

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

$$PV = nRT \quad] \text{ Ideal gas equation}$$

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

attempts to account for attractive / repulsive forces

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

H₂O: $a = 5,537$, $b = 0,03049$ small, but strong attractions between molecules

CH₃CH₂OH: $a = 12,56$ $b = 0,08710$ 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?



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. (Also g \rightarrow kg)

$$\textcircled{1} \quad PV = nRT \quad \left| \quad P = 1.00 \text{ atm} \quad V = 2500 \text{ L} \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right.$$

$$n = \frac{PV}{RT} \quad \left| \quad T = 25.0^\circ\text{C} = 298.2 \text{ K} \right.$$

$$n_{\text{Cl}_2} = \frac{(1.00 \text{ atm})(2500 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 102.1646983 \text{ mol Cl}_2$$

$$\text{mol Cl}_2 = 2 \text{ mol HCl} \quad \left| \quad 36.458 \text{ g HCl} = \text{mol HCl} \quad \left| \quad \text{kg} = 10^3 \text{ g} \right. \right.$$

$$102.1646983 \text{ mol Cl}_2 \times \frac{2 \text{ mol HCl}}{\text{mol Cl}_2} \times \frac{36.458 \text{ g HCl}}{\text{mol HCl}} \times \frac{\text{kg}}{10^3 \text{ g}} = \boxed{7.45 \text{ kg HCl}}$$



If 48.90 mL of hydrochloric acid solution react with sodium carbonate to produce 125.0 mL of carbon dioxide gas at 0.950 atm and 290.2 K. What is the molar concentration of the acid?

We need to find M of HCl:

$$M_{\text{HCl}} = \frac{\text{mol HCl}}{\text{L solution}} \leftarrow 48.90 \text{ mL} = 0.04890 \text{ L}$$

- 1 - Convert 125.0 mL of carbon dioxide gas to moles using IDEAL GAS EQUATION
 - 2 - Convert moles carbon dioxide to moles HCl using CHEMICAL EQUATION
 - 3 - Calculate molarity of HCl by dividing moles HCl and volume HCl solution
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$$\textcircled{1} \quad n = \frac{PV}{RT} \quad \left| \quad \begin{array}{l} P = 0.950 \text{ atm} \quad V = 125.0 \text{ mL} = 0.1250 \text{ L} \\ R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \quad T = 290.2 \text{ K} \end{array} \right.$$

$$n_{\text{CO}_2} = \frac{(0.950 \text{ atm})(0.1250 \text{ L})}{(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(290.2 \text{ K})} = 0.0049866019 \text{ mol CO}_2$$

$$\textcircled{2} \quad 2 \text{ mol HCl} = \text{mol CO}_2$$

$$0.0049866019 \text{ mol CO}_2 \times \frac{2 \text{ mol HCl}}{\text{mol CO}_2} = 0.0099732038 \text{ mol HCl}$$

$$\textcircled{3} \quad M_{\text{HCl}} = \frac{\text{mol HCl}}{\text{L solution}} = \frac{0.0099732038 \text{ mol HCl}}{0.04890 \text{ L}} = \boxed{0.204 \text{ M HCl}}$$