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

At 300 ^{0}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?

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

To simplify this problem, realize that the volume will depend on the total moles of ALL gaseous products, so relate THAT to the moles of ammonium nitrate!

$$\underline{2+1+4}$$

$$80.0434\,g\ NH_4NO_3 = 1\,mol\ NH_4NO_3\ ,\quad 2\,mol\ NH_4NO_3 = 7\ mol\ gas$$

$$15.0\,g\ NH_4NO_3 \times \frac{1\,mol\ NH_4NO_3}{80.0434\,g\ NH_4NO_3} \times \frac{7\ mol\ gas}{2\,mol\ NH_4NO_3} =$$

$$0.65589\ mol\ gas = n \qquad T = 573\ K \qquad P = 1.00\ atm$$

$$V = \frac{nRT}{P} = \frac{(0.65589\ mol)\left(0.08206\ \frac{L \cdot atm}{mol\ K}\right)(573\ K)}{(1.00\ atm)}$$

$$\boxed{V = 30.8\ L}$$

REAL GASES

- The empirical gas laws (including the ideal gas equation) do not always apply.

    - The gas laws don't apply in situations where the assumptions made by kinetic theory are not valid.

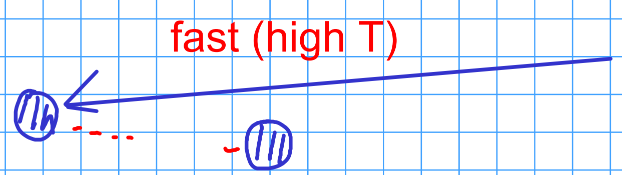
        - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

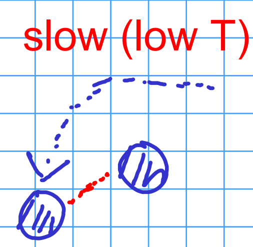
            - at high pressure, molecules would be much closer together!

        - When would it be FALSE that attractive and repulsive forces would be negligible?

            - at high pressure, attractions and repulsions should be stronger!

            - at low temperature, attractions and repulsions have a more significant affect on the paths of molecules





-The gas laws are highly inaccurate near the point where a gas changes to liquid!

- In general, the lower the pressure and the higher the temperature, the more IDEAL a gas behaves.

van der Waals equation

- an attempt to modify PV = nRT to account for several facts.
  - gas molecules actually have SIZE (they take up space)
  - attractive and repulsive forces

$$PV = nRT$$ Ideal gas equation

$$\left(P + \underbrace{\frac{n^2 a}{V^2}}_{\text{attempts to account for attractive / repulsive forces}}\right)\left(V - \underbrace{nb}_{\text{attempts to account for molecular size}}\right) = nRT$$ van der Waals equation

* "a" and "b" are experimentally determined parameters that are different for each gas. p211

He: $a = 0{,}0346$, $b = 0{,}0238$ tiny, no special attractive forces

H_2O: $a = 5.537$, $b = 0{,}03049$ small, but strong attractions between moleculres

CH_3CH_2OH: $a = 12.56$ $b = 0{,}08710$ larger, and strong attractions between molecules

Some more review problems:

Complete and balance these exchange reactions. Include phase labels. If no reaction occurs, write "NR".

$2K_3PO_4(aq) + 3MgCl_2(aq) \rightarrow 6KCl(aq) + Mg_3(PO_4)_2(s)$ ✓

K^+ PO_4^{3-} Mg^{2+} Cl^-

precipitation!

$2HCl(aq) + BaCO_3(s) \rightarrow H_2O(l) + CO_2(g) + BaCl_2(aq)$ ✓

H^+ Cl^- Ba^{2+} CO_3^{2-}

H_2CO_3

formation of gas from unstable molecule!

$FeSO_4(aq) + MgCl_2(aq) \rightarrow$ ~~$MgSO_4(aq) + FeCl_2(aq)$~~

Fe^{2+} SO_4^{2-} Mg^{2+} Cl^-

NR - NO REACTION!
Both ionic products are soluble.

base acid

$2NH_4OH(aq) + H_2SO_4(aq) \rightarrow 2H_2O(l) + (NH_4)_2SO_4(aq)$ ✓

NH_4^+ OH^- H^+ SO_4^{2-}

Neutralization! (formation of water by reaction of an acid and a base)

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

$\uparrow O_2$

*Volume of a 10'x10'x8' room

Calculate the number of moles of oxygen gas present using the ideal gas equation, then convert mass oxygen to moles using the formula weight.

$$PV = nRT$$

n ← # moles

$V = 22650\ L$

$P = 1.18\ atm$

$T = 298\ K \quad (25 + 273)$

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

$$n = \frac{PV}{RT} = \frac{(1.18\ atm)(22650\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol\ K}\right)(298\ K)}$$

$$= 1093\ mol\ O_2$$

$$1093\ mol\ O_2 \times \frac{32.00\ g\ O_2}{mol\ O_2} = 35\bar{0}00\ g\ O_2$$

$\boxed{35.0\ kg \quad \sim 77\ lb}$

$$2\,HCl + Na_2CO_3 \rightarrow CO_2 + H_2O + 2\,NaCl$$

If 48.90 mL of hydrochloric acid solution react with sodium carbonate to produce 125.0 mL of carbon dioxide gas at 0.950 atm and 290.2 K. What is the molar concentration of the acid?

We'll need to find the moles of carbon dioxide gas produced. Then, we will convert the moles of carbon dioxide to moles of hydrochloric acid. Finally, we'll calculate the concentration (molarity units) of the acid solution.

$$n_{CO_2} = \frac{PV}{RT} = \frac{(0.950\ atm)(0.1250\ L)}{\left(0.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(290.2\ K)} = 0.004986\ mol\ CO_2$$

Convert moles of carbon dioxide to moles of hydrochloric acid. Get the ratio from the chemical equation!

$$0.004986\ mol\ CO_2 \times \frac{2\ mol\ HCl}{1\ mol\ CO_2} = 0.009972\ mol\ HCl$$

Molarity is moles per liter, so divide the moles of acid by the volume of the solution (expressed in liters)

$$\frac{0.009972\ mol\ HCl}{0.04890\ L} = \boxed{0.2040\ \underline{M}\ HCl}$$