OXIDATION / REDUCTION CHEMISTRY

- Exchange reactions involve ions pairing up, but the ions themseves are not formed in exchange reactions. Exchanges start with pre-existing ions.

... but the ions have to be produced somehow - through a chemistry that involves the transfer of electrons.

- oxidation / reduction chemistry ("redox" chemistry) involves transfer of electrons and can make ions.

$$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s)$$

Elemental, metallic aluminum. Uncharged!

Al^0

Aluminum cation

Al^{3+}

These are called "half-reactions"

$$Al \rightarrow Al^{3+} + 3e^-$$

electron

oxidation: loss of electrons

$$Br_2 + 2e^- \rightarrow 2Br^-$$

reduction: gain of electrons

- oxidation and reduction always occur together. In other words, we can't just make free electrons using oxidation without giving them somewhere to go.

- Many of the five types of reactions that we learned about in previous courses are redox reactions!

  - Combinations (often but not always redox)

  - Decompositions (often redox)

  - Single replacement (always redox)

$$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$$

$$Cu \rightarrow Cu^{2+} + 2e^- \quad \text{oxidation}$$

$$2Ag^+ + 2e^- \rightarrow 2Ag(s) \quad \text{reduction}$$

$$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$$

  - Combustion

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$2Mg(s) \rightarrow 2Mg^{2+} + 4e^- \quad \text{oxidation}$$

$$O_2(g) + 4e^- \rightarrow 2O^{2-} \quad \text{reduction}$$

REDOX LANGUAGE

- "Exidation" is loss of electrons, but an OXIDIZING AGENT is something that causes ANOTHER substance to lose electrons. An oxidizing agent is itself reduced during a redox reaction.

- "Reduction" is gain of electrons, but a REDUCING AGENT is something that causes ANOTHER substace to gain electrons. Reducing agents are themselves oxidized during a redox reaction.

$$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s)$$

Aluminum is OXIDIZED during this process. We say that metallic aluminum is a REDUCING AGENT!

Bromine is REDUCED during this process. We say that bromine is an OXIDIZING AGENT!

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.
  - 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.

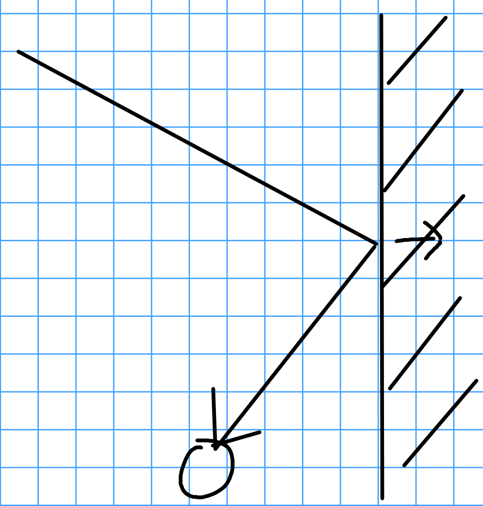
KINETIC THEORY

- 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

- caused by collisions of gas molecules with each other and the walls of the container the gas is in.



- Temperature:

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

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

velocity

mass

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

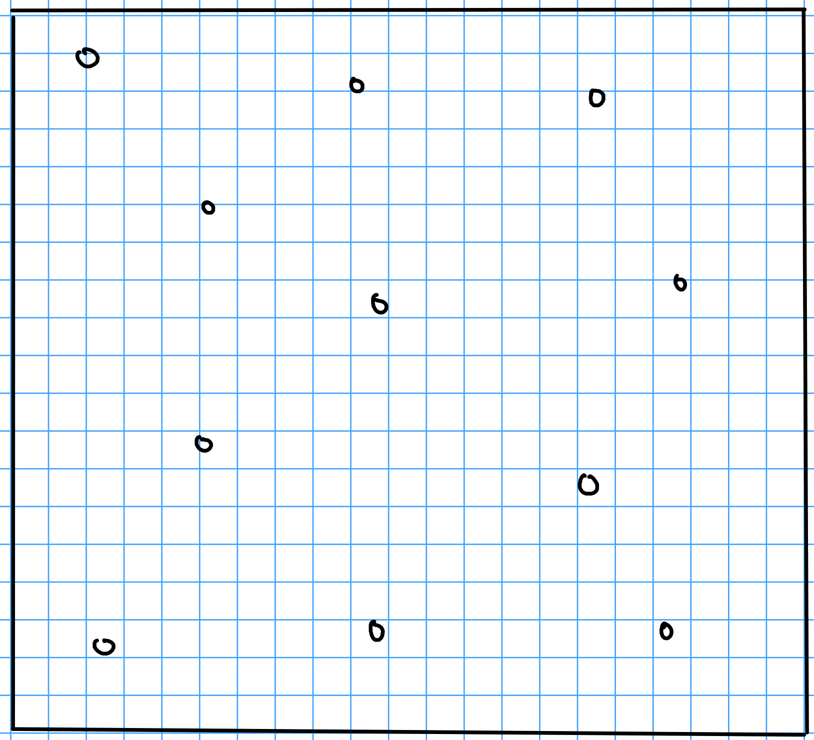
- The temperature scales used when working with gases are ABSOLUTE scales.

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

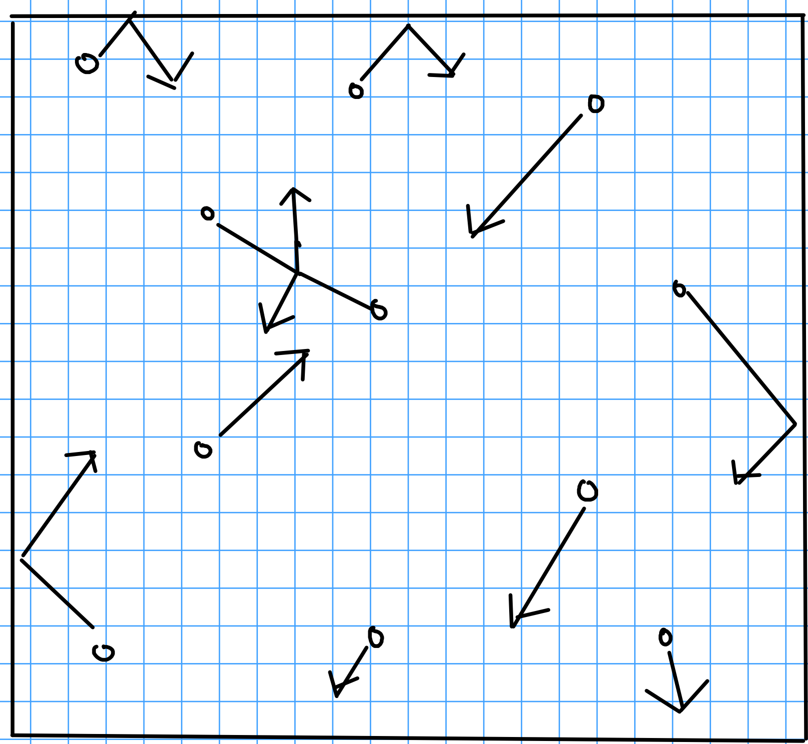
    - KELVIN: metric absolute temperature scale.

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

THE KINETIC PICTURE OF GASES



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!

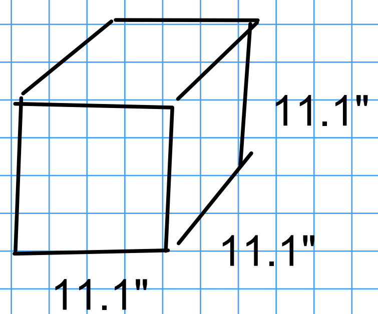
Avogadro's law:

- 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.

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

... combining this together ...

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

$$\boxed{PV = nRT}$$

P = pressure

V = volume

T = ABSOLUTE temperature

R = ideal gas constant

n = number of moles of gas molecules

CHEMICAL CALCULATIONS WITH THE GAS LAWS

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

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?

7,66 L

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

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

$T = 25,0\,^\circ C = 298.15\,K$

$P = 0,950\ atm$

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

$n = ?$

$$25,0\,g\ NaHCO_3 \times \frac{mol}{84.007\,g} \times \frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3} = 0,29759\ mol$$

$$V = \frac{(0,29759)(0,08206)(298.15)}{(0,950)} = \boxed{7.66\,L}$$

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

STP: 0°C, 1 atm

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

$P_1 = 0.950$ atm $P_2 = 1$ atm

$V_1 = 7.66$ L $V_2 = ?$

$T_1 = 298.15$ K $T_2 = 273.15$ K

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(0.950)(7.66)(273.15)}{(298.15)(1)} = \boxed{6.67 \text{ L}}$$

$$2\,NH_4NO_3(s) \longrightarrow 2\,N_2(g) + O_2(g) + 4\,H_2O(g)$$

At 300 C, ammonium nitrate violently decomposes to produce nitrogen gas, oxygen gas, and water vapor. What is the total volume of gas that would be produced at 1.00 atm by the decomposition of 15.0 grams of ammonium nitrate?

30.85 L

$$FW_{NH_4NO_3} = 80.0434\ g/mol$$

Find the moles of gas produced...

$$2\ mol\ NH_4NO_3 = 2\,N_2,\ 1\,O_2,\ 4\,H_2O$$

$$2\ mol\ NH_4NO_3 = 7\ mol\ gas$$

$$15.0\ g\ NH_4NO_3 \times \frac{mol}{80.0434\ g} \times \frac{7\ mol\ gas}{2\ mol\ NH_4NO_3} = 0.655894\ mol\ gas$$

$$V = \frac{nRT}{P} = \frac{(0.655894)(0.08206)(573.15)}{(1.00)} = \boxed{30.8\ L}$$