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

ideal gas law.

Density + Molar Mass

$d = m/V$, Molar mass $= \frac{\# g}{\# mol} = \frac{m}{n} = \mathcal{M}$

$n = \frac{m}{\mathcal{M}}$

$pV = nRT$

$pV = \frac{m}{\mathcal{M}} \cdot RT$ $\left(\times \mathcal{M} \atop \div V \right)$

$p\mathcal{M} = \frac{m}{V} \cdot RT$

$$\boxed{p\mathcal{M} = dRT}$$

ex: What's d of $CO_2(g)$ @ 25°C + 1.50 atm?

(25°C +273.15 = 298.15 K)

$\frac{p\mathcal{M}}{RT} = \frac{dRT}{RT}$ ⤳ $d = \frac{p\mathcal{M}}{RT} = \frac{1.50\,atm \times 44.01\,g/mol}{0.08206 \frac{atm \cdot L}{mol \cdot K} \times 298\,K}$

$d = 2.70\ g/L$

CO_2

1 × 12.01

2 × 16.00

$\mathcal{M} = 44.01\ g/mol$

What's $\mathcal{M}$ if gas has $d = 2.23\text{ g/L}$ @ 12.5 atm and 0°C

$$\frac{P\mathcal{M}}{P} = \frac{dRT}{P} \Rightarrow \mathcal{M} = \frac{dRT}{P}$$

$$\Rightarrow \mathcal{M} = \frac{2.23\text{ g/L} \times 0.08206 \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 273\text{ K}}{12.5\text{ atm}}$$

$$= 4.00\text{ g/mol} \quad (He(g))$$

Mixtures of gases

Air: $N_2(g)$, $O_2(g)$, $Ar(g)$

each gas in a mixture is assigned a PARTIAL PRESSURE

$$\boxed{P_{TOT} = P_{N_2} + P_{O_2} + P_{Ar}}$$ Dalton's law of partial pressures.

right now, P_{TOT} = 1 atm = 760 mmHg

x
×

$$P_A = x_A \cdot P_{TOT}$$

P_A: pp of A

x_A: mol fraction of A

P_{TOT}: tot. pressure

$$x_A = \frac{n_A}{n_A + n_B + n_C + \ldots}$$

or $x_A = \frac{n_A}{n_{TOT}}$

Air, $P_{TOT} = 760\,mmHg$

$x_{N_2} = 0.78$, $x_{O_2} = 0.21$, $x_{Ar} = 0.01$

$P_{N_2} = 0.78 \times 760\,mmHg = 592.8\,mmHg$ $P_{O_2} = 0.21 \times 760\,mmHg = 159.6\,mmHg$ $P_{Ar} = 0.01 \times 760\,mmHg = 7.6\,mmHg$

sum to 760 mmHg

$CH_4(g)$, $Ar(g)$ — $P_{TOT} = 580\,mmHg$

mass of $CH_4 = 18.5g$

$P_{CH_4} = 420\,mmHg$.

Q: What's P_{Ar}, n_{Ar}?

$n_{CH_4} = 18.5g\,CH_4 \times \frac{1\,mol\,CH_4}{16.04g\,CH_4} = 1.15\,mol\,CH_4$

✓ ✓ ?

$P_{TOT} = P_{CH_4} + P_{Ar} \rightsquigarrow P_{Ar} = P_{TOT} - P_{CH_4} = 580\,mmHg - 420\,mmHg = 160\,mmHg$

✓ ? ✓

$P_{Ar} = x_{Ar} \cdot P_{TOT} \Rightarrow x_{Ar} = \frac{P_{Ar}}{P_{TOT}} = \frac{160\,mmHg}{580\,mmHg} = 0.28$

✓ ?

$x_{Ar} = \frac{n_{Ar}}{n_{TOT}} = \frac{n_{Ar}}{n_{Ar} + n_{CH_4}}$ (? ✓)

$0.28 = \frac{n_{Ar}}{n_{Ar} + 1.15\,mol} \rightsquigarrow 0.28(n_{Ar} + 1.15\,mol) = n_{Ar}$

$\Rightarrow 0.28 n_{Ar} + 0.32\,mol = n_{Ar}$

$-0.28 n_{Ar} \qquad -0.28 n_{Ar}$

$\Rightarrow 0.32\,mol = 0.72 n_{Ar}$

$\dfrac{0.32\,mol}{0.72} = \dfrac{0.72 n_{Ar}}{0.72}$

$\Rightarrow \boxed{n_{Ar} = 0.44\,mol}$

$x_{Ar} = \dfrac{n_{Ar}}{n_{Ar} + n_{CH_4}} = \dfrac{0.44\,mol}{0.44\,mol + \sout{0.28\,mol}\ 1.15\,mol} = \sout{0.6}\ 0.28$ ✓

Gas Stoichiometry

mol ⟷ mol (coefficients)

g ⟷ mol (molar masses)

mol ⟷ L (molarity)

V ⟷ mol (gas law!)

ex: What's vol. of $H_2(g)$ needed to ~~syneth~~ synthesize 37.8g of NH_3 @ 8700. mmHg and 183°C

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

$37.8\,g\ NH_3 \xrightarrow[NH_3]{\text{molar mass}} ?\ mol\ NH_3 \xrightarrow{\text{coefficients}} ?\ mol\ H_2$

$?\ mol\ H_2 \xrightarrow{PV=nRT} \text{vol. of } H_2$