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?

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

① g bicarb → mol bicarb

② mol bicarb → mol CO_2

③ mol CO_2 → volume CO_2

① $84.007\,g\ NaHCO_3 = 1\ mol\ NaHCO_3$

② $2\ mol\ NaHCO_3 = 2\ mol\ CO_2$

$$25.0\,g\ NaHCO_3 \times \frac{1\ mol\ NaHCO_3}{84.007\,g\ NaHCO_3} \times \frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3} = 0.297594\ mol\ CO_2$$

We can relate this number of moles to volume using the ideal gas equation: PV=nRT

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

$P = 0.950\ atm$

$T = 25.0^\circ C = 298.2\ K$

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

$V = ???$

$n = 0.297594\ mol\ CO_2$

③ $$V = \frac{(0.297594\ mol\ CO_2)\left(0.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(298.2\ K)}{(0.950\ atm)} = \boxed{7.67\ L\ CO_2}$$

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

STP: 0°C, 1 atm

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

$P_1 = 0.950$ atm

$T_1 = 298.2$ K

$V_1 = 7.67$ L

$P_2 = 1.00$ atm

$T_2 = 273.2$ K

$V_2 = ???$

... so we can use the combined gas law here.

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

$$\frac{P_1 V_1 T_2}{T_1 P_2} = V_2 = \frac{(0.950 \text{ atm})(7.67 \text{ L})(273.2 \text{ K})}{(298.2 \text{ K})(1.00 \text{ atm})} =$$

$$V_2 = \boxed{6.68 \text{ L } CO_2 \text{ @STP}}$$

... since we had found out the number of moles in the last problem, we COULD have used the ideal gas law to solve this one, too!

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

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, lets start by calculating the TOTAL number of moles of gas.

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

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

1. g NH_4NO_3 → mol NH_4NO_3
2. mol NH_4NO_3 → mol gas
3. mol gas → volume gas

$$15.0\,g\ NH_4NO_3 \times \frac{mol\ NH_4NO_3}{80.0434\,g\ NH_4NO_3} \times \frac{7\ mol\ gas}{2\ mol\ NH_4NO_3} = 0.65584\ mol\ gas$$

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

$n = 0.65584\ mol$

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

$T = 300°C = 573K$

$P = 1.00\ atm$

$V = ???$

$$V = \frac{(0.65584\ mol)\left(0.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(573K)}{(1.00\ atm)} = \boxed{30.8\ L\ gas}$$

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?

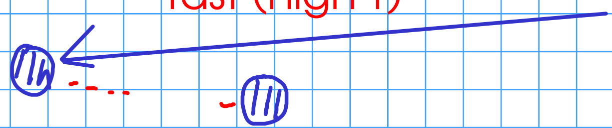
            - at high pressure, molecules would be much closer together!

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

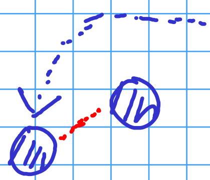
            - at high pressure, attractions and repulsions should be stronger!

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

fast (high T)



slow (low T)



-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.

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 molecules

CH_3CH_2OH: $a = 12.56$ $b = 0.08710$ larger, and strong attractions between molecules