# 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. 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 $2\ mol\ NaHCO_3 = 2\ mol\ CO_2$

$$25.0\ g\ NaHCO_3 \times \frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3} \times \frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3} = 0.2975942481\ mol\ CO_2$$

3 $PV = nRT$ | $n = 0.2975942481\ mol\ CO_2$ $R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$V = \frac{nRT}{P}$ | $T = 25.0^\circ C = 298.2\ K$ $P = 0.950\ atm$

$$V = \frac{(0.2975942481\ mol\ CO_2)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)}{(0.950\ atm)} = \boxed{7.67\ L \text{ at } 25.0^\circ C,\ 0.950\ atm}$$

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

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

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Let's use the combined gas law:

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

$P_1 = 0.950 \text{ atm}$     $P_2 = 1 \text{ atm}$

$V_1 = 7.67 \text{ L}$     $V_2 = ?$

$T_1 = 298.2 \text{ K}$     $T_2 = 273.2 \text{ K}$

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

$$\boxed{\begin{array}{c}6.67 \text{ L} \\ \text{at STP}\end{array}} = V_2$$

Alternate solution: Use PV=nRT at STP to find the volume. We can do this since we already calculated 'n' for the last problem.

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

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 simolify the problem, let's calculate the TOTAL MOLES OF GAS instead of the individual moles.

FW $NH_4NO_3$ = 80.052 g/mol

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

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

$$15.0\text{ g } NH_4NO_3 \times \underbrace{\frac{\text{mol } NH_4NO_3}{80.052\text{ g } NH_4NO_3}}_{1} \times \underbrace{\frac{7\text{ mol gas}}{2\text{ mol } NH_4NO_3}}_{2} = 0.6558237146\text{ mol gas}$$

3 $V = \dfrac{nRT}{P}$ | $n = 0.6558237146$ mol gas $\quad R = 0.08206\ \dfrac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$

$T = 300.°C = 573\text{ K} \quad P = 1.00\text{ atm}$

$$V = \frac{(0.6558237146\text{ mol gas})\left(0.08206\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(573\text{ K})}{(1.00\text{ atm})} = \boxed{30.8\text{ L at } 300.°C,\ 1.00\text{ atm}}$$

# 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.

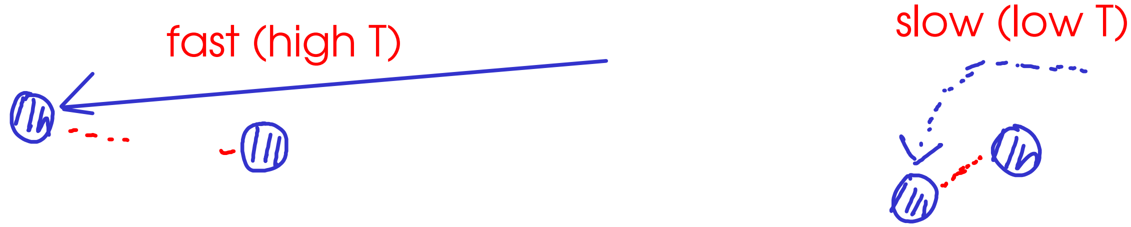
    - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

      - 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

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

attempts to account for molecular size

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