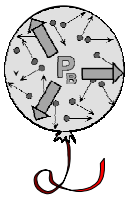
Unit 9

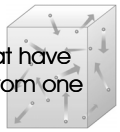
The Behavior of GAS The Gas Laws

(Chapter 12)



Let's Recap some Older Material about Gases …

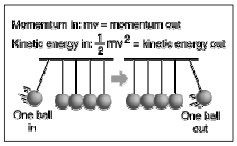
The Behavior of Gases, according to the Kinetic Theory.

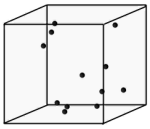


- A gas is composed of small spheres, that have insignificant volume, and are far apart from one another.
- The spheres move rapidly in constant motion, traveling in straight lines until they strike another sphere, or the wall of the container.
- As such, they fill their container, and assume the shape/volume of the container.
- The spheres collide in perfectly elastic collisions; the K.E. from one sphere is transferred w/o loss from one particle to another.

Kinetic Molecular Theory of Gases

- An Elastic Collision …

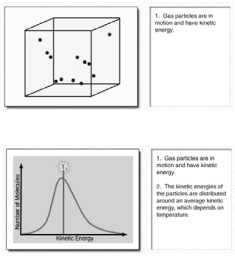




Do all of the particles in a Gas have the Same Energy?

Remember, the Kinetic Energy is a measure of the Average Energy of the gas particles within a sample.

Kinetic Energy, Movement, and Temperature



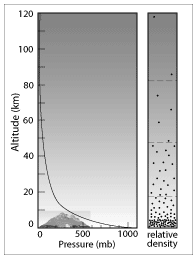
Gas Particles have different energies with respect to one another. Some particles move slower/faster than others.

The Kinetic energies are distributed around an Average KE, which corresponds to the temperature of the gas

http://www.chm.davidson.edu/chemistryapplets/KineticMolecularTheory/BasicConcepts.html

Atmospheric Pressure, How Does it Change at Varying Altitudes?

- At Higher altitudes, what happens to the weight of air?
- The "weight" of air at higher altitudes is less, so the atmospheric pressure is lower … the Air "thins out" at higher altitudes.
- the air at low altitudes is dense; higher weight of air corresponds to higher atmospheric pressure



Remember the Units of Pressure?

The pressure that the colliding gas "spheres" have on the container is Gas Pressure.

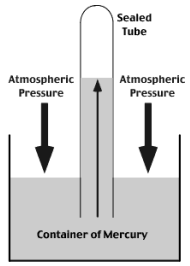
The Standard Unit of Pressure: pascal (Pa)

Table 1. Units of Pressure		
Units	**Abbreviation**	**Value at Standard Conditions**
Pounds per square inch	Psi	14.7
Millimeters of mercury	mm Hg	760
Inches of mercury	in. Hg	29.92
kilopascal	kPa	101.325
Feet of water column	ft W.C.	33.92
Units most commonly used in air pollution		
Inches of water column	in. W.C.	407
Atmosphere	Atm	1

Standard Atmospheric Pressure at Sea Level & 25°C:

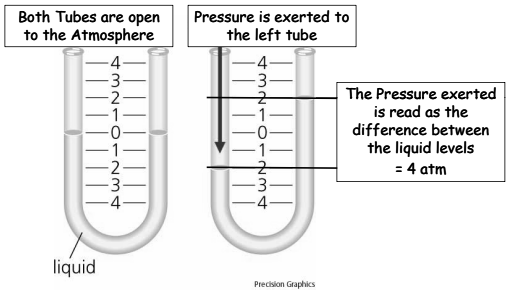
Atmospheric Pressure: is the pressure that "air" gases (N_2, O_2, Argon, CO_2) exert on the Earth's surface due to gravity.

How Do We Measure the Pressure of a Gas?
The Torricelli Barometer



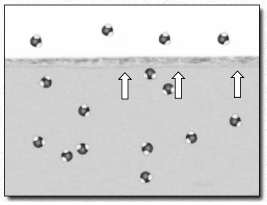
- As the Atmospheric Pressure increases, the level of Mercury in the Barometer increases.
- What would happen to the level of Mercury at the top of Mount Everest?

How Do We Measure the Pressure of a Gas?
The Manometer



Remember Vapor Pressure?

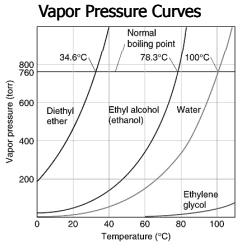
Vapor Pressure: can be thought of as the degree to which the liquid molecules are escaping into the vapor phase.



Vapor Pressure & Boiling Points

Boiling occurs when the vapor pressure reaches or exceeds the surrounding pressure from the atmosphere or whatever else is in contact with the liquid.

The Vapor Pressure EQUALS the Atmospheric Pressure at the Boiling Point ⇨



So now Let's Talk about Gas …

What are the Variables that Describe a Gas?

- The four variables and their common units:
  1. number of moles (n)
  2. volume (V) in Liters
  3. temperature (T) in Kelvin
  4. pressure (P) in kilopascals

Section 12.2
Factors Affecting Gas Pressure

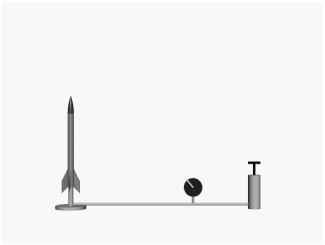
OBJECTIVES:

- Explain how the amount of gas and the volume of the container affect gas pressure.
- Infer (conclude or decide) the effect of temperature changes on the pressure exerted by a contained gas.

What Affects Gas Pressure?
Changing the Amount of Gas (n):

- When we inflate a balloon, we are <u>adding</u> gas molecules.
- Increasing the number of gas particles increases the number of collisions
  - thus, the pressure increases
- If temp. is constant- doubling the number of particles doubles pressure

What Affects Gas Pressure?
Changing the Amount of Gas (n):



$n \alpha$ Pressure

Pressure and the number of molecules are <u>directly related</u>

- More molecules means more collisions, & more pressure
- Fewer molecules means fewer collisions, & less pressure.
- Gases naturally move from/expand into areas of high pressure to low pressure
- Spray can is example.

<u>http://www.howstuffworks.com/animation26.htm</u>

What Affects Gas Pressure?
Changing the Volume of the Gas:

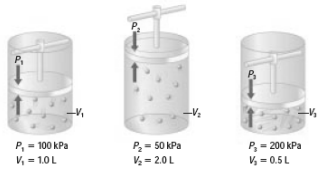
- You can increase the pressure of a gas by decreasing the volume of the gas.
- The more a gas is compressed, the greater the pressure of the gas.
- If we ½ the volume of the container, we double the pressure.

What Affects Gas Pressure?

Changing the Volume of the Gas:

- If we double the original volume of the container, we ½ the pressure.

Volume α 1 / Pressure



What Affects Gas Pressure?

Changing the Temperature of the Gas:

- If we increase the average kinetic energy (temperature) of the gas, the faster moving particles impact the walls of the container with more energy, increasing the pressure.
- Double Temp → Double Pressure

Temp α Pressure

These relationships of Temperature, Pressure, and Volumes of a gas are described in the Gas Laws …

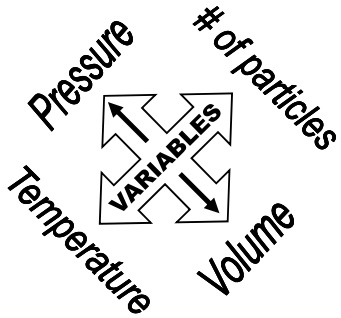
Manometer Worksheets

Section 12.3
The Gas Laws

OBJECTIVES:

- State:
  - Boyle's Law
  - Charles's Law
  - Gay-Lussac's Law
  - the Combined Gas Law.
- Apply the gas laws to problems involving the temperature, the volume, and the pressure of a contained gas.

Boyle's Law



Pressure and Volume are Variable, while Temperature and number of moles are constant.

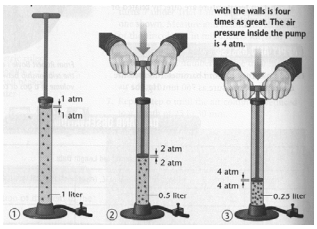
In Boyle's Law …

- Constant T and n (#particles)
- As volume decreases; the pressure increases
- V ↓ P ↑
- Inversely proportional

$V \propto 1 / P$

Remembering Boyle's Law …

Boyle's Law



KINETIC EXPLANATION

- As volume decreases the particles have less room and collide with the inside of the container more causing more pressure.

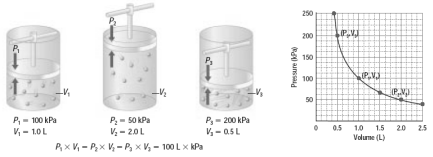
Boyle's Law: Constant n & T

$$P_1V_1 = P_2V_2$$

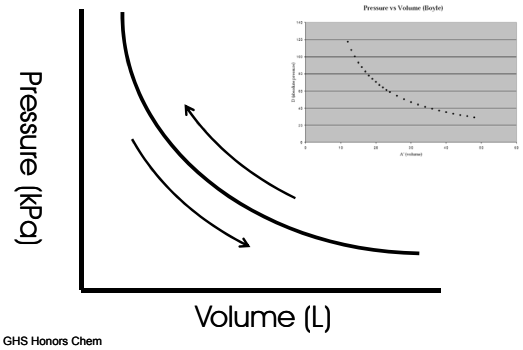
- P_1 & P_2 must have the same units (atm, mm Hg, or Torr).
- V_1 & V_2 must have the same units (Liters, milliliters).
- n & Temperature are constant.

Boyle's Law: Constant n & T

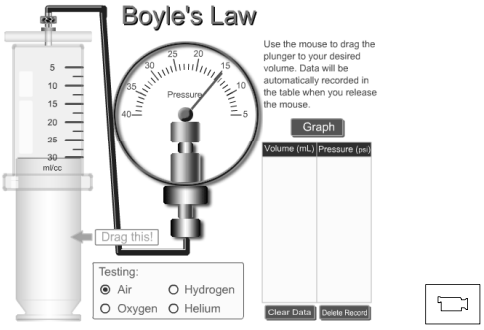
$$P_1V_1 = P_2V_2$$



Boyle's Law Plot of V vs. P



Boyle's Law



Boyle's Law Sample Problems:

The maximum volume a weather balloon can reach without rupturing is 22000 L. It is designed to reach an altitude of 30km. At this altitude, the atmospheric pressure is 0.0125 atm. What maximum volume of helium gas should be used to inflate the balloon at standard pressure before it is launched?

V_1 P_1 V_2 P_2

$V_1P_1 = V_2P_2$

$(22000L)*(0.0125\ atm) = (V_2)*(1\ atm)$

$V_2 = (22000L)*(0.0125\ atm)/(1\ atm)$

$V_2 = 275\ L$

Boyle's Law Sample Problems:

Two liters of air at atmospheric pressure are compressed into a 0.45 L canister of a warning horn. If it temperature remains constant, what is the pressure of the compressed air?

V_1 P_1 V_2 P_2

$V_1P_1 = V_2P_2$

$(2L)*(1atm) = (0.45L)*(P_2)$

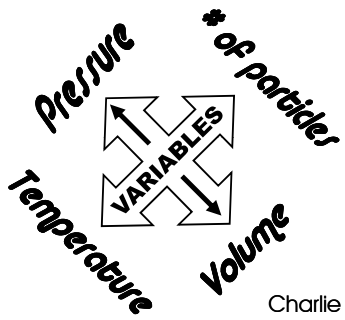
$P_2 = (2L)*(1atm)/(0.45L)$

$P_2 = 4.4\ atm$

Other Examples of Boyle's Law

- A balloon is filled with 25 L of air at 1.0 atm pressure. If the pressure is changed to 1.5 atm what is the new volume? 16.7 L
- A balloon is filled with 73 L of air at 1.3 atm pressure. What pressure is needed to change the volume to 43 L? 2.21 L

Charles' Law



Temperature and Volume are Variable, while Pressure and number of moles are constant.

Charlie Brown on TV

Charles' Law

Let's take a look at a plastic water bottle with Boiling Hot Water Inside …

Procedure:

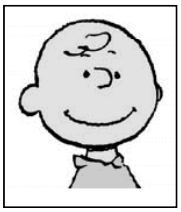
1. Carefully add 200 ml of Boiling water to an empty 2L soda bottle.
   After approximately 1 minute, place the cap on the bottle.
   Place the bottle filled with hot water on an ice bath, and observe the changes in the bottle.

Charles' Law

1. What effect does temperature have on the shape of the bottle?
2. What effect does an decrease in temperature have on the volume of water vapor within the bottle?
3. How could we return the bottle to it's original shape?

In Charles' Law …

- Constant P and n (#particles)
- As temperature decreases; volume decreases.
- T↑ V↑
- Directly proportional
  or T α V



GHS Honors Chem

In Charles' Law: Constant P & n

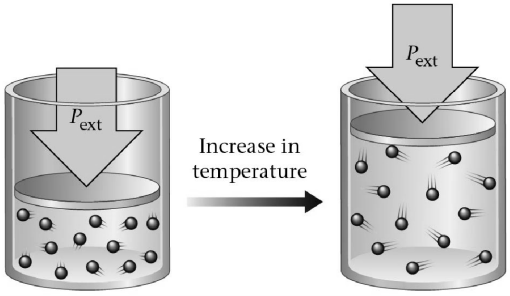
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

- V_1 & V_2 must have the same units (L, ml, etc.)
- T_1 & T_2 must be in Kelvin

GHS Honors Chem

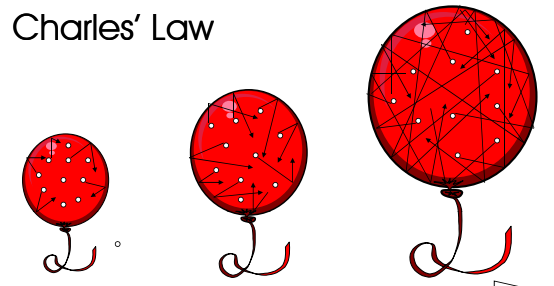
Charles' Law

How does an Increase in Temperature effect Volume?



GHS Honors Chem

Charles' Law



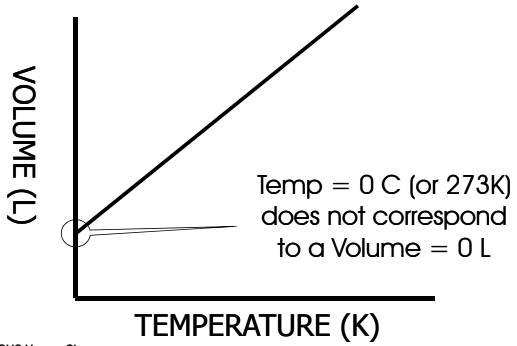
Increasing Temperature

The Kinetics Explanation:

As the temperature increases the molecules collide with the balloon more often with more energy and the balloon has higher volume.

GHS Honors Chem

A Plot of Charles' Law; V vs. T



Temp = 0 C (or 273K) does not correspond to a Volume = 0 L

GHS Honors Chem

Charles' Law and Absolute Zero

If the Volume vs. Temperature plot is extrapolated, then the point at which it crosses the T-axis where the gas has no volume (V = 0) occurs at T = -273.15 °C, or 0° Kelvin. This point is the Absolute Zero and it represents the theoretical lowest temperature attainable. All temperatures can now be defined with respect to absolute zero.

At Absolute Zero, particles have no kinetic energy, hence gases have no volume.

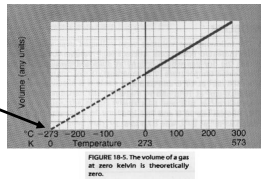
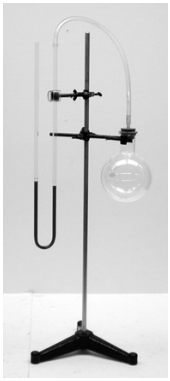


FIGURE 10-5. The volume of a gas at zero kelvin is theoretically zero.

GHS Honors Chem

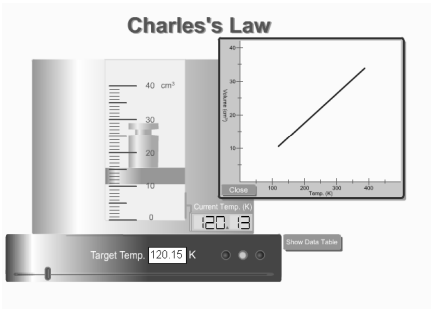
Charles' Law in Practice

Let's use a Manometer to verify Charles' Law:



GHS Honors Chem

A Charles' Law Experiment:



GHS Honors Chem

Charles' Law Sample Problems

A balloon is filled with 3.0 L of helium at 27° C and 760 mm Hg. It is then placed outdoors on a hot summer day when the temperature is 31° C. If the pressure remains constant, what will the volume of the balloon be?

$V_1/T_1 = V_2/T_2$

$(3.0L)/(298K) = (V_2)/*(304K)$

$V_2 = (3.0L)*(304K)/(298K)$

$V_2 = 3.1\ L$

GHS Honors Chem

Charles' Law Sample Problems

A balloon is filled with 3.0 L of helium at 310 K and 1 atm. The balloon is placed in an oven where the temperature reaches 340 K. What is the new volume of the balloon?

$V_1/T_1 = V_2/T_2$

$(3.0L)/(310K) = (V_2)/*(340K)$

$V_2 = (3.0L)*(340K)/(310K)$

$V_2 = 3.29\ L$

GHS Honors Chem

Charles' Law Sample Problems

At constant pressure, by what fraction of its volume will a quantity of gas change if the temperature changes from 0 degrees C to 50 degrees C?

$T_1 = 273\ K$
$T_2 = 323\ K$
$V_1 = 1$
$V_2 = ?$

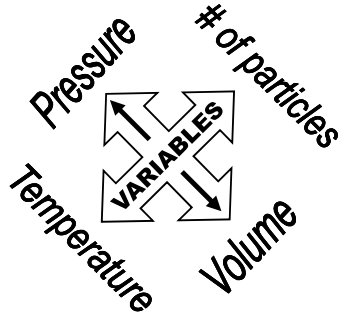
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{273\ K}{1} = \frac{323\ K}{X}$$

$X = 323 / 273$
or 1.18 x larger

GHS Honors Chem

Gay Lussac Law



Temperature and Pressure are Variable, while Volume and number of moles are constant.

GHS Honors Chem

Gay-Lussac Law

- As the Temperature of a Gas increases, the molecules have increased KE, move faster, collide against the container with greater force, thus increasing the pressure.
- The temperature and the pressure of a gas are directly related, at constant volume.

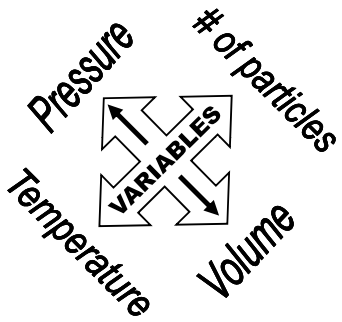
Formula: $P_1/T_1 = P_2/T_2$

Gay-Lussac Law Problems

- What is the pressure inside a 0.250 L can of deodorant that starts at 25 °C and 1.2 atm if the temperature is raised to 100 °C? 1.5 atm
- At what temperature will the can above have a pressure of 2.2 atm?

546 K

Combined Gas Law



Temperature, Pressure, and Volume are Variable, while the number of moles is constant.

Combined Gas Law

$$P_1V_1 = P_2V_2$$

Boyle's Law

Combined Gas Law

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

Charles' Law

Combined Gas Law

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

Gay-Lussac Law

Combined Gas Law Problems often cite Standard Conditions

- Standard Temperature and Pressure, or STP
- T = 273 K which is 0°C
- P = 101.3 kPa =1.00 atm
- = 760 mm Hg

Combined Gas Law Problems

A 154 mL sample of carbon dioxide gas is generated by burning graphite in pure oxygen. If the pressure of the gas generated is 121 kPa and its temperature is 117° C, what volume would the gas occupy at standard temperature and pressure, STP?

V_1 P_1 T_1 T_2&P_2

Ans: 129mL

Combined Gas Law Problems

A 2.7 L sample of nitrogen is collected at 121 kPa and 288 K. If the pressure increases to 202 kPa and the temperature rises to 303 K, what volume will the nitrogen occupy?

V_1 P_1 T_1 P_2 T_2 V_2

Ans: 1.7L

Gas Laws Worksheet 1