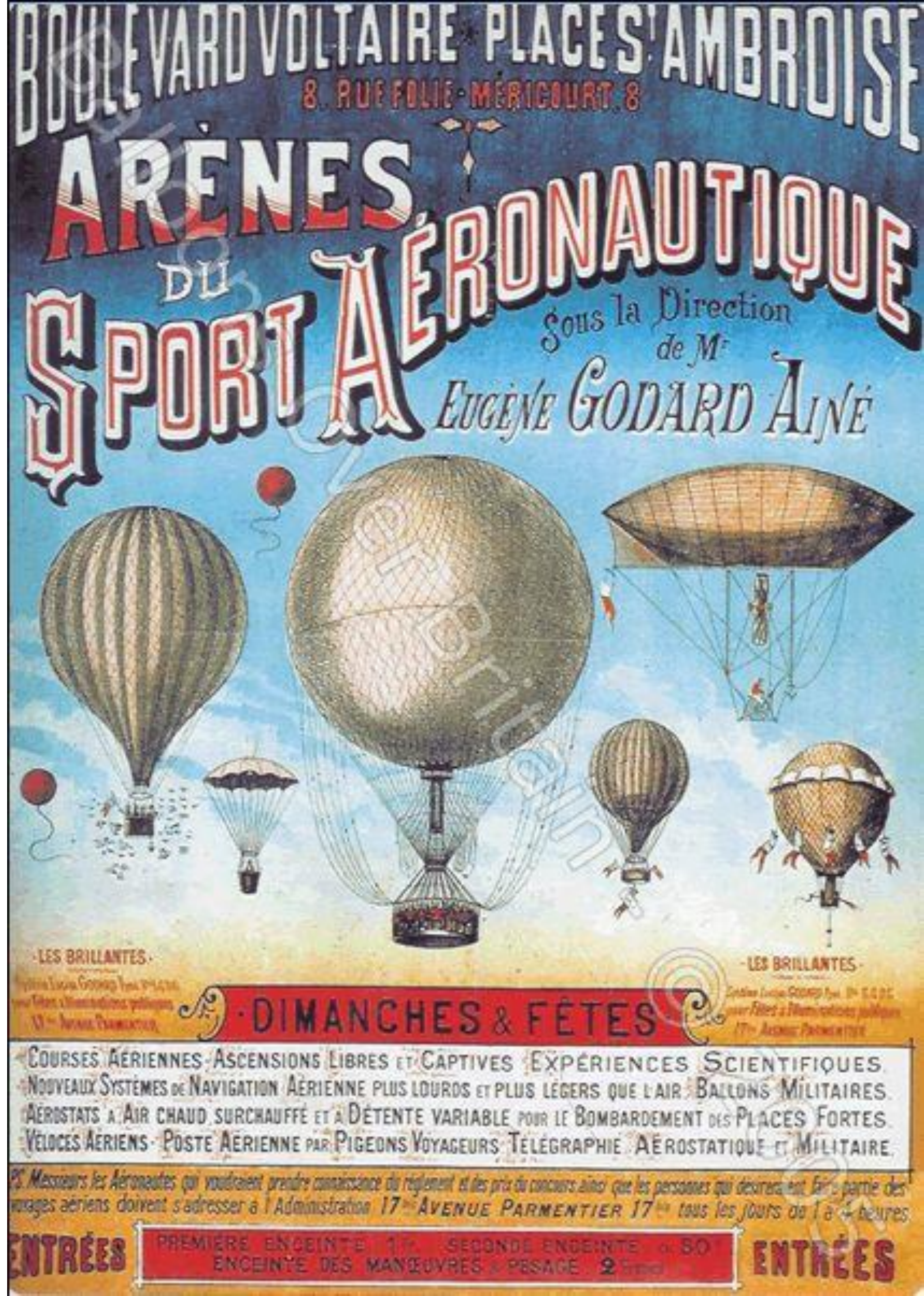
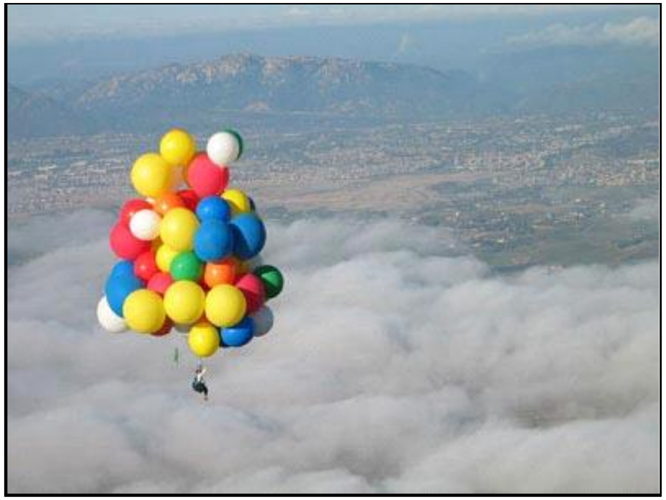
Gases and Gas Laws



Kinetic Molecular Theory

- Particles of matter are ALWAYS in motion
- Volume of individual particles is ≈ zero. Consists of large number of particles that are very far apart
- Collisions of particles with container walls cause pressure exerted by gas but are negated
- Particles exert no forces on each other (neither attraction or repulsion)
- Average kinetic energy ∝ Kelvin temperature of a gas. *(the warmer the faster)*

The Meaning of Temperature

$$(\mathrm{KE})_{\mathrm{avg}} = \frac{3}{2} RT$$

- Kelvin temperature is an index of the random motions of gas particles

- (higher *T* means greater motion.)

Kinetic Energy of Gas Particles

At the same conditions of temperature, all gases have the same average kinetic energy. Therefore at the same temperature lighter gases are moving FASTER

$$KE = \frac{1}{2} m v^2$$

m = mass

v = velocity

Measuring Pressure

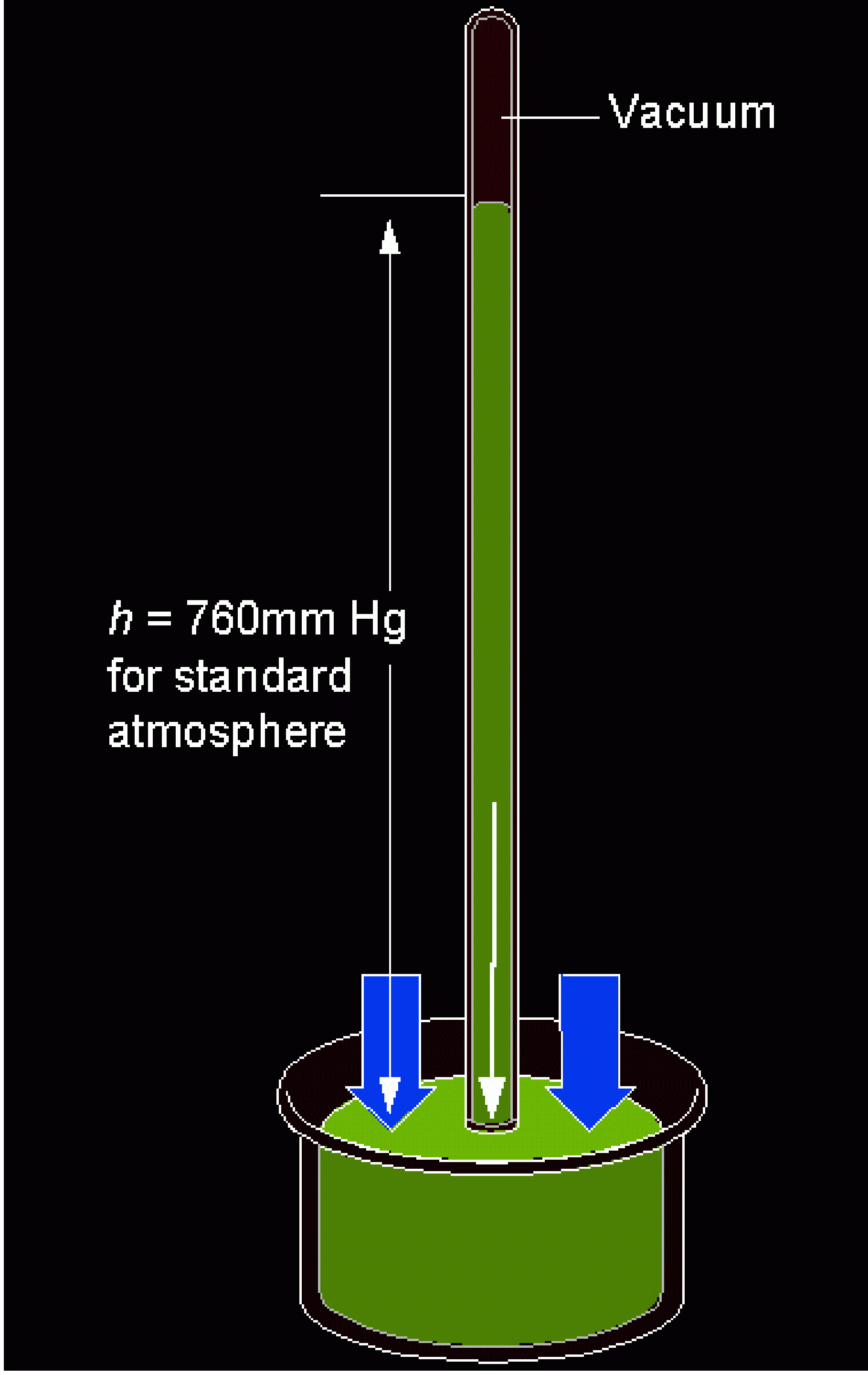
The first device for measuring atmospheric pressure was developed by Evangelista Torricelli during the 17th century.

The device was called a "barometer"

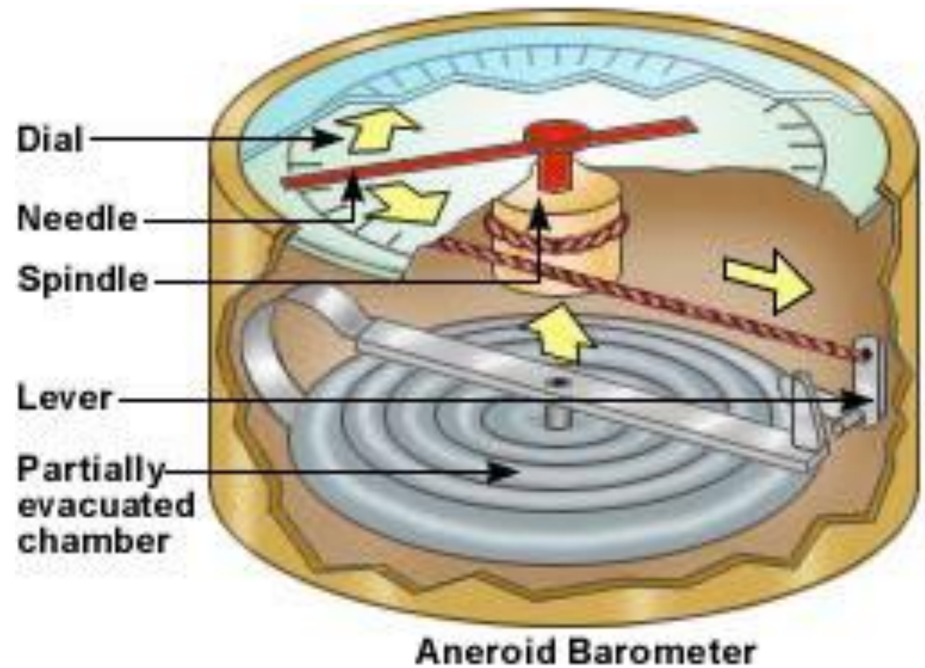
- Baro = weight
- Meter = measure

An Early Barometer

The normal pressure due to the atmosphere at sea level can support a column of mercury that is 760 mm high



The Aneroid Barometer



Pressure

- Is caused by the collisions of molecules with the walls of a container
- is equal to force/unit area
- SI units = Newton/meter^2 = 1 Pascal (Pa)
- 1 standard atmosphere = 101.3 kPa
- 1 standard atmosphere = 1 atm
- unit conversions:

  1 atm= 760 mm Hg = 760 torr = 101.3 kPa

Units of Pressure

Unit	*Symbol*	*Definition/Relationship*
Pascal	Pa	SI pressure unit 1 Pa = 1 newton/meter^2
Millimeter of mercury	mm Hg	Pressure that supports a 1 mm column of mercury in a barometer
Atmosphere	atm	Average atmospheric pressure at sea level and 0 °C
Torr	torr	1 torr = 1 mm Hg

Mathematical Computations:

- Convert the following:
- 737 mmHg to atm
- 97.5 kPa to atm
- 0.650 atm to mmHg

.785 atm to torr

The Nature of Gases

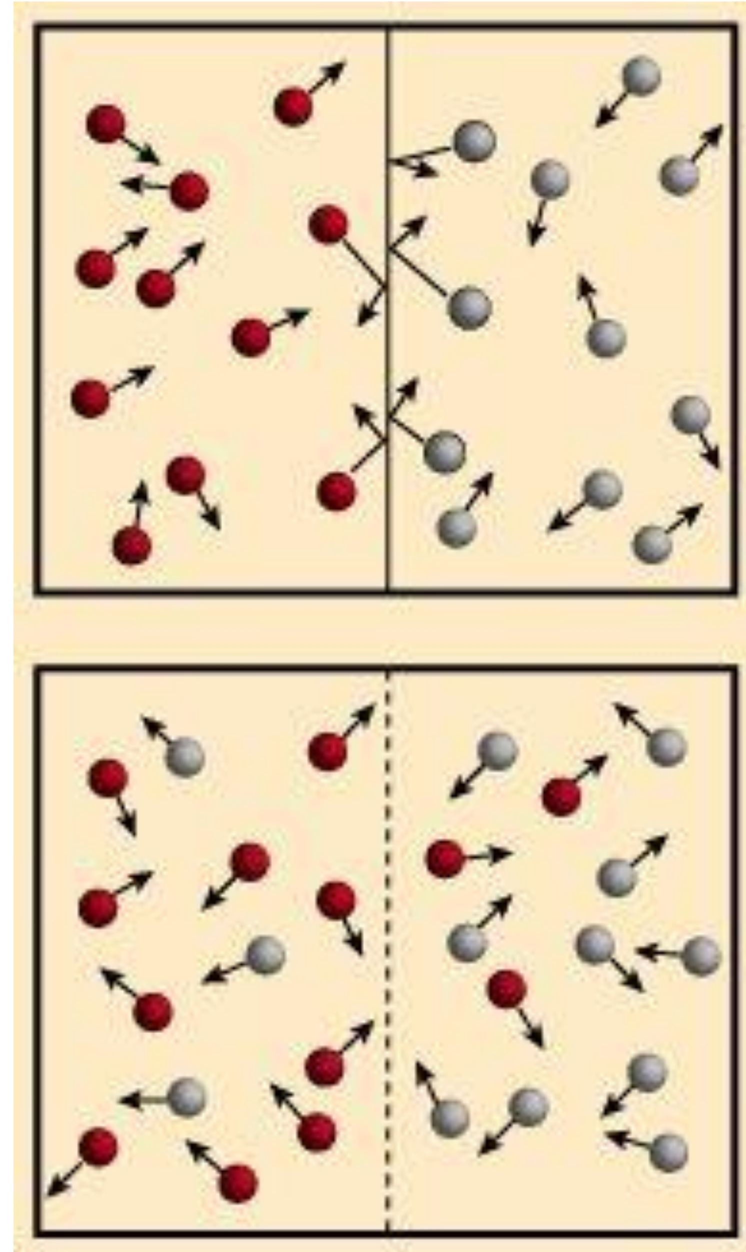
- **Expansion: Gases expand to fill their containers completely**
- **Fluidity: – they flow and slide past one another**
  - **Gases have low density**
    - **1/1000 the density of the equivalent liquid or solid**
- **Compressibility: can move molecules closer together**
- **Diffusion: Spontaneous mixing of molecules**

Depends on size, shape, force of attraction & temperature

effusion: forced through a tiny opening

Diffusion

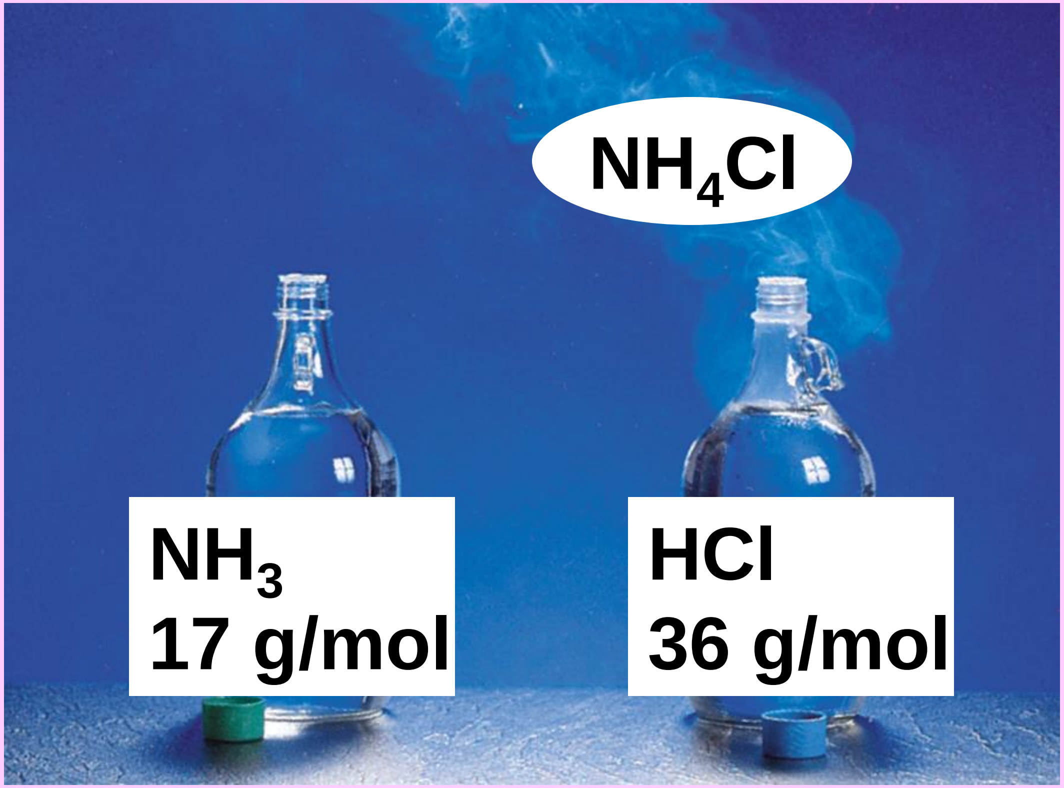
Diffusion: describes the mixing of gases. The rate of diffusion is the rate of gas mixing.



- Diffusion: ***The spontaneous mixing of molecules caused by the movement of molecules in the liquids or gases-***
- ***(The warmer the faster the diffusion)***

Gas diffusion is the gradual mixing of molecules of one gas with molecules of another by virtue of their kinetic

Consider the reaction of ammonia and hydrochloric acid given that both reagents are at the same temperature:



Standard Temperature & Pressure "STP"

- *P* = 1 atmosphere (atm),
  760 torr
  101.3 kPa
  760 mmHg
- *T* = 0°C, 273 Kelvins

Boyle's Law

The volume of a fixed mass of gas varies inversely with the pressure at a constant temperature (pressure and volume under both conditions must have the same units)

Think of a piston in a plunger: it is harder to push the plunger down at the end of the stroke where volume has decreased)

$$P_1V_1 = P_2V_2$$

Mathematical Computation Boyles Law # 1:

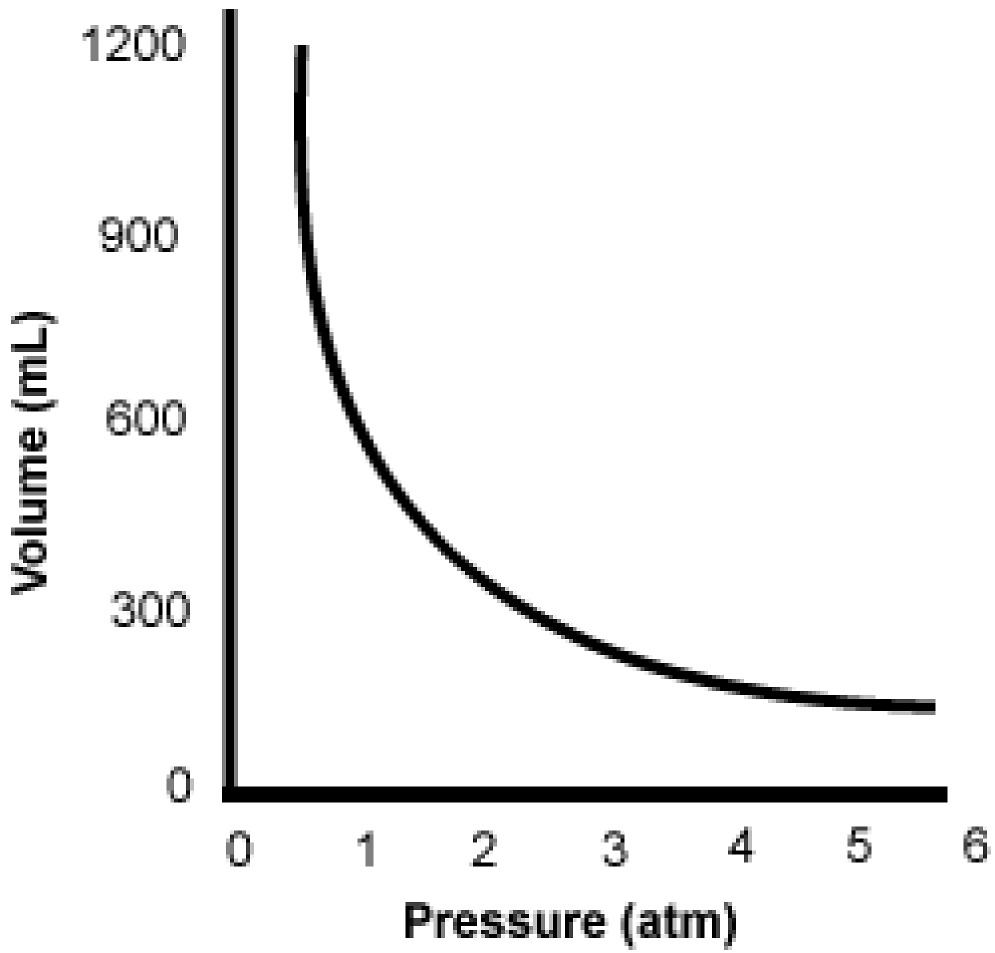
- A fixed sample of oxygen exerted a pressure of 789 mmHg in a 325 ml vessel. Providing the temperature remains constant, if the gas is transferred to a 275ml vessel what pressure would the gas exert in the new vessel in atm?

Mathematical Computation: Boyles Law #2

The pressure of a sample of nitrogen was observed to be <u>652 mmHg</u> in a <u>150 ml</u> vessel.

If the sample was transferred to an alternate container and extered a pressure of <u>1.39 atm,</u> what is the volume of the new container?

A Graph of Boyle's Law



Converting Celsius to Kelvin

Gas law problems involving temperature require that the temperature be in KELVINS!

$$\text{Kelvins} = {}^\circ\text{C} + 273.15$$

$$^\circ\text{C} = \text{Kelvins} - 273.15$$

Temperature Computations:

- Covert 22.0 ^{0}c to Kelvin

- Convert 285 Kelvin to ^{0}c

Charles's Law

- **The volume of a gas at constant pressure is directly proportional to Kelvin temperature, and extrapolates to zero at zero Kelvin.**

(P = constant)

Think about an inflated balloon in a warm home. You step out into the cold night air. What happens?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad (P = \text{constant})$$

Temperature MUST be in KELVINS!

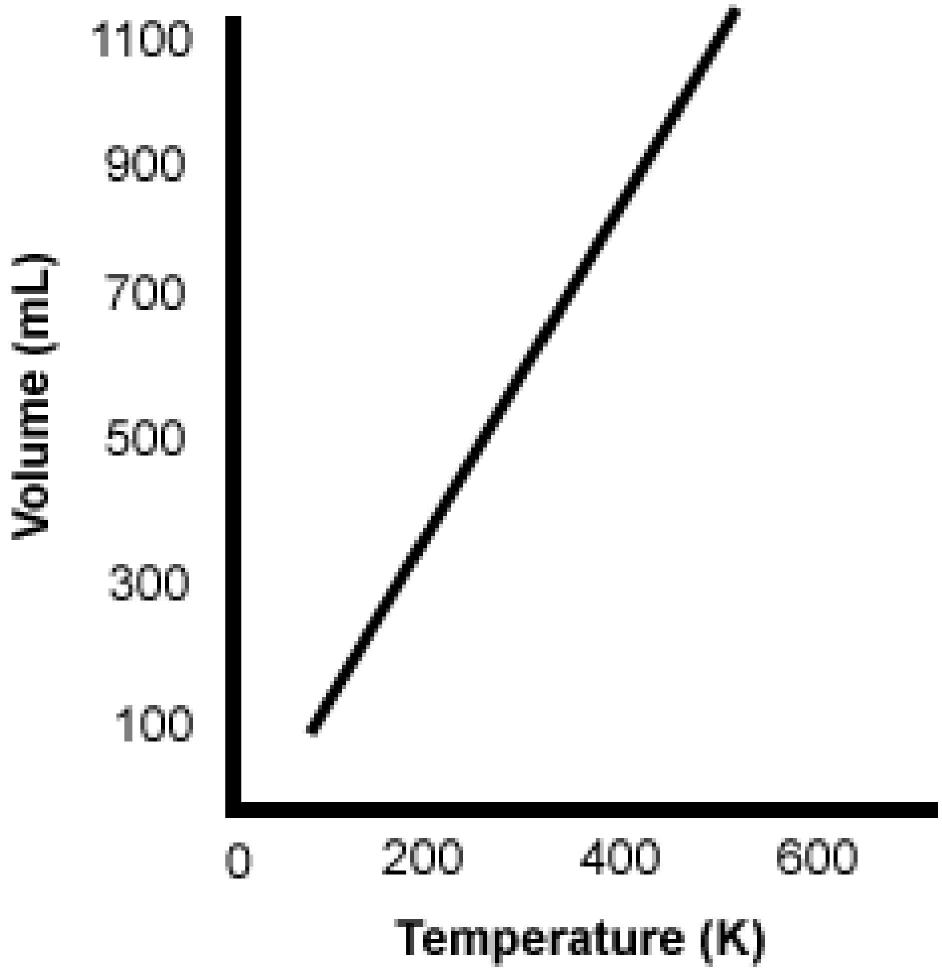
Mathematical Computation : Charles Law #1

- A sample of neon in a balloon at constant pressure has a volume of 725.ml at 22.0^{0}c. If the balloon is left in a car where the volume expeands to 800.00 ml, what temperature in 0c is the interior of the car assuming the pressure remains constant?

Mathematical Computation Charles Law #2

- **A helium filled balloon occupies a volume of1.25 liters at a temperature of 25.0^{0}c. A little boy walks outside where the temperature is –2.00^{0}c. If the pressure remains constant, what volume will the balloon occupy outside?**

A Graph of Charles' Law



Gay Lussac's Law

The pressure and Kelvin temperature of a gas are directly related, provided that the volume remains constant.

Think about when you have a fixed space and increase the temp, molecules will increase movement which increases collisions which is pressure (and vice versa)!

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

Temperature MUST be in <u>KELVINS</u>

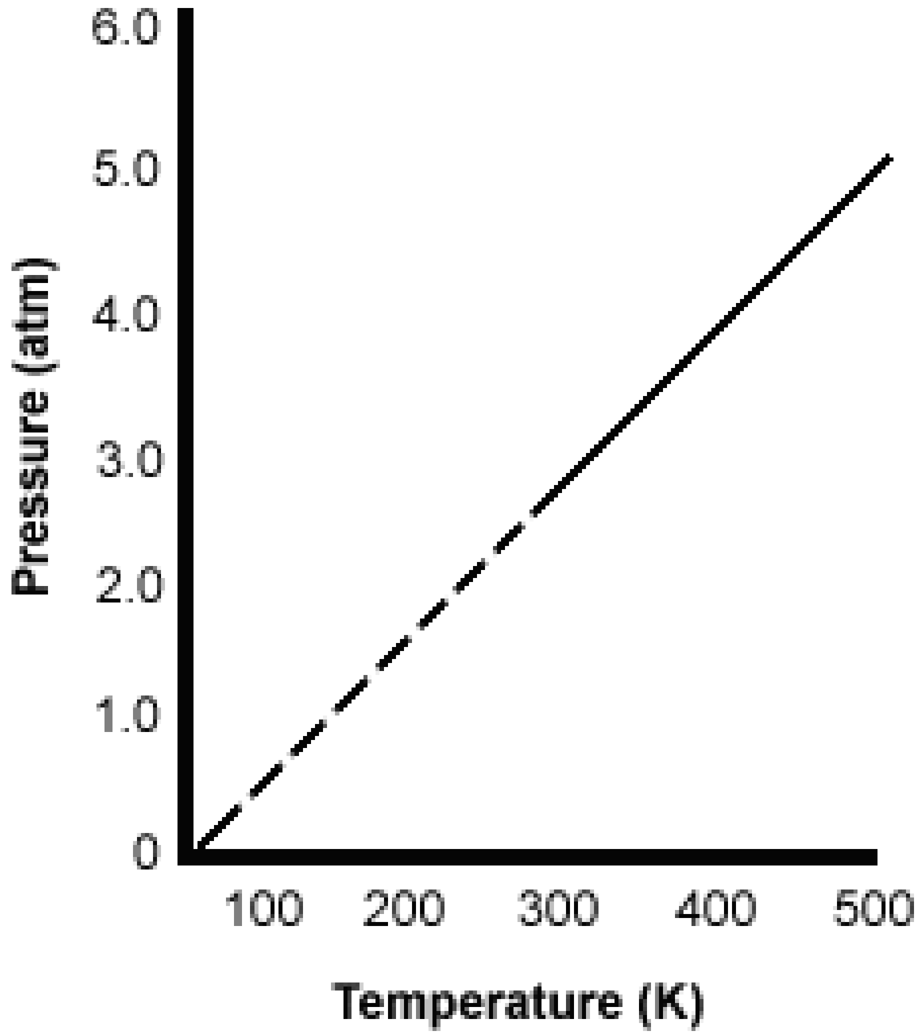
Mathematical Computation: Gay-Lussacs Law#1

- **Before a car ride the pressure in an automobile tire was measured with a pressure gauge to be 1370 mmHg at a temperature of 20.0^{0}c. At the end of a road trip the pressure was found to be 1.90 atm. Assuming the volume of the tires did not change, what is the temperature of gas inside the tire in Celsius?**

Ga-Lussac's Law #2

- **An aerosol can has a pressure of 2.75 atm at 22^{0}c. The directions on the can state not to store in a place where the temperature exeeds 52.0^{0}c. The can will burst at a pressure of 3.10 atm. If the can experiences a temperature of 53.0^{0}c, will it burst?**

A Graph of Gay-Lussac's Law



The Combined Gas Law

The combined gas law expresses the relationship between pressure, volume and temperature of a fixed amount of gas.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Boyle's law, Gay-Lussac's law, and Charles' law are all derived from this by holding a variable constant. Again temperature must be in Kelvins and units must match!

Mathematical Computation: Combined Gas Law #1

- **A sample of oxygen gas occupies a volume of 0.250 liters at 22.0^{0}c and exerts a pressure of 750.0 mmHg. What volume will the gas occupy if the temperature drops to 5.0^{0}c and the pressure decreased to 0.950 atm?**

Mathematical Computation Combined Gas Law #2

- **A sample of nitrogen gas occupies a volume of 1.25 liters at 22.0^{0}c and a pressure of 790.0 mmHg. What volume will the gas occupy at S.T.P conditions?**

Dalton's Law of Partial Pressures

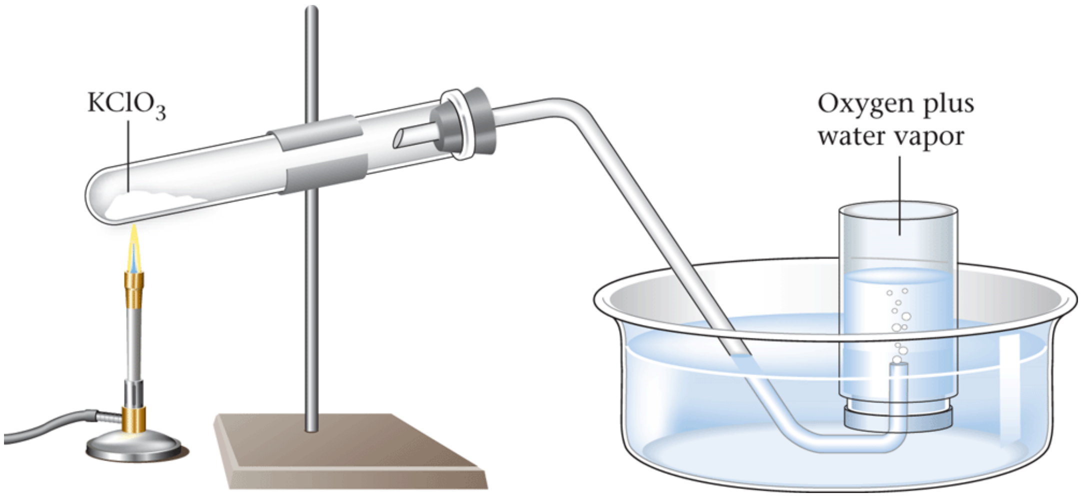
For a mixture of gases in a container, The total pressure is equal to the sum of the parts

$$P_{Total} = P_1 + P_2 + P_3 + \ldots P_n$$

(This is particularly useful in calculating the pressure of gases collected over water. Water vapor exerts a particular pressure at particular temperature –water vapor chart)

B. Dalton’s Law of Partial Pressures

Collecting a gas over water



- Total pressure is the pressure of the gas + the vapor pressure of the water.

Collecting Hydrogen

Vapor Pressure at various temperatures:

T ^{0}c	P mmHg	T ^{0}c	P mmHg	T ^{0}c	P mmHg
0	4.58	32	37.0	70	233.7
5	6.54	35	42.2	80	355.1
10	9.21	37	47.07	90	525.8
15	12.79	40	55.3	100	760
20	17.54	45	73.9		
22	19.8	50	92.5		
25	23.76	55	121		
27	26.7	60	149.4		
30	31.8	65	192		

Mathematical Computations Daltons Law

- Three gases are in a rigid vessel at 25.0^{0}c. Neon exerts a pressure of 0.895 atm. Oxygen exerts a pressure of 777 mmHg. The third gas is water vapor. What pressure does the gauge on the vessel read in atm?

Dalton's Law Computation #2

- A sample of oxygen in a 1.0 liter vessel exerts a pressure of 0.55 atm. A sample of nitrogen in a 1.0 liter vessel exerts a pressure of 193 mmHg. If the gases were placed in the same vessel what would the pressure gauge read?

Computation #1:
EVERYTHING TOGETHER! Combined and Daltons

- 355 ml of oxygen gas was collected by water displacement in the decomposition of potassium chlorate. During the experiment, the temperature was recorded as 25.0^{0}c and the pressure was recorded as 850.0 mmHg. What volume would the dry gas occupy at STP conditions?

Everything #2

- Zinc metal reacts with aqueous phosphoric acid releasing hydrogen gas. 12.0 ml of hydrogen was collected at 22.0^{0}c and 1.25 atm. If the dry gas was cooled to 20.0^{0}c and the pressure decreased to 780.0 mmHg, what volume would the dry gas occupy?

Everything # 3

- **25.0 ml of hydrogen gas was collected over water from the reaction of magnesium with hydrochloric acid. The pressure during the reaction was recorded to be 787 mmHg and the temperature was 30.0^{0}c. What volume would the sample of dry hydrogen gas occupy at S.T.P. conditions?**

Ideal Gases

Ideal gases are imaginary gases that perfectly fit all of the assumptions of the kinetic molecular theory.

- Gases consist of tiny particles that are far apart relative to their size.

- Collisions between gas particles and between particles and the walls of the container are elastic collisions

- No kinetic energy is lost in elastic collisions

Ideal Gases (continued)

- Gas particles are in constant, rapid motion. They therefore possess kinetic energy, the energy of motion
- There are no forces of attraction between gas particles
- The average kinetic energy of gas particles depends on temperature, not on the identity of the particle.

Real Gases Do Not Behave Ideally

Real gases DO experience inter-molecular attractions

Real gases DO have volume

Real gases DO NOT have elastic collisions

Deviations from Ideal Behavior

Likely to behave nearly ideally	*Likely not to behave ideally*
Conditions: Gases at high temperature and low pressure	Conditions: Gases at low temperature and high pressure
Charateristics: Small symmetrical non-polar gas molecules	Characteristics Large, non-symmetrical polar gas molecules