Department of Chemical Engineering
Thapar Institute of Engineering & Technology, Patiala
Course: Material and Energy Balances
UCH301

Course Instructor:

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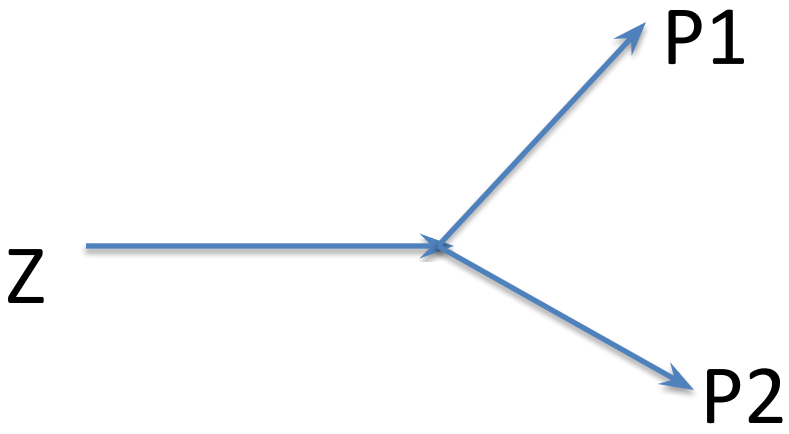
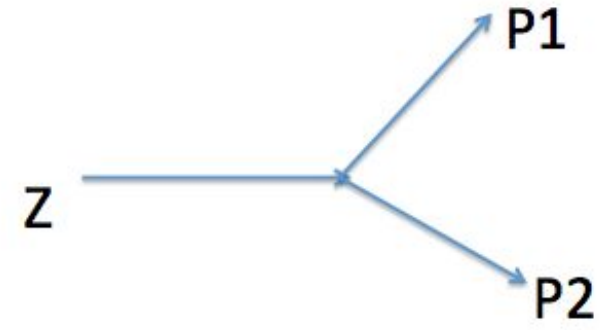
DoF (Stream Splitter)



- $N_V = 3(N_{sp}+2) = 3N_{sp} +6$



Relations/Equations:

Material balances = 1 (Z =P1+P2) (why??)

$x_{1,Z} Z = x_{1,P1} P1 + x_{1,P2} P2$ (since $x_{1,Z} = x_{1,P1} = x_{1,P2}$)

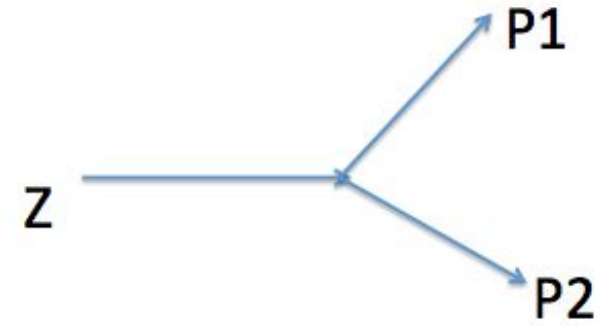
Composition equalities $=2(N_{sp}-1)$

$x_{1,Z} = x_{1,P1}$; $x_{1,Z} = x_{1,P2}$ (two equations for each component)

$N_R = 2N_{sp} - 1$

DoF $= 3N_{sp}+6 -(2N_{sp}-1) = N_{sp} + 7$

Identify what is required to be specified



Flow (Z) : 1

Comosition of Z : N_{sp}-1

Temperature : : 3

Pressure : 3

Ratio in which flow is divided(P1/P2): 1

Total = N_{sp}+7

Analysis of DOF for a Pump

- Obtain degrees of freedom for a Pump

Solution

One inlet material stream and

One outlet material stream

- Other variables, Q=0, W=?
- $Nv = 2(N_{sp}+2) +1+1$ (for W)
- $= 2N_{sp} +6$
- N_R : Material balance = 1

  Composition equalities = $N_{sp}-1$

  Energy Balance = 1

  Value of Q = 1

$NR = N_{sp}+2$

- DoF = $N_V - N_R = 2N_{sp} + 6 - (N_{sp}+2)$
- $= N_{sp}+4$

Which values are to be specified ?

✔ T_1, P_1, T_2, P_2 = 4

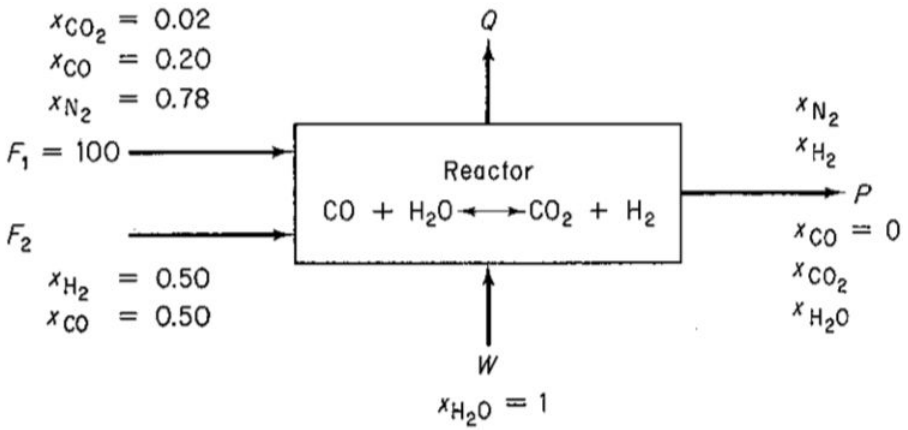
✔ Inlet stream flow rate = 1

✔ Compositions in inlet stream = $N_{sp}-1$

DEGREES OF FREEEDOM FOR PROCESSES WHEN A REACTION IS TAKING PLACE

Exercise

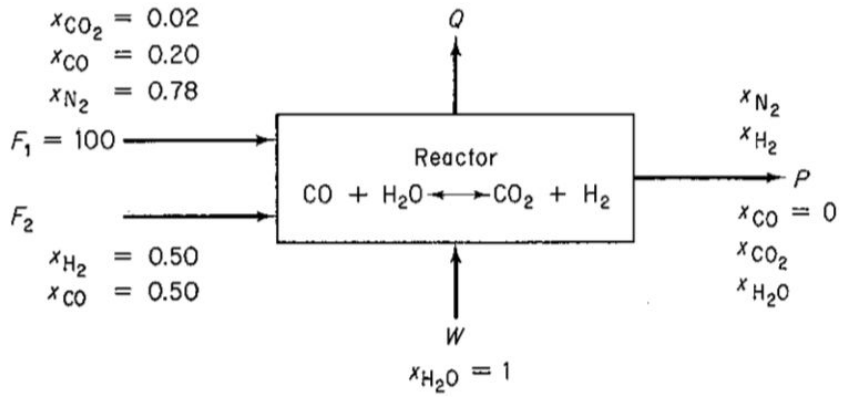
Figure below shows a process involving a reaction. Obtain degrees of freedom for this process. Assume temperature and pressures of all entering and exiting streams are same. The excess amount of water used in the reaction to convert CO to CO_2 is specified.



Note that Q is not a material stream.

Solution

$N_d = N_V - N_R$



$N_v = N_s(N_{sp} + 2) + 1 = 4(5 + 2) + 1 =$ 29

($+1$ is for Q)

N_r: Independent material balances

(C, O, N, H)	4	
Energy balance	1	
$T_{F_1} = T_{F_2} = T_W = T_P$	3	
$p_{F_1} = p_{F_2} = p_W = p_P$	3	11
Compositions and flows specified:		
In F_1 ($x_{H_2O} = x_{H_2} = 0$)	5	
In F_2 ($x_{N_2} = x_{CO_2} = x_{H_2O} = 0$)	4	
In W (all but x_{H_2O} are 0)	4	
In P ($x_{CO} = 0$)	1	14
Excess W given		1
		26

$N_d = 29 - 26 =$ 3

Variables to be specified:

T_{F1} (1 value) = 1

P_{F1} (1 value) = 1

Amount of F2/P/or any one composition in P

= 1

Problem (Involving Multiple Reactions)

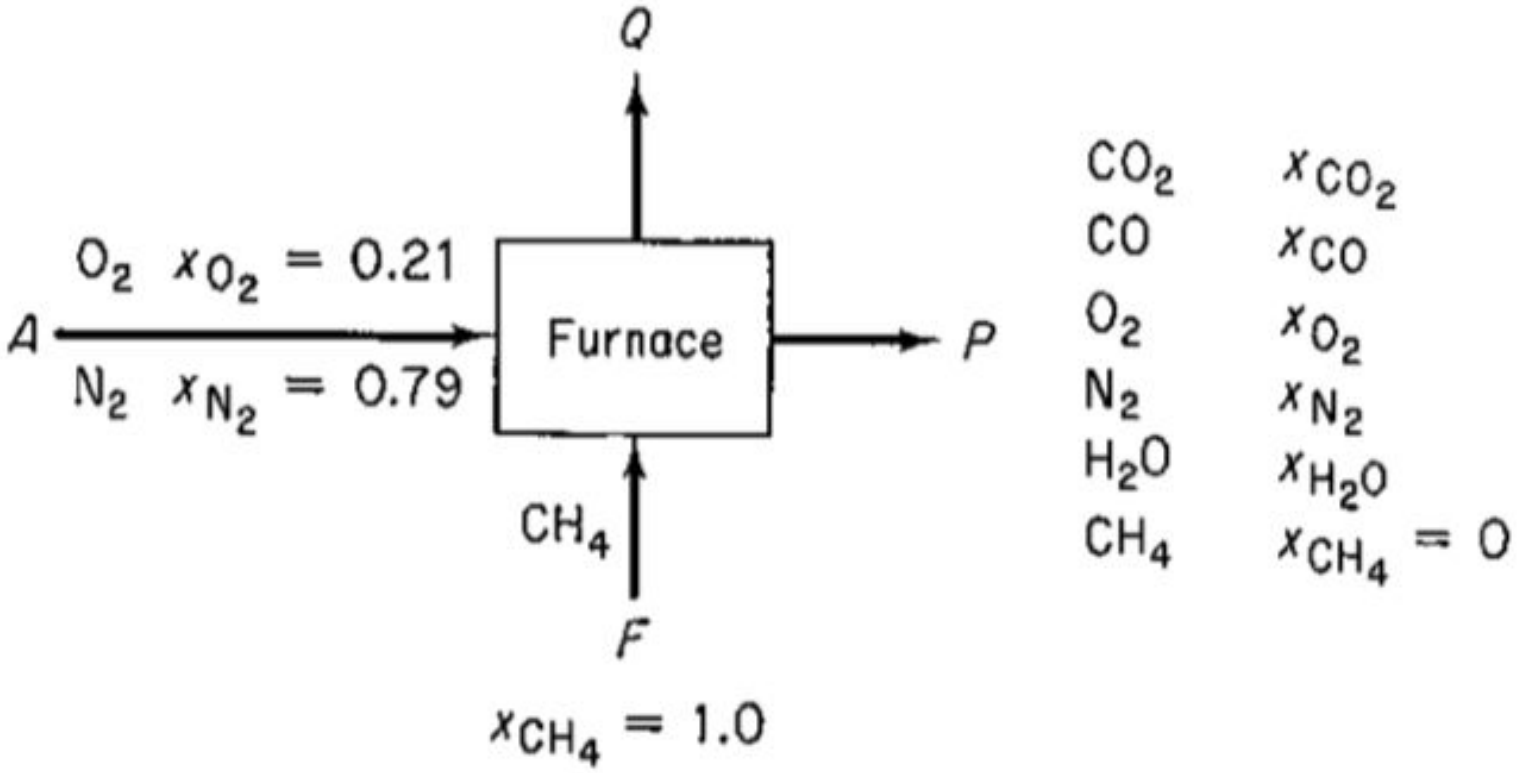
Methane is burned with 10% excess air. In then products some CO comes out but methane is products is zero. Assume Temperature and pressures of all streams are same.

The reactions that are occurring are:

$$CH_4 + 1.5O_2 \longrightarrow CO + 2H_2O$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$
$$CO + 0.5O_2 \longrightarrow CO_2$$

Carry out degree of freedom analysis for this problem.

Solution



- Excess Air amount is 10%, and CH_4 in P =0

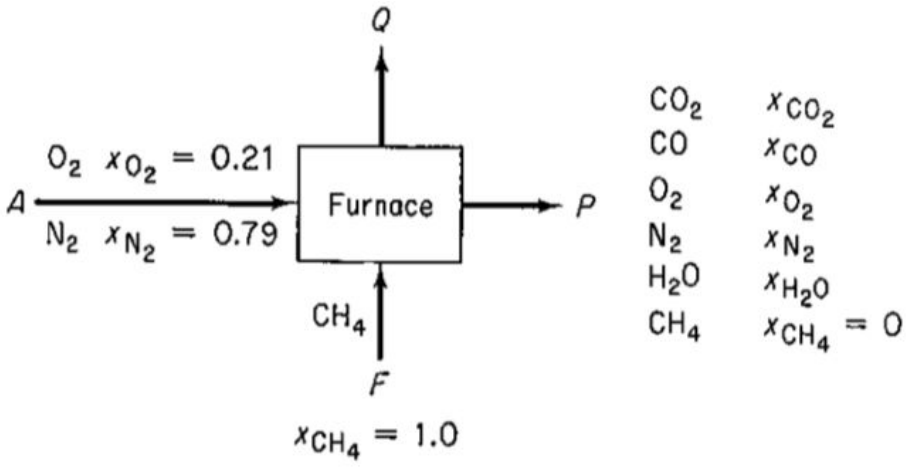
$N_d = N_V - N_R$

$N_v = 3(6 + 2) + 1 = 25$
(+1 is for Q)

N_r:

Material balances (C, H, O, N)	4	
Energy balance	1	
$T_A = T_F = T_P$	2	
$p_A = p_F = p_P$	2	
Compositions specified:		
In A $(N_{sp} - 1)$	5	
In F $(N_{sp} - 1)$	5	
In P	1	11
Percent excess air:		1
		21

$N_d = 25 - 21 = 4$



Try Yourself

One kg of jam is to be made from strawberries. To make this jam, crushed strawberries (containing about 15 wt% solids and 85 wt% water) and sugar are mixed in a 45:55 mass ratio, and the mixture is heated to evaporate water until the residue contain one-third water by weight. Carry out a degree of freedom analysis for this problem clearly indicating total number of variables, and total number of independent relations.

Ignore temperature and pressure variables, and also Q.