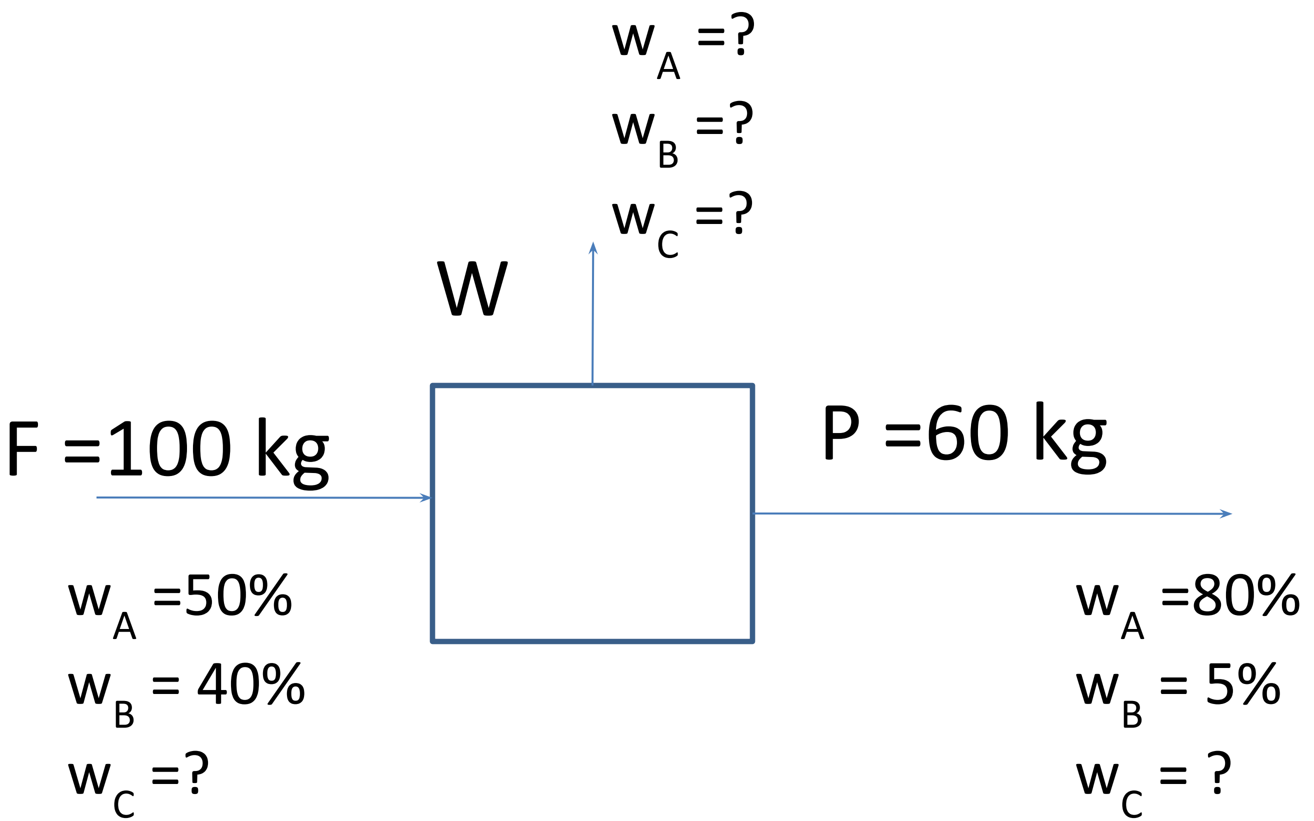
Department of Chemical Engineering
Thapar Institute of Engineering & Technology, Patiala

Course: Material and Energy Balances UCH301

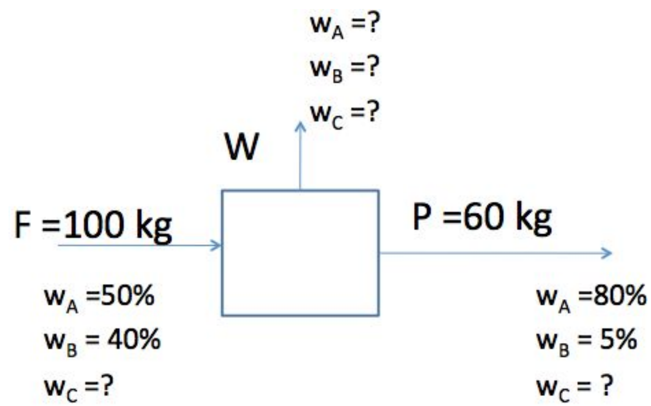
Course Instructor:
Dr. R. K. Gupta, Professor, Chemical Engineering

Carry out degrees of freedom analysis for a separator problem shown in the figure



Solution

- If we have to solve this problem for material balance, we can ignore T & P variables
- $N_V = N_s(N_{sp} + \cancel{2}) = 3(N_{sp}) = 3N_{sp}$
- $N_{sp} = 3$ (i.e., A, B, & C)
- **$N_V = 3*3 = 9$**



N_R (identifying independent relations):

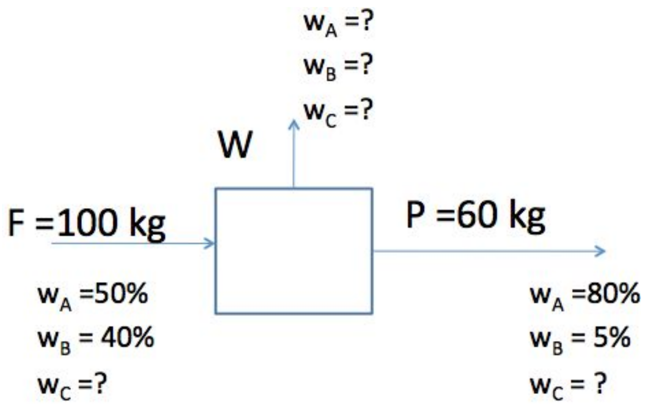
- Material balances = number of species = 3
- Known values in stream F = 3 (F, w_A, w_B)
- Known values in stream P = 3 (P, w_A, w_B)

Therefore, $N_R = 3+3+3 = 9$

Thus, $N_d = 9-9 = 0$

We can say that the problem is properly specified and no additional information is required to solve this problem.

Alternate Solution



N_d= Number of unknown variables- Number of independent equations

There are three unknown variables:

W, w_A, w_B (in stream W)

The three independent equations are:

Two component balance equations &one total balance

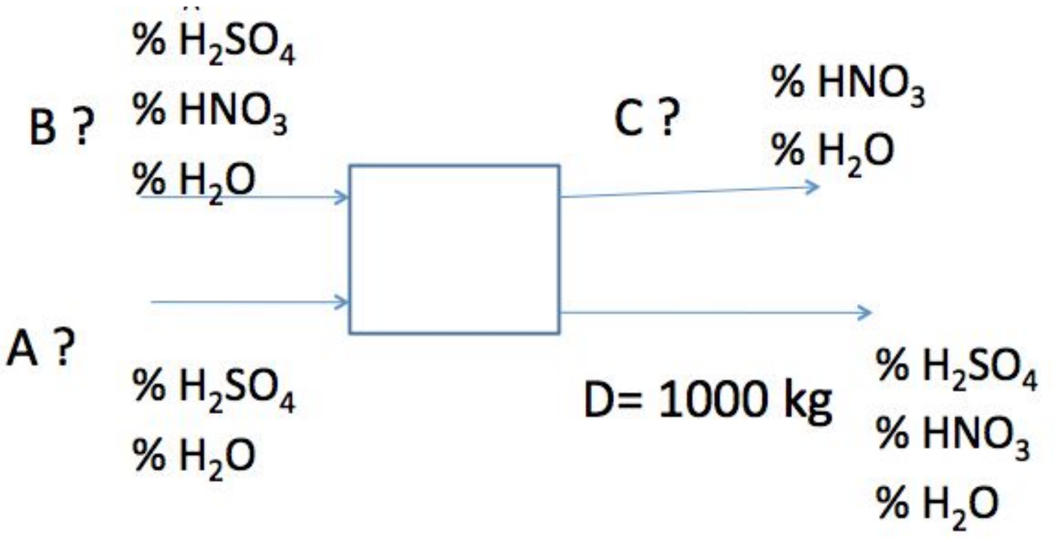
Or

Three component balance equatoins

Thus, $N_d = 3\text{-}3 = 0$

Exercise

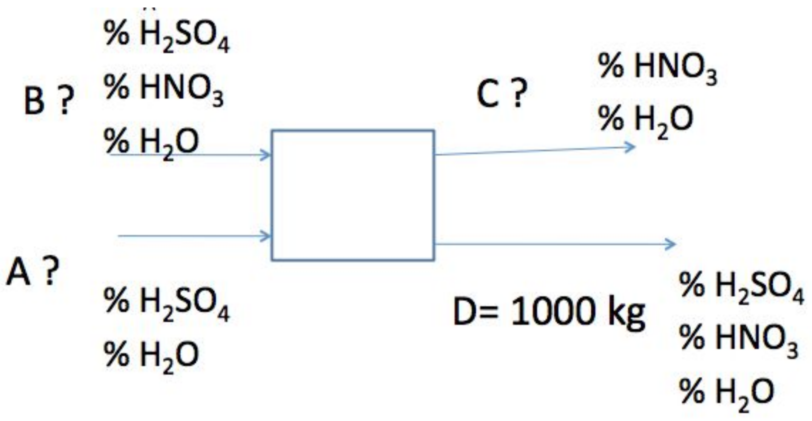
- Determine number of degrees of freedom for the following process(assume that the T, and P of all streams are same , T_A =30 ^{0}C, P_A = 1 atm)



Solution

- Number of Species: 3 (H_2SO_4, HNO_3, H_2O)
- Stream Variables

Stream	Variables
A	3 +2
B	3 +2
C	3 +2
D	3 +2



Total variables (N_V) : Ns (Nsp+2) =4(3+2) =20

Number of independent relations (N_R):

Material balances = 3

No. of Variables specified = 1 (in stream A, %HNO_3=0)

= 1 (in stream C, %H_2SO_4=0)

= 1 (in stream D, Amount of D=1000 kg)

= 3 Temp equalities ($T_A = T_B$; $T_B = T_C$; $T_C = T_D$)

= 3 Pressure equalities ($P_A = P_B$; $P_B = P_C$; $P_C = P_D$)

= 1 Temperature of stream A (T_A 30 ^{0}C)

= 1 Pressure of stream A (P_A =1 atm)

We get, $N_R = 14$

Degree of freedom $= N_V - N_R$

$= 20 - 14 = 6$

Now 6 variable values that need to be specified may be:

2 flows, any two from A, B & C = 2

1 composition in A = 1

2 compositions in B = 2

1 composition in any of the outlet streams = 1

PROBLEM

An experiment on the growth rate of certain organisms requires an environment of humid air enriched in oxygen. Three streams are fed into an evaporation chamber to produce an output stream of air having desired composition.

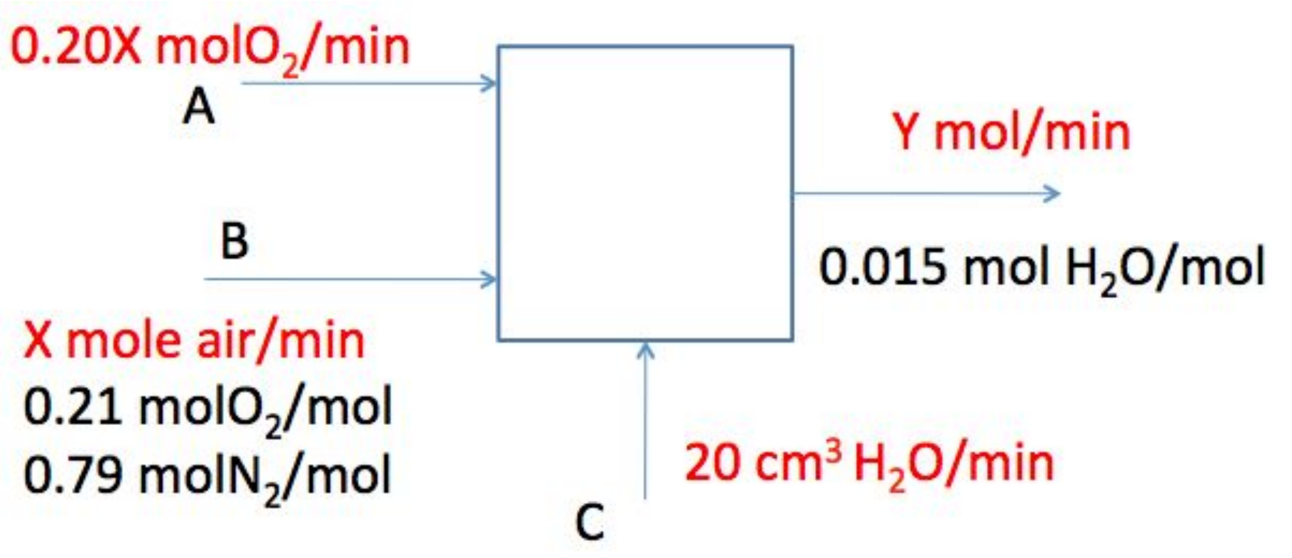
- STRAEM A: Pure oxygen, with a molar flow rate one fifth of the molar flow rate of stream B.
- STREAM B: Air (21% O_2, 79%N_2)
- STREAM C: Liquid water, fed at a rate of 20 cm^3/min

The output gas stream is analyzed and is found to contain 1.5 mol% water. Carry out DOF analysis for this process.

(Ignore Temperature and Pressure variables)

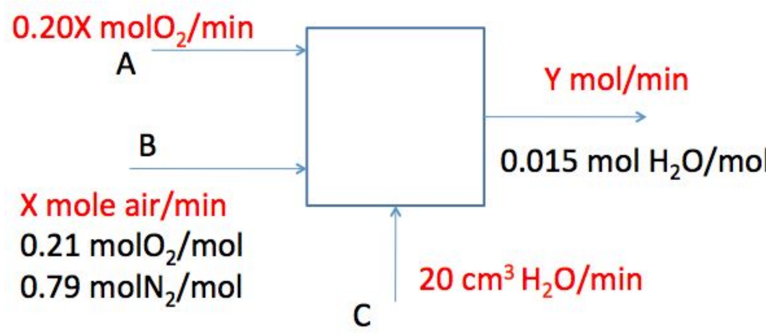
SOLUTION

- Please note that you do not have to do any calculation, but find out value for the degrees of freedom for this process



DOF

- Nsp = 3 (O_2, N_2, H_2O)
- N_S = 4
- $N_V = N_S(N_{sp}) = 4(3) = 12$
  (T, P variables not taken)
- N_R:



Material balance equations= 3
Specifications: = 2 (stream A),
= 2 (stream B),
= 3 (stream C, Two comp. & 1 Flow)
= 1 (flow rate relation for A and B)
= 1 (stream Y)

N_R = 12

Thus, N_d = 12-12 = 0

The problem is properly specified.