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 grams sodium bicarbonate to moles using FORMULA WEIGHT.
2 - Convert moles sodium bicarbonate to moles carbon dioxide using CHEMICAL EQUATION
3- Convert moles carbon dioxide to volume using IDEAL GAS EQUATION

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

$$25.0\ g\ NaHCO_3 \times \underbrace{\frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3}}_{(1)} \times \underbrace{\frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3}}_{(2)} = 0.2975942481\ mol\ CO_2$$

$PV = nRT$

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

$n = 0.2975942481\ mol\ CO_2$ $\quad R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$T = 25.0°C = 298.2\ K$ $\quad P = 0.950\ atm$

$$V = \frac{(0.2975942481\ mol\ CO_2)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{(0.950\ atm)} =$$

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)

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

$P_1 = 0.950$ atm $\quad P_2 = 1$ atm

$V_1 = 7.67$ L $\quad V_2 = ?$

$T_1 = 298.2$ K $\quad T_2 = 273.2$ K

$$\frac{(0.950 \text{ atm})(7.67 \text{ L})}{(298.2 \text{ K})} = \frac{(1 \text{ atm})\, V_2}{(273.2 \text{ K})} \; ; \; V_2 = 6.68 \text{ L at STP}$$

Alternatively., we could use the ideal gas equation since we already know moles!

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

$n = 0.2975942481$ mol CO_2 $\quad R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

$T = 273.2$ K $\quad P = 1$ atm

$$V = \frac{(0.2975942481 \text{ mol } CO_2)\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(273.2 \text{ K})}{(1 \text{ atm})} = 6.67 \text{ L at STP}$$

the difference here is just roundoff error in the first calculation

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

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?

To simplify the problem, we'll calculate the TOTAL MOLES OF GAS instead of calculating the gas moles separately.

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

NH_4NO_3: 80.052 g NH_4NO_3 = mol NH_4NO_3

2 mol NH_4NO_3 = 7 mol gas (2+1+4)

① ②

$$15.0\,g\,NH_4NO_3 \times \frac{mol\,NH_4NO_3}{80.052\,g\,NH_4NO_3} \times \frac{7\,mol\,gas}{2\,mol\,NH_4NO_3} = 0.6558237146\,mol\,gas$$

③ $V = \frac{nRT}{P}$

$n = 0.6558237146$ mol gas $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

$T = 300.°C = 573\,K$ $P = 1.00$ atm

$$V = \frac{(0.6558237146\,mol\,gas)\left(0.08206\,\frac{L \cdot atm}{mol \cdot K}\right)(573\,K)}{(1.00\,atm)} = 30.8\,L$$

30.8 L gas 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.

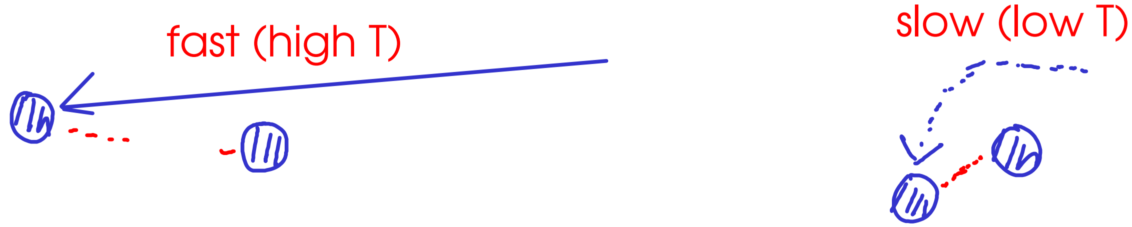
    - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

      - 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

nb: attempts to account for molecular size

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

* "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

$25\bar{0}0$ L of chlorine gas at 25.0 C and 1.00 atm are used to make hydrochloric acid. How many kilograms of hydrochloric acid could be produced if all the chlorine reacts?

$$H_2 + Cl_2 \rightarrow 2\,HCl$$

---

1 - Convert volume chlorine gas to moles using IDEAL GAS EQUATION
2 - Convert moles chlorine gas to moles HCl using chemical equation
3 - Convert moles HCl to mass using FORMULA WEIGHT.

① $PV = nRT$, $n = \frac{PV}{RT}$ | $P = 1.00$ atm, $V = 25\bar{0}0$ L, $T = 25.0°C = 298.2$ K, $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

$$n_{Cl_2} = \frac{(1.00\ atm)(25\bar{0}0\ L)}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)} = 102.164983\ mol\ Cl_2$$

mol Cl_2 = 2 mol HCl | HCl: 36.458 g HCl = mol HCl

$$102.164983\ mol\ Cl_2 \times \frac{2\ mol\ HCl}{mol\ Cl_2} \times \frac{36.458\ g\ HCl}{mol\ HCl} = 7450\ g\ HCl$$

We are asked for kilograms, so we'll do a quick unit conversion:

$$kg = 10^3\ g$$

$$7450\ g\ HCl \times \frac{kg}{10^3\ g} = \boxed{7.50\ kg\ HCl}$$