Example 3.3-2

A Solution contains 15% A by mass ($x_A = 0.15$) and 20 mole % B ($y_B = 0.2$)

⇒ 1. Calc. mass of A in 175 kg of solution.

$$\frac{175 \text{ kg soln}}{} \bigg| \frac{0.15 \text{ kg A}}{\text{kg soln}} = 26 \text{ kg A}$$

2. Calc. mass flow rate of A in a stream of solution flowing at a rate of 53 lbm/hr.

$$\frac{53 \text{ lb}_m \text{ soln}}{\text{hr}} \bigg| \frac{0.15 \text{ lb}_m \text{ A}}{\text{lb}_m \text{ soln}} = 8.0 \ \text{lb}_m \text{ A}/\text{hr}$$

3. Calc. molar flow rate of B in a stream flowing at a rate of 1000 mol/min.

$$\frac{1000 \text{ mol soln}}{\text{min}} \bigg| \frac{0.2 \text{ mol B}}{\text{mol soln}} = 200 \ \text{mol B}/\text{min}$$

4. Calc. total soln flow rate corresponding to a flowrate of 28 $\frac{\text{kmole B}}{\text{sec}}$

$$\frac{28 \text{ kmole B}}{\text{sec}} \bigg| \frac{\text{kmole Soln}}{0.2 \text{ kmole B}} = 140 \ \text{kmole soln}/\text{sec}$$

5. Calc. the mass of soln that contains 300 lbm of A.

$$\frac{300 \text{ lb}_m \text{ A}}{} \bigg| \frac{\text{lb}_m \text{ soln}}{0.15 \text{ lb}_m \text{ A}} = 2000 \ \text{lb}_m \text{ soln}$$

Important Point:

The numerical value of a mass or mole fraction does not depend on the mass units in the numerator or denominator as long as these units are the same. (i.e. $x_A = 0.15 \Rightarrow 0.15 \ \text{kg A}/\text{kg soln}$ & $0.15 \ \frac{\text{lb}_m \text{ A}}{\text{lb}_m \text{ soln}}$)

Conversion from Mass Composition to Molar Composition

I'll motivate this section with an example and, then, follow up with a procedure:

Example: A gas mixture has the following mass composition:

O_2	16%	($X_{O_2} = 0.16$ gm O_2 / gm total)
CO	4.0%	
CO_2	17%	
N_2	63%	

What is the molar composition?

⇒ To do this we need to assume some amount of the mixture to serve as the basis for our calculations.

Basis: 100 gms of the mixture

⇒ Doing this type of conversion calculation in tabular form makes it easier.

i	X_i	Mass m_i (g)	(g/gmole) M.W.	Moles (gmole) $n_i = m_i / M.W.$	Mole Fraction $y_i = n_i / n_{total}$
O_2	0.16	16	32	0.500	0.152
CO	0.04	4	28	0.143	0.044
CO_2	0.17	17	44	0.386	0.118
N_2	0.63	63	28	2.250	0.686
	1.00	100		3.279	1.000

PROCEDURE: (Mass to Mole Fraction Conversion)

1. Assume a basis of calculation (e.g. 100 g of mixture).
2. Calc. Mass of each species (from x_i & Basis)
3. Calc. Moles of each species (from m_i & MW)
4. Calc. mole fraction of each species ($y_i = n_i / n_{total}$).

NOTE: The procedure's similar for converting from mole fractions to mass fractions except your basis will be in moles rather than mass units.

Average Molecular Weight of a Mixture

This quantity, defined as $\bar{M}$ is the ratio of a mixture's total mass to its total number of moles.

$$\bar{M} = \frac{\text{total sample mass}}{\text{total sample moles}}$$

$$\bar{M} = \sum_{\substack{\text{all} \\ \text{components}}} \underbrace{y_i}_{\text{mole fractions}} \underbrace{M_i}_{\text{molecular weight}} \quad \text{or} \quad \frac{1}{\bar{M}} = \sum_{\substack{\text{all} \\ \text{components}}} \frac{\overbrace{x_i}^{\text{mass fractions}}}{\underbrace{M_i}_{\text{molecular weight}}}$$

Example: Calculate the average molecular weight of air from its approximate molar composition of 79% N_2 & 21% O_2.

$$\bar{M} = y_{N_2} M_{N_2} + y_{O_2} M_{O_2}$$

$$= \frac{0.79 \text{ kgmole } N_2}{\text{kgmole total}} \bigg| \frac{28 \text{ kg } N_2}{\text{kgmole } N_2} + \frac{0.21 \text{ kgmole } O_2}{\text{kgmole total}} \bigg| \frac{32 \text{ kg } O_2}{\text{kgmole } O_2}$$

$$= 28.84 \text{ kg total} / \text{kgmole total}$$

Concentration

Mass Concentration - mass of the component per unit volume of the mixture (g/cm^3, lb_m/ft^3, etc).

Molar Concentration - moles of the component per unit volume of the mixture ($gmole/cm^3$, $kgmole/m^3$, $lbmole/ft^3$).

Molarity - molar concentration of the solute expressed in gmoles solute/Liter soln.

⟹ A substance's concentration in a mixture can be used as a conversion factor between the component's mass/moles and its solution volume.

Example 1: Given 5 liters of a 0.02 gmole/L solution of NaOH, how many moles NaOH are contained in the solution?

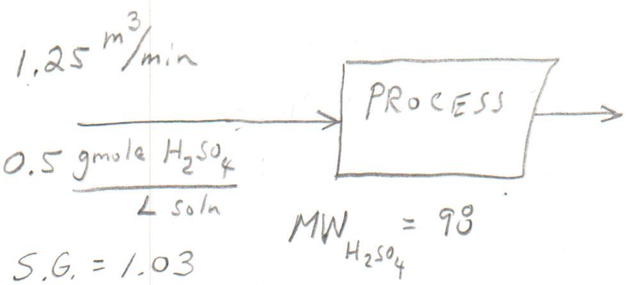
Volume: 5L   Concentration: 0.02 gmole NaOH/L

$$\text{gmole NaOH} = \frac{0.02 \text{ gmole NaOH}}{\text{L soln}} \bigg| \frac{5 \text{ L soln}}{} = 0.1 \text{ gmole NaOH}$$

Example 2: If a stream of this soln flows at a rate of 2 L/min, what is the molar flow rate of NaOH?

$$\frac{2 \text{ L soln}}{\text{min}} \bigg| \frac{0.02 \text{ gmole NaOH}}{\text{L soln}} = 0,04 \text{ gmole NaOH}/\text{min}$$

Example 3.3-5 (p. 52)



Calculate:

1. Mass conc. H_2SO_4 in kg/m^3.
2. Mass flowrate H_2SO_4 in kg/s.
3. Mass fraction H_2SO_4.

1. Want kg H_2SO_4 / m^3 soln

$$\frac{0.5 \text{ gmole } H_2SO_4}{L \text{ soln}} \Bigg| \frac{98 \text{ gm } H_2SO_4}{\text{gmole } H_2SO_4} \Bigg| \frac{kg}{1000 \text{ gm}} \Bigg| \frac{10^3 L}{m^3} = \underline{49 \text{ kg } H_2SO_4 / m^3 \text{ soln}}$$

2. Want kg H_2SO_4 / s

$$\frac{1.25 \, m^3}{min} \Bigg| \frac{min}{60 \text{ sec}} \Bigg| \frac{49 \text{ kg } H_2SO_4}{m^3 \text{ soln}} = \underline{1.02 \text{ kg } H_2SO_4 / sec}$$

3. Want kg H_2SO_4 / kg soln.

$$\rho_{soln} = (1.03)(1000 \, kg/m^3) = 1030 \text{ kg soln}/m^3 \text{ soln}$$

$$X_{H_2SO_4} = \frac{49 \text{ kg } H_2SO_4}{m^3 \text{ soln}} \Bigg| \frac{m^3 \text{ soln}}{1030 \text{ kg soln}} = 0.048 \frac{\text{kg } H_2SO_4}{\text{kg soln}}$$

NOTE: You could also determine the mass fraction by taking the ratio of the H_2SO_4 flowrate (kg H_2SO_4/sec) to the total soln flowrate (kg soln/sec).