# Department of Chemical Engineering Thapar Institute of Engineering & Technology, Patiala

# Course: Material and Energy Balances UCH301

Course Instructor:

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# DEGREES OF FREEDOM FOR A PROCESS

# Analysis of Degrees of Freedom

- Identify What is expected from solving the problem
- determine the number of degrees of freedom so that the additional information that is required may be obtained

# Degrees of Freedom

- Identify the equations , and decide which equations are to be used if there are redundant equations

- Solve N independent equations for N variables

- Retain in memory the implicit constraints in a problem (What are these constraints?)

- For a given problem there may be (i)no solution, (ii) there may be number of solutions, and (iii) there may be a unique solution

(i) $N_d > 0$; (ii) $N_d < 0$; (iii) $N_d = 0$

- First two situations are not satisfactory and tells you that the problem is not properly posed. Third situation tells you that the problem is properly specified

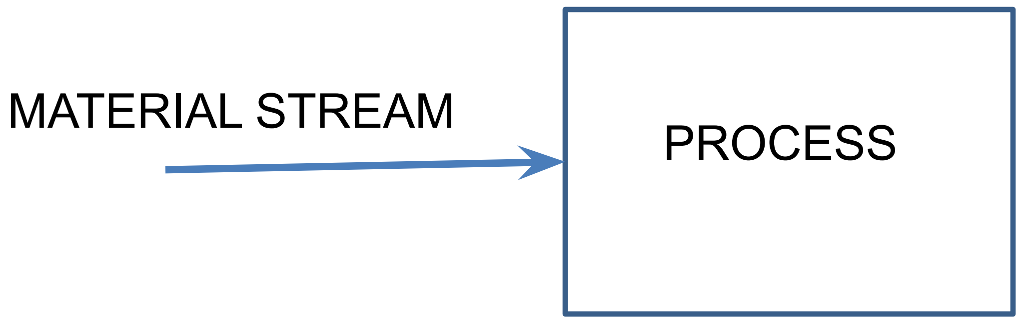
- For a unique solution the necessary condition is that the number of unknown variables is equal to the number of independent equations/relations

- Usually, in a material balance problem the number of independent material balances equals the number of components involved

- If Mass flow rate of a stream is F, & there can be several components in material stream as we have seen while solving material balances, then $m_i$ can be denoted as mass flow rate of component *i* in that material stream

- The mass/mole flow of a component in a stream may me expressed as $m_i/n_i$, if $w_i$ and $x_i$ are mass and mol fractions and F and M are total mass and mole flows, then

$$m_i = w_i F \quad \& \; n_i = x_i M$$




- In a mixture of N components, N+2 number of stream variables exists (N-1 compositions, 1 total flow, 1 T, and 1 P)

- These variables are either N values of $m_i$ or $n_i$, as the case may be, or N-1 values of $x_i$, and the stream flow F (or M), and *T, P*

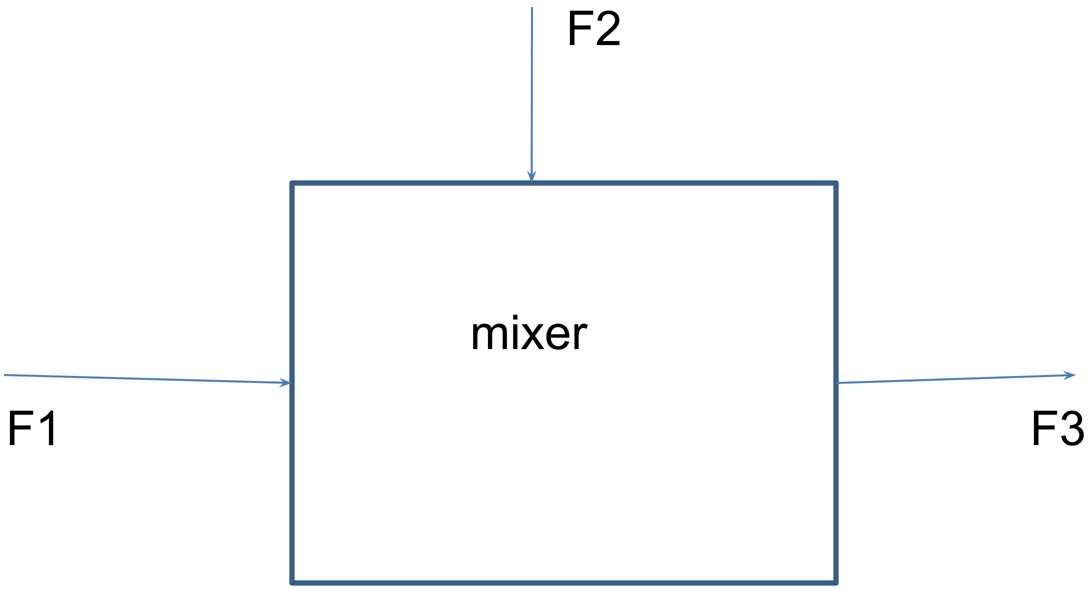

- Let us say that material stream is of Air, now you know that Air has $O_2$ and $N_2$, i.e. two components.
- I have two ways of specifying the data; One: I provide you the amounts of moles of $O_2$ entering and moles of $N_2$ entering, Two: I provide you the Total moles of Air entering and composition of any one component in air.

- N-1 mass fraction values are the only independent relation as the implicit constraint $\sum w_i = 1.0$, fixes the value of the $N^{th}$ mass fraction.

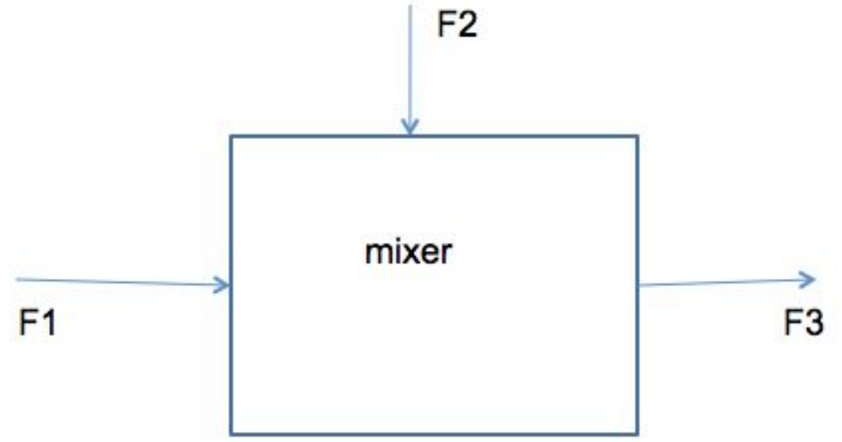
- So for completely specifying a material stream, the number of variables needed are:

$$\mathbf{N_{sp} + 2} \qquad (N_{sp} \text{ is used for number of species})$$

# Degree of freedom for a mixer



# Degree of Freedom



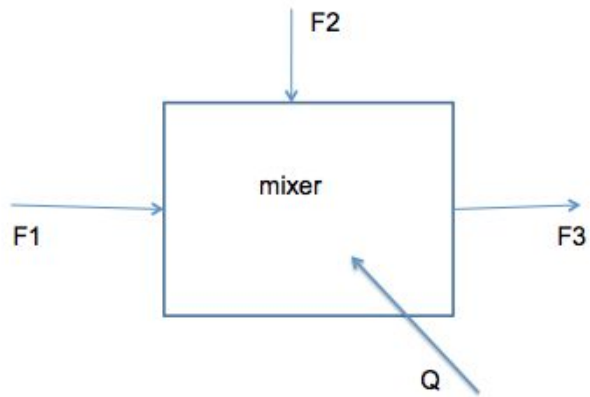

- $N_d = N_V - N_R$
- $N_d$ = number of degrees of freedom
- $N_v$ = Total number of variables
- $N_R$ = Number of independent relations
- $N_V = N_s(N_{sp} + 2) = 3(N_{sp} + 2) = 3N_{sp} + 6$
- $N_R$: $N_{sp}$ material balances

Thus, $N_d = 3N_{sp} + 6 – N_{sp} = 2Nsp + 6$

- What values must be specified?

# Including Energy Stream

## DoF for Mixer




$N_d = N_V - N_R$

$N_V = Ns(N_{sp} + 2)+1$ (take note of this change)

$= 3(N_{sp} +2)+1 = 3Nsp + 7$

$N_R$: $N_{sp}$ material balances

1 Energy balance

$N_R = N_{sp} + 1$

$N_d = 3N_{sp} +7 – (N_{sp}+1) = 2N_{sp} +6$

What values must be specified?