AXIOM 5

[LECTURE-12][continued]

89] Axiom 5 : mass of individual components in a multi-component mixture is conserved

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Mass Transfer

NOTE: If the overall mixture itself is moved across a region

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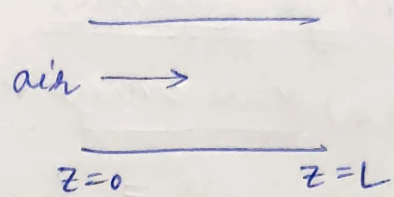
that is

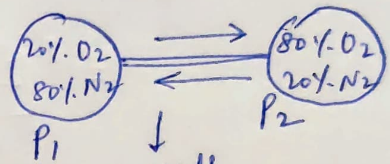
Bulk mass transport



But when we talk of mass transport

↓

it is about transport of components



For $P_1 = P_2 \Rightarrow$ overall no bulk transport is occuring

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but O_2 and N_2 will move (thus mass transport is occuring)

But if $P_1 >> P_2$

⇓

Both bulk as well as mass transport will occur

90] Notation

different components (n in total)

	1	2	3	4	...	n
Velocities	$\underline{v}_1$	$\underline{v}_2$	$\underline{v}_3$	$\underline{v}_4$	...	$\underline{v}_n$
Concentration						
a) Mass concentration	ρ_1	ρ_2	ρ_3	ρ_4	...	ρ_n
b) Molar Concentration	C_1	C_2	C_3	C_4	...	C_n

definition: $\rho_1 = \dfrac{\text{mass of component 1}}{\text{Total Volume}}$

↓

this is NOT density ⇒ (density will be if it was Vol^m of component 1)

Now, density of mixture $\Rightarrow \rho_{mix} = \rho = \dfrac{m_1 + m_2 + \ldots + m_n}{V}$

* (which is EQUAL to the mass concentration of the mixture)

$$= \rho_1 + \rho_2 + \rho_3 + \ldots + \rho_n$$

$$= \sum_{i=1}^{n} \rho_i$$

→ i.e. sum of mass conc.'s of components

91] Average velocities

(i) Mass average velocity

$$\underline{v} = \frac{\rho_1 \underline{v_1} + \rho_2 \underline{v_2} + \ldots + \rho_n \underline{v_n}}{\rho_1 + \rho_2 + \ldots + \rho_n}$$

$$= \frac{\sum \rho_i \underline{v_i}}{\sum \rho_i}$$

$$\Rightarrow \underline{v}\,[\rho_1 + \rho_2 + \ldots + \rho_n] = \sum \rho_i \underline{v_i}$$

$$\Rightarrow \underline{v}\,\rho = \sum \rho_i \underline{v_i}$$

this is the real velocity

↓

i.e. if we use an instrument to measure the velocity in the mixture

↓

it will give the value of mass avg. velocity

(ii) Molar average velocity

$$\underline{v}^* = \frac{c_1 \underline{v_1} + c_2 \underline{v_2} + \ldots + c_n \underline{v_n}}{c_1 + c_2 + \ldots + c_n}$$

Now, $c = c_1 + c_2 + c_3 + \ldots + c_n$

Thus, $c\,\underline{v}^* = \sum_i c_i \underline{v_i}$

92] **Fluxes**

	Mass Fluxes ($*$ (indicated by small letters))	**Molar Fluxes** (indicated by Capital letters)
1. Stationary observer	$\underline{n}_i = \rho_i \underline{v}_i$	$\underline{N}_i = c_i \underline{v}_i$
2. Observer moving with mass avg. velocity ($\underline{v}$)	$\underline{j}_i = \rho_i(\underline{v}_i - \underline{v})$	$\underline{J}_i = c_i(\underline{v}_i - \underline{v})$
3. Observer moving with molar avg. velocity ($\underline{v}^*$)	$\underline{j}_i^* = \rho_i(\underline{v}_i - \underline{v}^*)$	$\underline{J}_i^* = c_i(\underline{v}_i - \underline{v}^*)$

{ NOTE: 1 & 2 are most commonly used in mass fluxes

But 1 & 3 are most commonly used in molar fluxes }

93]

$$\rho_i = \frac{\text{mass of comp. } i}{\text{Total volume}} = \frac{m_i}{V}$$

$$c_i = \frac{\text{moles of comp. } i}{\text{Total volume}} = \frac{n_i}{V}$$

Now, we know: $\dfrac{m_i}{M_{w_i}} = n_i$ $\Rightarrow$ $\boxed{c_i = \dfrac{\rho_i}{M_{w_i}}}$

M_{w_i}: molecular weight of i

thus we can convert between c_i and ρ_i

94] **Relations between various fluxes**

Most important are:

(i) how $\underline{n}_i$ is related to $\underline{j}_i$

(ii) how $\underline{N}_i$ is related to $\underline{J}_i^*$

For (i): We know: $\underline{n}_i = \rho_i \underline{v}_i$, $\underline{j}_i = \rho_i(\underline{v}_i - \underline{v})$

Thus, $\underline{v}_i = \underline{v}_i - \underline{v} + \underline{v}$

Multiplying by ρ_i:

$$\rho_i \underline{v_i} = \rho_i(\underline{v_i} - \underline{v}) + \rho_i \underline{v}$$

$$\Rightarrow \underline{n_i} = \underline{j_i} + \rho_i \left(\frac{\sum \rho_i \underline{v_i}}{\rho} \right)$$

$$\Rightarrow \underline{n_i} = \underline{j_i} + \underbrace{\frac{\rho_i}{\rho}}_{\text{we call this } w_i} \sum \underline{n_i}$$

(weight fraction of comp. i) (or mass fraction)

$$\Rightarrow \boxed{\underline{n_i} = \underbrace{w_i \sum \underline{n_i}}_{\text{due to overall flux of mixture}} + \underbrace{\underline{j_i}}_{\text{diffusional flux}}}$$

diffusional flux → this is the part that is most imp. for us in mass transport

(it is what we discuss in fick's law)

Similarly, we will get:

$$\underline{N_i} = x_i \sum \underline{n_i} + \underline{J_i}^*$$

{ NOTES BEYOND THIS PORTION NOT TAKEN
(But they can be read on NPTEL) }