Questions

Name ______________________________ Date ________________ Class ________________

CHAPTER 13 STUDY GUIDE

Gases

Section 13.1 The Gas Laws

In your textbook, read about the basic concepts of the three gas laws.

Use each of the terms below to complete the passage. Each term may be used more than once.

pressure	temperature	volume

Boyle's law relates **(1)** ________________ and **(2)** ________________ if **(3)** ________________ and amount of gas are held constant. Charles's law relates **(4)** ________________ and **(5)** ________________ if **(6)** ________________ and amount of gas are held constant. Gay-Lussac's law relates **(7)** ________________ and **(8)** ________________ if **(9)** ________________ and amount of gas are held constant.

In your textbook, read about the effects of changing conditions on a sample of gas.

For each question below, write *increases*, *decreases*, or *stays the same*.

________________ **10.** The room temperature increases from 20°C to 24°C. What happens to the pressure inside a cylinder of oxygen contained in the room?

________________ **11.** What happens to the pressure of the gas in an inflated expandable balloon if the temperature is increased?

________________ **12.** An aerosol can of air freshener is sprayed into a room. What happens to the pressure of the gas if its temperature stays constant?

________________ **13.** The volume of air in human lungs increases before it is exhaled. What happens to the temperature of the air in the lungs to cause this change, assuming pressure stays constant?

________________ **14.** A leftover hamburger patty is sealed in a plastic bag and placed in the refrigerator. What happens to the volume of the air in the bag?

________________ **15.** What happens to the pressure of a gas in a lightbulb a few minutes after the light is turned on?

Section 13.2 The Combined Gas Law and Avogadro's Principle

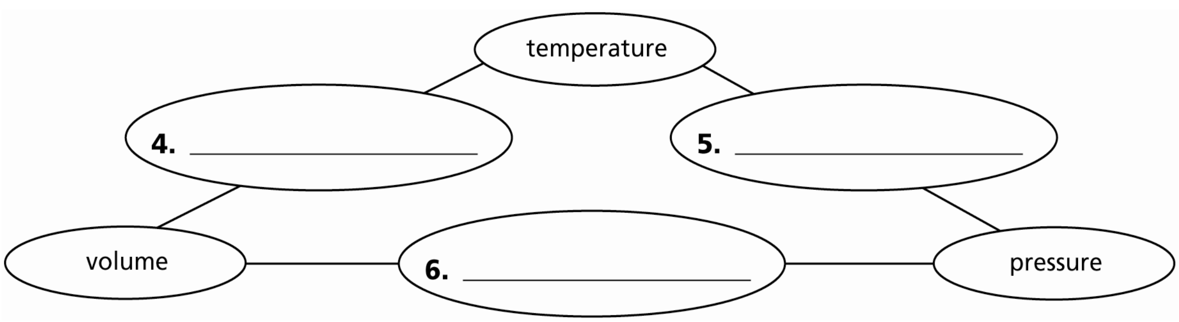
In your textbook, read about the combined gas law.

Fill in the following table. State what gas law is derived from the combined gas law when the variable listed in the first column stays constant and the variables in the second column change.

Derivations from the Combined Gas Law		
Stays constant	**Change**	**Becomes this law**
Volume	Temperature, pressure	**1.**
Temperature	Pressure, volume	**2.**
Pressure	Temperature, volume	**3.**

In your textbook, read about the relationships among temperature, pressure, and volume of a sample of gas.

Fill in the blanks between the variables in the following concept map to show whether the variables are directly or inversely proportional to each other. Write direct or inverse between the variables.



In your textbook, read about the combined gas law and Avogadro's principle.

Circle the letter of the choice that best completes the statement or answers the question.

7. The variable that stays constant when using the combined gas law is
   a. amount of gas. **b.** pressure. **c.** temperature. **d.** volume.

8. The equation for the combined gas law can be used instead of which of the following equations?
   a. Boyle's law **b.** Charles's law **c.** Gay-Lussac's law **d.** all of these

9. Which of the following expresses Avogadro's principle?
   a. Equal volumes of gases at the same temperature and pressure contain equal numbers of particles.
   b. One mole of any gas will occupy a certain volume at STP.
   c. STP stands for standard temperature and pressure.
   d. The molar volume of a gas is the volume that one mole occupies at STP.

Section 13.2 *continued*

Answer the following questions.

10. What is standard temperature and pressure (STP)?

____

11. What is the molar volume of a gas equal to at STP?

____

In your textbook, read about how to solve problems using the combined gas law and Avogadro's principle.

Each problem below needs more information to determine the answer. List as many letters as are needed to solve the problem.

a. molar volume of the gas
b. molar mass of the gas
c. temperature of the gas
d. pressure of the gas
e. volume of the gas
f. No further information is needed.

__________ **12.** What volume will 1.0 g N_2 gas occupy at STP?

__________ **13.** What volume will 2.4 mol He occupy at STP?

__________ **14.** A gas sample occupies 3.7 L at 4.0 atm and 25°C. What volume will the sample occupy at 27°C?

__________ **15.** A sample of carbon dioxide is at 273 K and 244 kPa. What will its volume be at 400 kPa?

__________ **16.** A sample of oxygen occupies 10.0 L at 4.00 atm pressure. At what temperature will the pressure equal 3.00 atm if the final volume is 8.00 L?

__________ **17.** At what pressure will a sample of gas occupy a 5.0 L container at 25°C if it occupies 3.2 L at 1.3 atm pressure and 20°C?

__________ **18.** How many grams of helium are in a 2-L balloon at STP?

__________ **19.** One mole of hydrogen gas occupies 22.4 L. What volume will the sample occupy if the temperature is 290 K and the pressure is 2.0 atm?

Section 13.2 The Ideal Gas Law

In your textbook, read about the ideal gas law.

Answer the following questions.

1. Why is the mathematical relationship among the amount, volume, temperature, and pressure of a gas sample called the ideal gas law?

____

____

2. Define the ideal gas constant, R.

____

____

3. In Table 13.2 in your textbook, why does R have different numerical values?

____

____

4. What variable is considered in the ideal gas law that is not considered in the combined gas law?

____

In your textbook, read about real versus ideal gases.

For each statement below, write *true* or *false*.

____________________ **5.** An ideal gas is one whose particles take up space.

____________________ **6.** At low temperatures, ideal gases liquefy.

____________________ **7.** In the real world, gases consisting of small molecules are the only gases that are truly ideal.

____________________ **8.** Most gases behave like ideal gases at many temperatures and pressures.

____________________ **9.** No intermolecular attractive forces exist in an ideal gas.

____________________ **10.** Nonpolar gas molecules behave more like ideal gases than do gas molecules that are polar.

____________________ **11.** Real gases deviate most from ideal gas behavior at high pressures and low temperatures.

____________________ **12.** The smaller the gas molecule, the more the gas behaves like an ideal gas.

Section 13.2 *continued*

In your textbook, read about applying the ideal gas law.

Rearrange the ideal gas law, *PV* = *n*R*T*, to solve for each of the following variables. Write your answers in the table.

Rearranging the Ideal Gas Law Equation	
Variable to Find	**Rearranged Ideal Gas Law Equation**
n	**13.**
P	**14.**
T	**15.**
V	**16.**

In your textbook, read about using the ideal gas law to solve for molar mass, mass, or density.

Use the following terms below to complete the statements. Each term may be used more than once.

mass	molar mass	molume

The number of moles of a gas is equal to the **(17)** ________________________ divided by the **(18)** ________________________.

Density is defined as **(19)** ________________________ per unit **(20)** ________________________.

To solve for M in the equation $M = \frac{mRT}{PV}$, the **(21)** ___________________________ and the **(22)** ________________________ of the gas must be known.

According to the equation $D = \frac{MP}{RT}$, the **(23)** __________________________ of the gas must be known when calculating density.

Section 13.3 Gas Stoichiometry

In your textbook, read about gas stoichiometry.

Balance the following chemical equation. Then use the balanced equation to answer the questions.

1. _________ $H_2(g)$ + _________ $O_2(g) \rightarrow$ _________ $H_2O(g)$

2. List at least two types of information provided by the coefficients in the equation.

____

____

3. If 4.0 L of water vapor is produced, what volume of hydrogen reacted? What volume of oxygen?

____

4. If it is known that 2 mol of hydrogen reacts, what additional information would you need to know to find the volume of oxygen that would react with it?

____

____

____

5. List the steps you would use to find the mass of oxygen that would react with a known number of moles of hydrogen.

____

____

____

6. Find the mass of water produced from 4.00 L H_2 at STP if all of it reacts. Show your work.

____

____

____

____

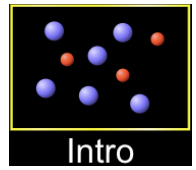
Exploring the behavior of Gases

Name: ___________________________ Date: _________

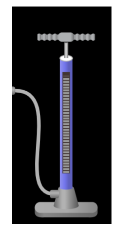
Get Started: Click on this link to open the gas simulation

Part I

1. Go to intro. **Choose only one type of particle.**
2. Record the pressure, temperature and volume.



3. Give one pump of gas and observe the behavior. How would you describe this?



Record the pressure, temperature and volume.

4. Hold volume and temperature constant and give one more pump.
Record the number of particles and the pressure in the data table below.
Describe what you saw.

Repeat this a few times, either increasing or decreasing the number of the same type of particles.

Number of particles	Pressure (atm)

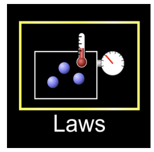
5. Is there a relationship between the number of particles and the pressure? Briefly describe this.

What is the pressure in the container due to? (what assumption are we making?)

Part II:

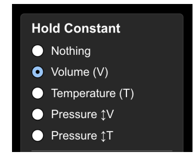
There are 3 parameters that need to be specified when describing a specific quantity of a gas. They are: Pressure, Volume and Temperature. **We will keep the number of particles constant** in each "experiment" and explore the effect (if any) a change in any of these parameters may have on the behavior of the gas.

Choose the Laws option on the right. See picture



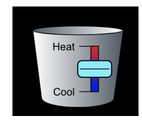
Experiment 1- Volume

1. Give one pump of gas into the chamber.
2. Choose to **hold the volume constant** by selecting that option in the upper right-hand corner. See the picture.



What is the initial temperature (in K) and pressure (in atm) in the chamber?

3. Use the slider at the bottom of the simulator to add heat and double the temperature.



Did the pressure go up or go down? What is the new pressure in the chamber?

4. Keeping the volume constant (and the number of particles constant), change the temperature and record the pressure. Repeat 4 times and record your data. Sketch a graph to the right of the table. Be sure to give a title to your graph and label the axis completely.
   Independent variable is : ____________________
   Dependent Variable: ________________________
   Constants: _________________________________

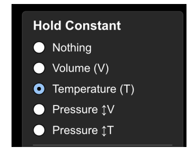
Temperature (K)	Pressure (atm)

Describe the graph and relationship:

Experiment 2 - Temperature

1. Reset the simulator by selecting the reset button in the bottom right corner of the simulation.

2. Give one pump of gas into the chamber.
3. **Choose to hold the temperature constant** by selecting that option in the upper right-hand corner. See the picture.
   What is the initial pressure (in atm) in the chamber?



4. Locate the handle on the left of the chamber and slide it to the right as far as it will go.
What units are used to measure the width of the chamber? ___________
Does the volume go up or go down when you slide it to the right? _________, Did the pressure go up or go down? ____________; Why?

5. Slide the handle all the way to the left as far as it will go.
   Did the pressure go up or go down? ________________; Why?

6. Keeping the temperature constant (and the number of particles constant), change the volume and record the pressure. Repeat 4 times and record your data. Sketch a graph to the right of the table. Be sure to give a title to your graph and label the axis completely
   Independent variable is : _____________________
   Dependent Variable: _________________________
   Constants: ___________________________________

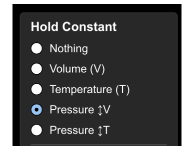
Volume (nm^3)	Pressure (atm)

Describe the graph and relationship:

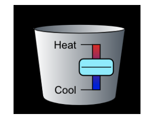
Experiment 3 - Pressure

1. Reset the simulator by selecting the reset button in the bottom right corner of the simulation.

2. Give one pump of gas into the chamber.
3. **Choose to hold the pressure constant** by selecting that option in the upper right-hand corner. See the picture.
   What is the initial temperature (in K) in the chamber?____________



4. Use the slider at the bottom of the simulator to add heat and increase the temperature.
   Did the volume go up or go down? ______________



5. Keeping the pressure constant (and the number of particles constant), change the temperature and record the volume. Repeat 4 times and record your data. Sketch a graph to the right of the table. Be sure to give a title to your graph and label the axis completely

   Independent variable is : ___________________
   Dependent Variable: ______________________
   Constants: ________________________________

Temperature (K)	Volume (nm^3)

Describe the graph and relationship:

Analysis

In each of the experiments, you hold one parameter constant while changing the other 2. Summarize the findings of your experiments by using arrows (↑ or ↓) to represent what happened.

Experiment 1: When temperature went _________, the pressure went __________.

Possible reason?

Real world example?

Experiment 2: When volume went _________, the pressure went __________.

Possible reason?

Real world example?

Experiment 3: When temperature went _________, the volume went __________.

Possible reason?

Real world example?