GASES

- Gases differ from the other two phases of matter in many ways:

  - They have very low viscosity (resistance to flow), so they flow from one place to another very easily.

  - They will take the volume of their container. In other words, gas volumes are variable.

  - They are the least dense of all three phases.

  - Most gases are transparent, and many are invisible.

  thermal expansion!

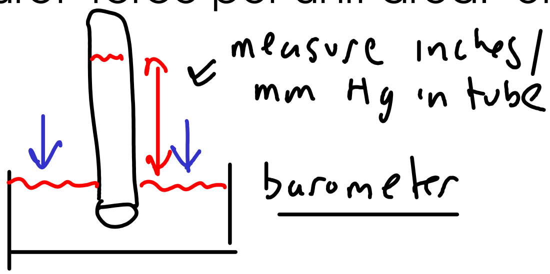
  - Gases show a much larger change of volume on heating or cooling than the other phases.

  - Gases react to changes in temperature and pressure in a very similar way. This reaction often does not depend on what the gas is actually made of.

KINETIC THEORY

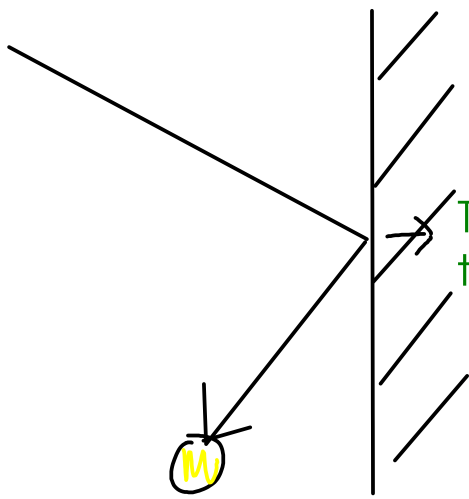
- is a way to explain the behavior of gases.
- views the properties of gases as arising from them being molecules in motion.

- Pressure: force per unit area. Units: Pascal, bar, mm Hg, in Hg, atm, etc.



760 mm Hg = 1 atm

- According to kinetic theory, pressure is caused by collisions of gas molecules with each other and the walls of the container the gas is in.



This collision exerts a force on the wall!

135- Temperature:

- a measure of the average kinetic energy of the molecules of the gas

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

(m = mass, v = velocity)

- The faster the gas molecules move, the higher the temperature!

- The temperature scales used when working with gases are ABSOLUTE scales.

- ABSOLUTE: scales which have no values less than zero.

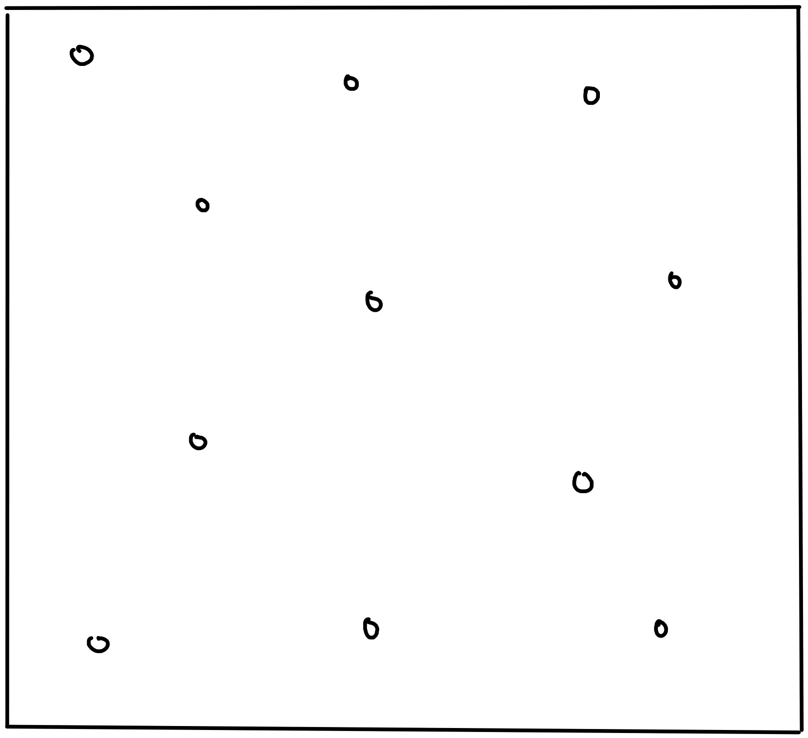
- KELVIN: metric absolute temperature scale.

$$K = 273.15 + {}^{\circ}C$$

Quick comparison of temperature scales!

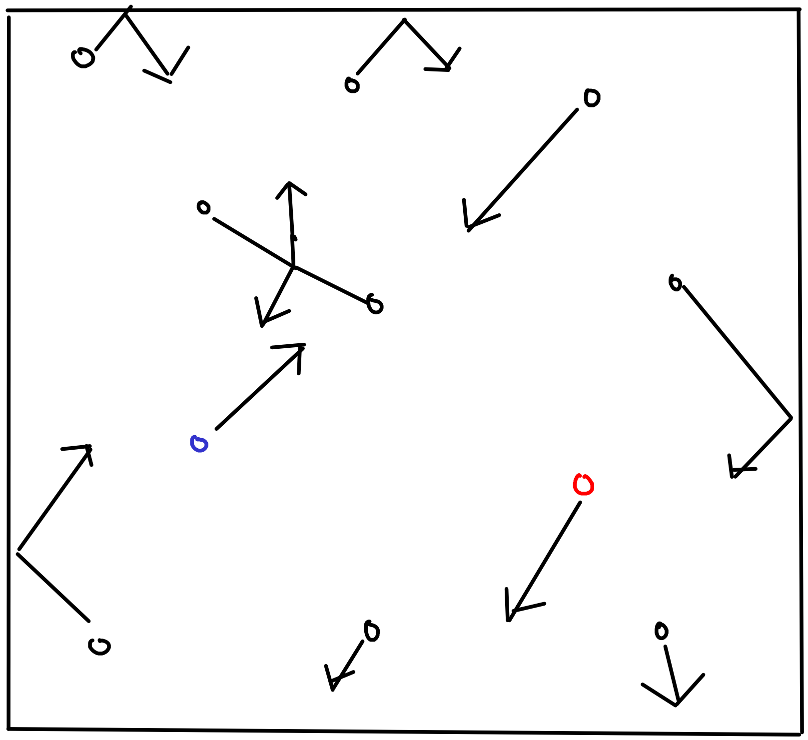
212	100	373	Water boils
77	25	298	Room temperature
32	0	273	Water freezes
-460	-273	0	Absolute zero!
°F	°C	K	

THE KINETIC PICTURE OF GASES



LOW DENSITY!

(1) Gas molecules are small compared to the space between the gas molecules!



(2) Gas molecules are constantly in motion. They move in straight lines in random directions and with various speeds.

(3) Attractive and repulsive forces between gas molecules are so small that they can be neglected except in a collision.

- Each gas molecule behaves independently of the others.

(4) Collisions between gas molecules and each other or the walls are ELASTIC.

(5) The average kinetic energy of gas molecules is proportional to the absolute temperature.

How does this picture explain the properties of gases?

- Gases expanding to fill their container? Agrees with kinetic picture, since gas molecules are independent
- Thermal expansion of gas at constant pressure? Agrees, because the container has to EXPAND to keep the pressure (from collisions) constant when the gas molecules move faster.
- Pressure increases with temperature at constant volume: Agrees, because the number and force of collisions increases with molecular speed.

GAS LAWS

- were derived by experiment long before kinetic theory, but agree with the kinetic picture!

Boyle's Law:

$$PV = \text{constant}$$

True at constant temperature

$$P_1V_1 = \text{constant} \qquad P_2V_2 = \text{constant}$$

$$\boxed{P_1V_1 = P_2V_2}$$

True at constant temperature

Charles's Law:

$$\frac{V}{T} = \text{constant}$$

True at constant pressure, and using ABSOLUTE temperature

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

True at constant pressure, and using ABSOLUTE temperature

Combined gas law:

$$\frac{PV}{T} = \text{constant}$$

Must use ABSOLUTE temperature units!

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

Must use ABSOLUTE temperature units!

↑ amount (moles) of gas must be constant!

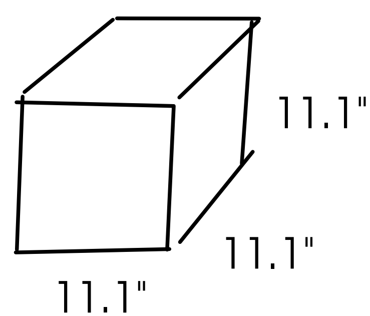
Avogadro's law:

- a mole of any gas at the same conditions has the same volume.

1 mol gas molecules @ 0°C and 1 atm

"STP"
Standard Temperature and Pressure

volume = 22.4 L



= 22.4 L

Ideal gas law:

$$\frac{PV}{T} = \text{constant}$$

... but this constant actually depends on the amount of gas!

$$= n \times \text{"}R\text{"}$$

The ideal gas constant.

$$0.08206 \ \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

... combining these together ...

$$\frac{PV}{T} = nR$$

$$PV = nRT$$

P = pressure atm

V = volume L

T = ABSOLUTE temperature K

R = ideal gas constant

n = number of moles of gas molecules

A balloon is taken from a room where the temperature is 27.0 C to a freezer where the temperature is -5.0 C. If the balloon has a volume of 3.5 L in the 27.0 C room, what is the volume of the balloon in the freezer. Assume pressure is constant.

$$\frac{P_1V_1}{T} = \frac{P_2V_2}{T_2} \xrightarrow{\text{const } P} \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$V_1 = 3.5\,L$

$T_1 = 27.0°C = 300.2\,K$

$V_2 = ?$

$T_2 = -5.0°C = 268.2\,K$

$$\frac{(3.5\,L)}{(300.2\,K)} = \frac{V_2}{(268.2\,K)}$$

$$\boxed{3.1\,L} = V_2$$

2.25 L of nitrogen gas is trapped in a piston at 25.0 C and 1.00 atm pressure. If the piston is pushed in so that the gas's volume is 1.00 L while the temperature increases to 31.0 C, what is the pressure of the gas in the piston?

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

$P_1 = 1.00\,atm$

$V_1 = 2.25\,L$

$T_1 = 25.0°C = 298.2\,K$

$P_2 = ?$

$V_2 = 1.00\,L$

$T_2 = 31.0°C = 304.2\,K$

$$\frac{(1.00\,atm)(2.25\,L)}{298.2\,K} = \frac{P_2(1.00\,L)}{304.2\,K}$$

$$\boxed{2.30\,atm = P_2}$$

Calculate the mass of 22650* L of oxygen gas at 25.0 C and 1.18 atm pressure.

↖ O_2

*Volume of a 10'x10'x8' room

O_2: 32.00 g O_2 = mol O_2

1 - Calculate MOLES of oxygen gas using IDEAL GAS EQUATION

2 - Convert moles oxygen gas to mass using FORMULA WEIGHT.

$PV = nRT$

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

$P = 1.18\ atm$ $\quad R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

$V = 22650L$ $\quad T = 25.0°C = 298.2K$

(1) $n_{O_2} = \frac{(1.18\ atm)(22650\ L)}{(0.08206 \frac{L \cdot atm}{mol \cdot K})(298.2\ K)} = 1092.222357\ mol\ O_2$

(2) 32.00 g O_2 = mol O_2

$1092.222357\ mol\ O_2 \times \frac{32.00\ g\ O_2}{mol\ O_2} = \boxed{35\bar{0}00\ g\ O_2}$

35.0 kg

~77 lb

CHEMICAL CALCULATIONS WITH THE GAS LAWS

$FW_{NaHCO_3} = 84.007\ g/mol$

$$H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow 2H_2O(l) + 2CO_2(g) + Na_2SO_4(aq)$$

Given 25.0 g of sodium bicarbonate and sufficient sulfuric acid, what volume of carbon dioxide gas would be produced at 25.0 C and 0.950 atm pressure?

1 - Convert 25.0 grams sodium bicarbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium bicarbonate to moles carbon dioxide. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide to volume. Use IDEAL GAS EQUATION.

(1) $84.007\ g\ NaHCO_3 = mol\ NaHCO_3$ (2) $2\ mol\ NaHCO_3 = 2\ mol\ CO_2$

$$25.0\ g\ NaHCO_3 \times \frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3} \times \frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3} = 0.2975942481\ mol\ CO_2$$

(1) (2)

(3) $PV = nRT$

$$V = \frac{nRT}{P}$$

$n = 0.2975942481\ mol\ CO_2$

$R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$T = 25.0°C = 298.2\ K$

$P = 0.950\ atm$

$$V = \frac{(0.2975942481\ mol\ CO_2)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{0.950\ atm}$$

$$= 7.67\ L\ of\ CO_2\ @\ 25.0°C,\ 0.950\ atm$$

What volume would the gas in the last example problem have at STP?

STP: "Standard Temperature and Pressure" (0 C and 1 atm)

Since STP is just another set of conditions for the same gas, we can use the combined gas law.

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

$P_1 = 0.950$ atm $\quad P_2 = 1$ atm

$V_1 = 7.67$ L $\quad V_2 = ?$

$T_1 = 298.2$ K $\quad T_2 = 0°C = 273.2$ K

$$\frac{(0.950\text{ atm})(7.67\text{ L})}{298.2\text{ K}} = \frac{(1\text{ atm})(V_2)}{273.2\text{ K}}$$

6.67 L @ STP = V_2

Alternate solution: We already calculated moles of gas. So we can just use the ideal gas equation again:

$$V = \frac{nRT}{P}$$

$n = 0.2975942481$ mol CO_2 $\quad T = 273.2$ K

$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$ $\quad P = 1$ atm

$$V = \frac{(0.2975942481\text{ mol }CO_2)(0.08206\frac{L\cdot atm}{mol\cdot K})(273.2\text{ K})}{(1\text{ atm})} = 6.67\text{ L @ STP}$$