  $P_T = P_A + P_B = \frac{(n_A+n_B)RT}{V}$

  - Mole fraction $(X_i) = \frac{n_i}{n_T}$    $X_A = \frac{n_A}{n_A+n_B}$    $X_A + X_B = 1$

    $P_i = X_i P_T$
  - A sample of natural gas contains 8.24 moles of $CH_4$, 0.421 moles of $C_2H_6$ and 0.116 moles of $C_3H_8$. If the total pressure of the gases is 1.37 atm, what is the partial pressure of propane ($C_3H_8$)?
    - $P_{C_3H_8} = X_{C_3H_8} P_T$

      $X_{C_3H_8} = \frac{0.116\ mol}{(8.24+0.42+0.116)\ mol} = 0.0132$

      $P_{C_3H_8} = (0.0132)(1.37\ atm) = 0.0181\ atm$
  - Dry air, which is made up of 21.0% oxygen, 78.0% nitrogen, and less than 0.9% argon by volume has a total pressure of 790. mmHg. What is the partial pressure of each gas?
    - $P_{O_2} = 0.210(790.\ mmHg) = 166\ mmHg$

      $P_{N_2} = 0.780(790.\ mmHg) = 616\ mmHg$

      $P_{Ar} = 0.009(790.\ mmHg) = 7\ mmHg$

- Hydrogen gas is generated when Ca reacts with water. The hydrogen gas is collected <u>over water</u> at 30℃ and 988 mmHg pressure. The volume of gas collected was 641 mL.
  - What is the mass of hydrogen obtained? The pressure of water vapor is 31.82 mmHg at 30℃.
  - How much Ca (in g) must have reacted?

Part 1:

$$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$$

$$P_{H_2} = P_T - P_{H_2O} = (988 - 31.82)mmHg = 956\ mmHg$$

$$956\ mmHg * \frac{1\ atm}{760\ mmHg} = 1.26\ atm$$

$$T = (30 + 273.15)K = 303\ K$$

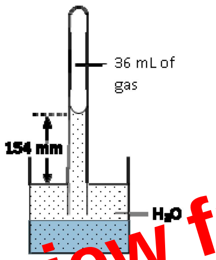
$$n_{H_2} = \frac{PV}{RT} = \frac{(1.26\ atm)(0.641\ L)}{(0.08206\ \frac{L*atm}{mol*K})(303\ K)} = 0.0325\ mol$$

$$0.0325\ mol\ H_2 * \frac{2.016\ g\ H_2}{mol\ H_2} = 0.0655\ g\ H_2$$

Part 2:

$$0.0325\ mol\ H_2 * \frac{mol\ Ca}{mol\ H_2} * \frac{40.08\ g\ Ca}{mol\ Ca} = 1.30\ g\ Ca$$

- Unequal Pressures
  - Density Hg = 13.6 g/mL
  - Density water = 1.00 g/mL
  - 1 mmHg = 13.6 $mmH_2O$
  - Example: What is the pressure of the gas in the drawing if T=22℃ and $P_{atm}$ = 743.7 mmHg?



$$P_{gas} = P_{atm} - P_{H_2O} - P_{height\ difference}$$

$$P_h = 154\ mmH_2O * \frac{1\ mmHg}{13.6\ mmH_2O} = 11.3\ mmHg$$

$$P_{gas} = (743.7 - 19.5 - 11.3)mmHg = 712.9\ mmHg$$

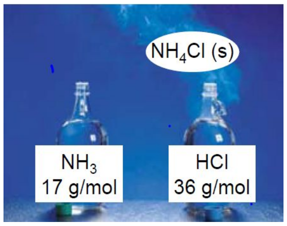
- Kinetic molecular theory of gases - explains the behavior of gases that act ideally.
  1. $V_{gas\ particle}$ << (much less than) space between particles (particles have negligible volume)
  2. Particles are in constant random motion. Collisions are perfectly elastic (the total kinetic energy remains constant)
  3. Gas particles exert no forces on one another.
  4. Average kinetic energy of particles is proportional to temperature in Kelvins (same T = same avg KE but different speeds)
     a. $KE = \frac{1}{2}m(\uparrow)v^2(\downarrow)\ \alpha\ T$

        Example: 1 mol He and 1 mol Ne at 273 K

        → same KE

→ He is faster

- Maxwell Speed Distribution Curves
    - At higher temperatures, more molecules are moving faster
- Diffusion - the gradual mixing of molecules of one gas with molecules of another by virtue of their kinetic properties.
    - Region of higher concentration → Region of lower concentration
    - Lighter gas will diffuse faster than a heavier gas
    - $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$ r = rate of diffusion



- $\frac{r_{NH_3}}{r_{HCl}} = \sqrt{\frac{M_{HCl}}{M_{NH_3}}} = \sqrt{\frac{36\ g/mol}{17\ g/mol}} = 1.46 = 1.5$
    - $r_{NH_3} = 1.5\ r_{HCl}\ or\ \frac{3}{2}\ r_{HCl}$
    - $r_{HCl} = \frac{2}{3}\ r_{NH_3}$

- Graham's law of effusion
    - Effusion - gas under pressure escapes into another area by passing through a small opening.
    - Effusion of mixture of 2 gases:

      $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$ r = rate of effusion (same as diffusion)
    - $\frac{r_{NH_3}}{r_{O_2}} = \sqrt{\frac{32\ g/mol}{17\ g/mol}} = 1.37 = 1.4$

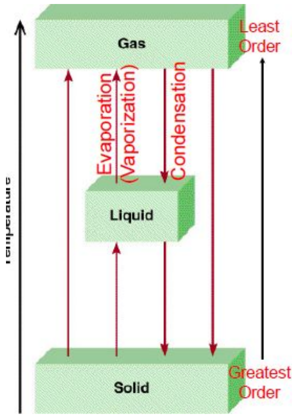
      $r_{NH_3} = 1.4\ r_{O_2}$

- If CO gas effuses at a rate that is 1.48 times that of an unknown gas under the same experimental conditions, what is the molar mass of the unknown gas?
    - $r_{CO} = 1.48\ r_X$

      $\frac{r_{CO}}{r_X} = (1.48)^2 = (\sqrt{\frac{M_X}{M_{CO}}})^2$

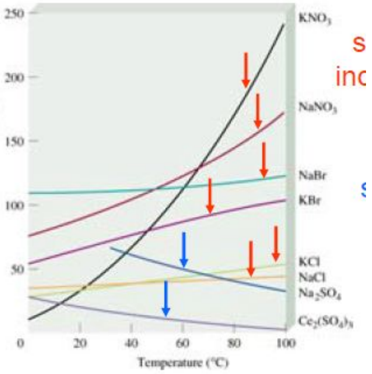
      $(1.48)^2 = \frac{M_X}{28.01\ g/mol}$

      $M_X = 61.4\ g/mol$

- Water is a unique substance
  - Ice is less dense than water
- **Phase Changes from liquid to gas**
  - 

- Evaporation (Vaporization)
  - Liquids are constantly evaporating even when the temperature is less than the boiling point.
  - Dynamic Equilibrium
    - Rate of Condensation = Rate of Evaporation
- Equilibrium Vapor Pressure - partial pressure of a gas in dynamic equilibrium with its liquid.
- Boiling point - vapor pressure = atm pressure
- To figure which substance has stronger IMF,
  - Compare vapor pressures (at the same temperature)
  - Compare boiling points (at the same vapor pressure)

- Calculate the % weight of a solution that is 32.1 ppm benzene.
    - $\frac{32.1\ g\ benzene}{10^{6}\ g\ soln} * \frac{10^{-4}}{10^{-4}} \qquad \frac{g\ benzene}{100\ g\ soln}$
    - $\frac{3.21*10^{-3}\ g\ benzene}{100\ g\ soln} = 3.21 * 10^{-3}\%$

- Temperature and Solubility of Solids
    - Temperature dependence of solubility for several solid ionic compounds.
    - Solubility increases with increasing temp for most substances
    - 

- Temperature and Solubility of Gases
    - Solubility decreases with increasing temperature for ALL gases
        - Side note: solubility increases with increasing pressure for ALL gases.

**Lecture 5.25.17**

- Henry's Law - the solubility of a gas in a liquid is proportional to the pressure of the gas over the solution.
    - $c = kP$
    - c - concentration ( $M = \frac{mol}{L}$ ) of dissolved gas
    - P - partial pressure (atm) of gas over solution.
    - k - constant ( $\frac{mol}{L*atm}$ ) - depends only on temperature
- Practice using Henry's Law
    - What is the molality of oxygen in water at 25ºC for a partial pressure of 0.22 atm (Henry's law constant for oxygen is 1.3 x 10-3 mol/L·atm and density is the same as water).
        - $c = kP$

                - $\Delta P = (1 - 0.896)(42.18\ mmHg)$

                  $\Delta P = 4.39\ mmHg$
            - $\Delta P = P^0{}_1 - P_1$
                - $\Delta P = 42.18\ mmHg - 37.8\ mmHg$
                - $\Delta P = 4.4\ mmHg$

- Boiling Point Elevation
    - Lower vapor pressure → higher boiling point
    - More solute particles → greater increase in boiling point
    - $\Delta T_b = T_b - T^0{}_b$
        - Always positive.  Just take the larger - smaller.
        - $T^0{}_b - boiling\ point\ PURE\ solvent$
        - $T_b - boiling\ point\ SOLUTION$
        - $T_b > T^0{}_b \qquad \Delta T_b > 0$
        - $\Delta T_b = K_b m$
            - m - molality
            - $K_b$ - constant (°C/m) for solvent
- Freezing Point Depression
    - Freezing - disordered → ordered, remove energy
    - Solution is more disordered so need to remove more energy (freeze at a lower temperature)
    - The more solute particles → more disorder → greater the decrease in freezing point.
    - $\Delta T_f = T^0{}_f - T_f$
        - Always positive.
        - $T^0{}_f - freezing\ point\ PURE\ solvent$
        - $T_f - freezing\ point\ SOLUTION$
        - $T^0{}_f > T_f \qquad \Delta T_f > 0$
        - $\Delta T_f = K_f m$