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 of sodium bicarbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium bicarbonate to moles carbon dioxide. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide to volume. Use IDEAL GAS EQUATION (PV=nRT)

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

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

(3) $PV = nRT$

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

$n = 0.2975942481\ mol\ CO_2$ $P = 0.950\ atm$

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

$T = 25.0°C = 298.2\ K$

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

$= 7.67\ L$ of CO_2 at $0.950\ atm$, $25.0°C$

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

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

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

$P_1 = 0.950$ atm, $P_2 = 1$ atm

$V_1 = 7.67$ L, $V_2 = ?$

$T_1 = 298.2$ K, $T_2 = 0°C = 273.2$ 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 = $ **6.67 L at STP**

Alternate solution ... use PV=nRT

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

$n = 0.2975942481$ mol CO_2, $T = 273.2$ K

$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$, $P = 1$ atm

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

$=$ **6.67 L at STP**

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.

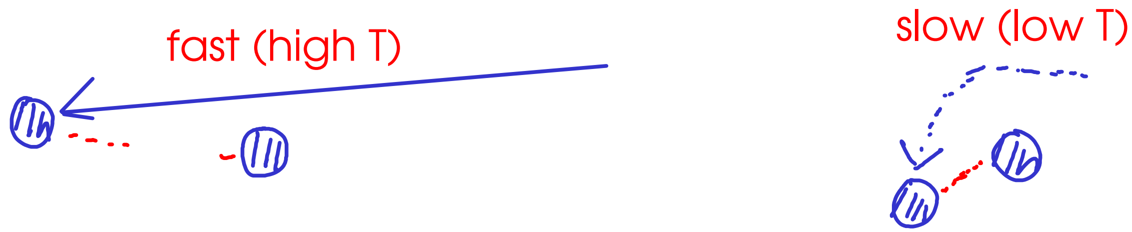
        - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

            - 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

2500 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 2500 L chlorine gas to moles. Use IDEAL GAS EQUATION, PV=nRT
2 - Convert moles chlorine gas to moles HCl. Use CHEMICAL EQUATION.
3 - Convert moles HCl to mass. Use FORMULA WEIGHT.

(1) $PV = nRT$ | $P = 1.00\ atm$ $\quad R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$n = \frac{PV}{RT}$ | $V = 2500\ L$ $\quad T = 25.0°C = 298.2\ K$

$$n_{Cl_2} = \frac{(1.00\ atm)(2500\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)} = 102.1646783\ mol\ Cl_2$$

(2) $1\ mol\ Cl_2 = 2\ mol\ HCl$

(3) HCl → H: 1 × 1.008
Cl: 1 × 35.45
36.458 g HCl = mol HCl

$$102.1646783\ mol\ Cl_2 \times \frac{2\ mol\ HCl}{mol\ Cl_2}\ (2) \times \frac{36.458\ g\ HCl}{mol\ HCl}\ (3) = 7450\ g\ HCl$$

Convert final answer to kg (specified in problem): $kg = 10^3\ g$

$$7450\ g \times \frac{kg}{10^3\ g} = \boxed{7.45\ kg\ HCl}$$