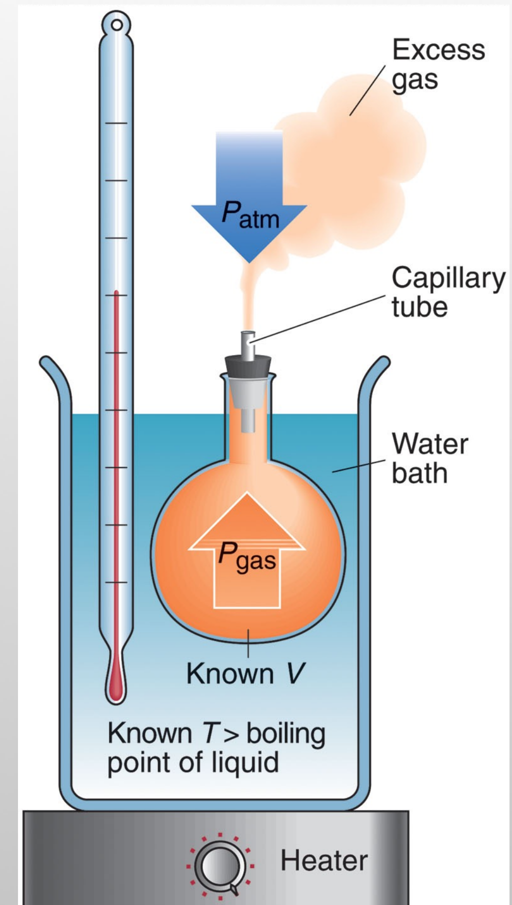
Molar Mass of Gases

Determination of the molar mass of a unknown volatile liquid

Based upon the method of J.B.A Dumas (1800 – 1884)



Volume of flask: 213 mL

mass of flask + gas = 78.416 g

mass of flask: 77.834 g

P = 754 torr

T = 100 °C

$$m = 78.416\,g - 77.834\,g = 0.582\,g$$

$$T(K) = 100\,°C + 273 = 373\,K$$

$$P = 754\,torr \cdot \frac{1\,atm}{760\,torr} = 0.992\,atm$$

$$V(L) = 213\,mL \cdot \frac{1\,L}{1000\,mL} = 0.213\,L$$

$$PV = nRT \Rightarrow n = \frac{PV}{RT} \Rightarrow \frac{m}{M} = \frac{PV}{RT} \Rightarrow M = \frac{mRT}{PV}$$

$$M = \frac{0.582\,g \cdot 0.0821\,\frac{L\,atm}{mol\,K} \cdot 373\,K}{0.992\,atm \cdot 0.213\,L} = 84.4\,g/mol$$

Partial Pressure of an Ideal Gas in a Mixture

The partial pressure of an ideal gas in a mixture is equal to the pressure it would exert if it occupied the same volume at the same temperature

$$P_a = n_a \frac{RT}{V} \qquad P_b = n_b \frac{RT}{V} \qquad P_c = n_c \frac{RT}{V}$$

Dalton's Law of Partial Pressures

"The sum of all partial pressures of the components in a gas mixture must equal the total pressure"

$$P_{total} = P_a + P_b + P_c + \ldots$$

$$P_{total} = P_a + P_b + P_c \ldots$$

$$= n_a \frac{RT}{V} + n_b \frac{RT}{V} + n_c \frac{RT}{V} \ldots$$

$$= (n_a + n_b + n_c + \ldots) \frac{RT}{V}$$

$$= n_{total} \frac{RT}{V}$$

Since $P_A = n_a \dfrac{RT}{V}$

$$\frac{P_A}{P_{total}} = \frac{n_a\,(\cancel{RT/V})}{n_{tot.}\,(\cancel{RT/V})} = \frac{n_a}{n_{total}}$$

Mole Fraction

"The number of moles n_a of a component A in a mixture divided by the total number of moles n_{total} is the mole fraction X_a."

$$X_a = \frac{n_a}{n_{total}}$$

The sum of all mole fractions is equal to 1

$$X_{total} = X_a + X_b + X_c + \ldots$$

$$X_{total} = \frac{n_a}{n_{total}} + \frac{n_b}{n_{total}} + \frac{n_c}{n_{total}} + \ldots$$

$$X_{total} = \frac{(n_a + n_b + n_c + \ldots)}{n_{total}} = 1$$

two component mixture:

$X_A = 0.3$

$x_A + x_B = 1$

$\Rightarrow x_B = 1 - 0.3$
$= 0.7$

$x_A = 0.15 \quad x_B = 0.25 \quad x_C =$

$x_C = 1 - 0.15 - 0.25 = 0.60$

$$\frac{P_A}{P_{total}} = \frac{n_a}{n_{total}} \Rightarrow P_A = P_{total} \cdot \frac{n_a}{n_{total}} \Rightarrow P_A = x_A P_{total}$$

For gases, the mole fraction is equal to its % by volume divided by 100%.

Air has 78% N_2

$$P_{N_2} = \underbrace{\frac{78\%}{100\%}}_{X_{N_2}} \cdot 1.00 \text{ atm} = 0.78 \text{ atm}$$

"Artificial Atmosphere" 79 mol% N_2; 17 mol% $^{16}O_2$ and 4.0% mol $^{18}O_2$ (measured). The total 0.75 atm. Calculate the mol fraction and partial pressure of $^{18}O_2$ in the mixture.

a). $X_{^{18}O_2} = \frac{4.0 \text{ mol\%}}{100 \text{ mol\%}} = 0.040$

$P_{^{18}O_2} = 0.040 \cdot 0.75 \text{ atm} = 0.030 \text{ atm}$

The partial pressure of oxygen was observed to 156 torr in air with a pressure of 743 torr
Calculate the mole fraction of O_2

$$P_{O_2} = X_{O_2} \cdot P_{total}$$

$$X_{O_2} = \frac{P_{O_2}}{P_{total}} = \frac{156 \text{ torr}}{743 \text{ torr}} = 0.210$$

A 12.5L scuba diving tank contains helium-oxygen mixture made up of 24.2g of He and 4.32g of O_2 at 298K. Calculate the mole fraction and partial pressure of each component in the mixture and the total pressure of the mixture.

$$n(He) = 24.2g \cdot \frac{1 mol}{4.00 g} = 6.05 mol$$

$$n(O_2) = 4.32g \cdot \frac{1 mol}{32.00 g} = 0.135 mol$$

$$X_{He} = \frac{6.05 mol}{6.05 mol + 0.135 mol} = 0.978$$

$$X_{O_2} = \frac{0.135 mol}{6.05 mol + 0.135 mol} = 0.0218$$

$$X_{O_2} = 1 - X_{He} = 1 - 0.978 = 0.0218$$

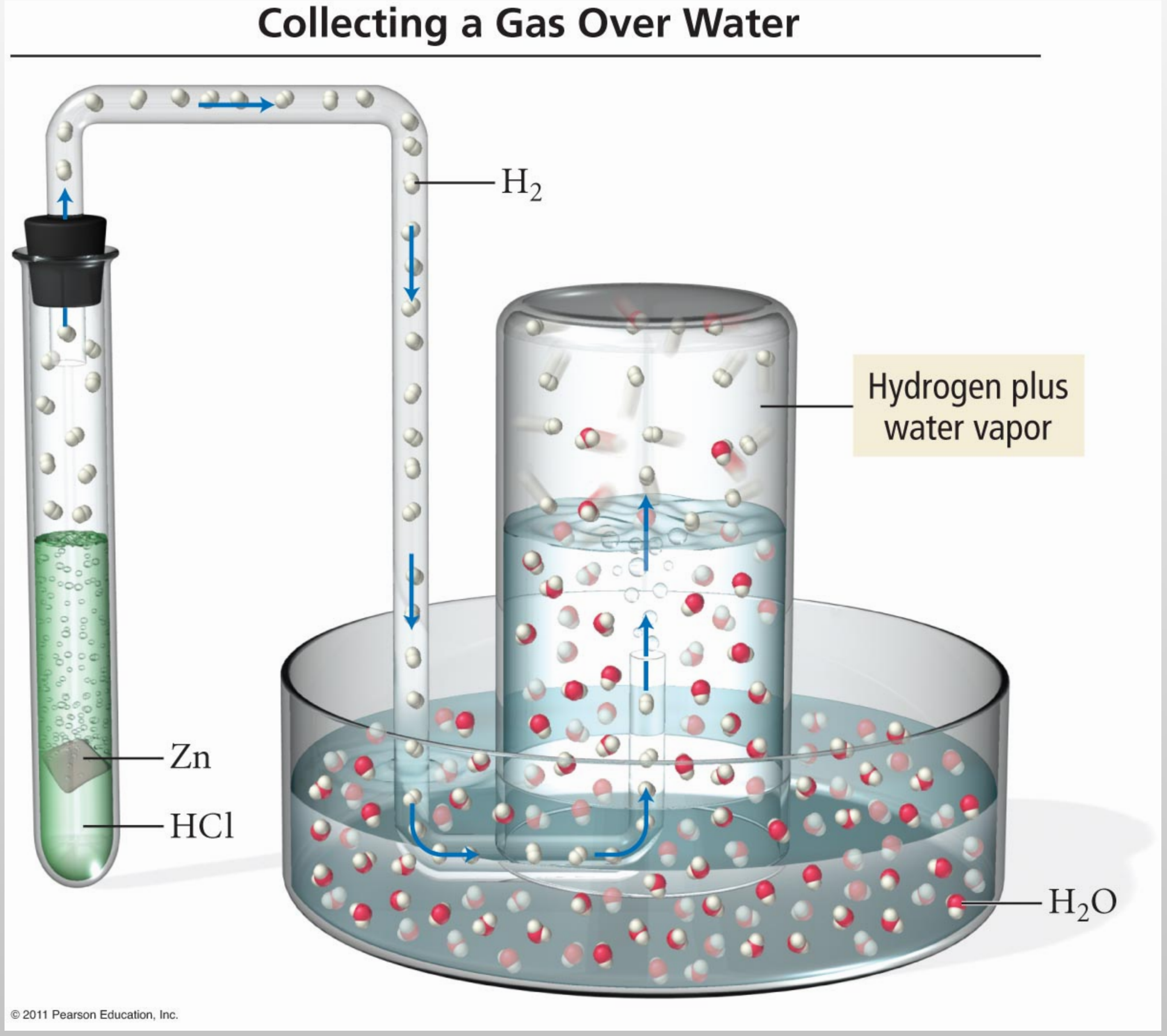
$$PV = nRT \Rightarrow P_{total} = \frac{[n(He) + n(O_2)] \cdot 0.0821 \frac{L\,atm}{mol\,K} \cdot 298K}{12.5L}$$

$$P_{total} = 12.1\ atm$$

$$P_{He} = X_{He} P_{total} = 0.978 \cdot 12.1\ atm = 11.8\ atm$$

$$P_{O_2} = X_{O_2} P_{total} = 0.0218 \cdot 12.1\ atm = 0.264\ atm$$

Collecting a Gas over Water



$$Zn(s) + 2HCl \longrightarrow ZnCl_2 + H_2$$

$$CaC_2(s) + 2H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2$$

For a sample of acetylene collected over water the total pressure is 738 torr and the volume is 523 mL. At the temp. of the gas (23°C) the water vapor pressure is 21 torr. How many grams C_2H_2 are obtained?

$$P_{total} = P_{C_2H_2} + P_{H_2O} \Rightarrow P_{C_2H_2} = P_{total} - P_{H_2O}$$

$$= 738\text{ torr} - 21\text{ torr} = 717\text{ torr}$$

$$= 717\text{ torr} \cdot \frac{1\text{ atm}}{760\text{ torr}} = 0.943\text{ atm}$$

$V = 0.523\text{ L}$ $T = 296\text{ K}$

$$n = \frac{PV}{RT} = \frac{0.943\text{ atm} \cdot 0.523\text{ L}}{0.0821\frac{\text{L atm}}{\text{mol K}} \cdot 296\text{ K}} = 0.0203\text{ mol}$$

$$\Rightarrow 0.529\text{ g } C_2H_2$$