[146]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, 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) $PV = nRT$

$n = \frac{PV}{RT}$

$P = 1.00\ atm$

$V = 25\bar{0}0\ L$

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

$T = 25.0°C = 298.2\ K$

$$n_{Cl_2} = \frac{(1.00\ atm)(25\bar{0}0\ L)}{\left(0.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(298.2\ K)} = 102.164698\ mol\ Cl_2$$

$mol\ Cl_2 = 2\ mol\ HCl$ | $36.458\ g\ HCl = mol\ HCl$ | $kg = 10^3\ g$

(2) (3)

$$102.164698\ mol\ Cl_2 \times \frac{2\ mol\ HCl}{mol\ Cl_2} \times \frac{36.458\ g\ HCl}{mol\ HCl} \times \frac{kg}{10^3\ g} = 7.45\ kg\ HCl$$

Calculate the mass of 22650 L of oxygen gas at 25.0 C and 1.18 atm pressure.

← O_2

*Volume of a 10'x10'x8' room

$$PV = nRT$$

1 - Convert the volume of gas to moles using moles using IDEAL GAS EQUATION
2 - Convert moles gas to mass using FORMULA WEIGHT

$$n_{O_2} = \frac{PV}{RT}$$

$P = 1.18$ atm

$V = 22650$ L

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

$T = 25.0°C = 298.2$ K

$$n_{O_2} = \frac{(1.18 \text{ atm})(22650 \text{ L})}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2 \text{ K})} = 1092.222357 \text{ mol } O_2$$

O_2: 32.00 g O_2 = mol O_2

$$1092.222357 \text{ mol } O_2 \times \frac{32.00 \text{ g } O_2}{\text{mol } O_2} = 35\bar{0}00 \text{ g } O_2$$

35.0 kg

~77 lb

$$2\,HCl + Na_2CO_3 \rightarrow CO_2 + H_2O + 2\,NaCl$$

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: $M_{HCl} = \frac{\text{mol HCl}}{\text{L solution}}$ ← 48.90 mL = 0.04890 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 / volume solution

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(1) $n = \frac{PV}{RT}$ | P = 0.950 atm, $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$, V = 125.0 mL = 0.1250 L, T = 290.2 K

$$n_{CO_2} = \frac{(0.950\ atm)(0.1250\ L)}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(290.2\ K)} = 0.004986019\ mol\ CO_2$$

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2 mol HCl = mol CO_2 (2)

$$0.004986019\ mol\ CO_2 \times \frac{2\ mol\ HCl}{mol\ CO_2} = 0.009972038\ mol\ HCl$$

(3) $$M_{HCl} = \frac{\text{mol HCl}}{\text{L solution}} = \frac{0.009972038\ mol\ HCl}{0.04890\ L} = \boxed{0.204\ M\ HCl}$$

A balloon is taken from a room where the temperature is 27.0 C to a freezer where the temperature is -5.0 C. If the balloon has a volume of 3.5 L in the 27.0 C room, what is the volume of the balloon in the freezer. Assume pressure is constant.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$$ since pressure is constant!

$V_1 = 3.5\,L$

$T_1 = 27.0°C = 300.2\,K$

$V_2 = ?\,L$

$T_2 = -5.0°C = 268.2\,K$

$$\frac{3.5\,L}{300.2\,K} = \frac{V_2}{268.2\,K}$$

$V_2 = $ **3.1 L in freezer**

2.25 L of nitrogen gas is trapped in a piston at 25.0 C and 1.00 atm pressure. If the piston is pushed in so that the gas's volume is 1.00 L while the temperature increases to 31.0 C, what is the pressure of the gas in the piston?

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

$P_1 = 1.00\,atm$ $T_1 = 25.0°C = 298.2\,K$

$V_1 = 2.25\,L$

$P_2 = ?$ $V_2 = 1.00\,L$ $T_2 = 31.0°C = 304.2\,K$

$$\frac{(1.00\,atm)(2.25\,L)}{(298.2\,K)} = \frac{P_2(1.00\,L)}{(304.2\,K)};\ P_2 = 2.30\,atm$$