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 g sodium bicarbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium bicarbonate to moles carbon dioxide gas. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide gas to VOLUME. Use IDEAL GAS EQUATION.

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

$$25.0\ g\ NaHCO_3 \times \underbrace{\frac{1\ mol\ NaHCO_3}{84.007\ g\ NaHCO_3}}_{①} \times \underbrace{\frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3}}_{②} = 0.297594248\ mol\ CO_2$$

③ $PV = nRT$

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

$n = 0.297594248\ mol\ CO_2$ $T = 25.0°C = 298.2\ K$

$R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$ $P = 0.950\ atm$

$$V = \frac{(0.297594248\ mol\ CO_2)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{(0.950\ atm)} = 7.67\ L\ CO_2\ at\ 25.0°C,\ 0.950\ atm$$

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

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

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

$P_1 = 0.950\ atm$ $\quad V_1 = 7.67\ L$ $\quad T_1 = 298.2K$

$P_2 = 1\ atm$ $\quad V_2 = ?$ $\quad T_2 = 0^\circ C = 273.2K$

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

$V_2 = 6.67\ L$ at STP

Alternate solution: Since we know the moles of gas (we found it in the solution to the previous problem), we can plug that number of moles into the ideal gas equation along with the P and T values of STP.

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

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?

Simplify by calculating TOTAL MOLES GAS instead of finding moles of each gas separately... $F_W\ NH_4NO_3 = 80.052\ g/mol$

1 - Convert 15.0 grams ammonium nitrate to moles. Use FORMULA WEIGHT.
2 - Convert moles ammonium nitrate to TOTAL MOLES GAS using CHEMICAL EQUATION.
3 - Convert TOTAL MOLES GAS to volume using IDEAL GAS EQUATION.

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① $80.052\ g\ NH_4NO_3 = 1\ mol\ NH_4NO_3$ ② $2\ mol\ NH_4NO_3 = 7\ mol\ gas$ $(2+1+4=7)$

$$15.0\ g\ NH_4NO_3 \times \frac{1\ mol\ NH_4NO_3}{80.052\ g\ NH_4NO_3} \times \frac{7\ mol\ gas}{2\ mol\ NH_4NO_3} = 0.655823714\ 6\ mol\ gas$$

(① ②)

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③ $PV = nRT$

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

$n = 0.655823714\ 6\ mol\ gas$ $\quad T = 300.°C = 573K$

$R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$ $\quad P = 1.00\ atm$

$$V = \frac{(0.655823714\ 6\ mol\ gas)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(573K)}{(1.00\ atm)} = 30.8L$$

at 300.°C, 1.00 atm

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

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$] van der Waals equation

$\frac{n^2 a}{V^2}$ attempts to account for attractive / repulsive forces

nb attempts to account for molecular size

* "a" and "b" are experimentally determined parameters that are different for each gas. p 208

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