

Component Flows

Recall the variant or the material balance Table

	1	2
A	x_{A1}	x_{A2}
B	x_{B1}	x_{B2}
Total	F_1	F_2
Component flows		
A	f_{A1}	f_{A2}
B	f_{B1}	f_{B2}

where the f_{ij} 's are component flows:

$$f_{ij} = x_{ij} F_j$$

The component flows are sometimes an easier way to solve a problem than the compositions, depending on how the information about the problem is provided.

- 1) The degrees of freedom don't change.
- 2) Where there is some information about compositions, it can be expressed in terms of component flow ratios as follows:

$$\frac{x_{A1}}{x_{B1}} = \frac{x_{A1} F_1}{x_{B1} F_1} = \frac{f_{A1}}{f_{B1}}$$

These will be process spec's.

- 3) instead of writing $\sum x_{ij} = 1$, we can write $\sum f_{ij} = F_j$. We can choose to use the F_j 's in the balances (opening up the $\sum f_{ij}$ equations), or just leave them until the end.
- 3) Only consider either MB's based on x_{ij} 's or MB's based on f_{ij} 's in one solution.
- Component flows are another tool in the toolbox.
- * Remember - rows in the table give us MB's, column's give us $\sum x_{ij}$ and $\sum f_{ij}$'s.

CME 265 L11 Component Flows

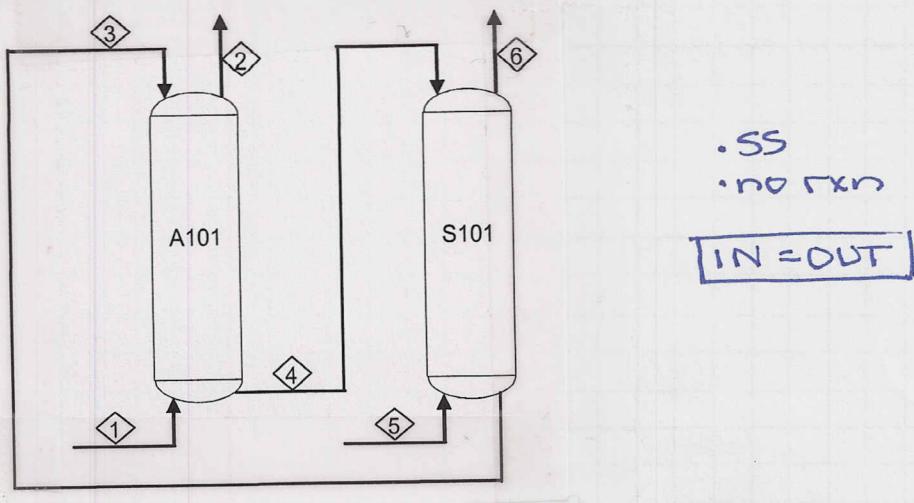
Problem 4-35 F+R

A process consisting of an absorption tower and a stripping tower is used to separate a gas which is 30% CO₂ and the balance methane. A stream of this gas is fed to the bottom of the absorber. A liquid containing 0.5 mole% CO₂ and the balance methanol is recycled from the bottom of the stripper and fed to the top of the absorber. The product gas leaving the top of the absorber contains 1 mole% CO₂ and essentially all of the methane fed to the unit. The CO₂ rich liquid leaving the bottom of the absorber is fed to the top of the stripper and a stream of nitrogen gas is fed to the bottom. Ninety percent of the CO₂ in the liquid feed to the stripper comes out of solution in the column, and the nitrogen/CO₂ stream leaving the stripper passes out to the atmosphere through a stack. The liquid stream leaving the stripper is the 0.5% CO₂ solution recycled to the absorber. Methanol may be considered non-volatile, and nitrogen is considered insoluble in methanol. Take a basis of 100 mol/hr of feed gas and complete the material balances.

ABS

REGEN

Ex 4.35 (Ass't 3, 2004) solved using component flows



	1	2	3	4	5	6
CH ₄ (M)	0.70	0.99	—	—	—	—
CD ₂ (D)	0.30	0.01	0.005	x_{D4}	—	x_{D6}
CH ₃ DH (S)	—	—	0.995	x_{S4}	—	—
N ₂ (N)	—	—	—	—	1.0	x_{N6}
Streams Flows (mol/hr)	100	F_2	F_3	F_4	F_5	F_6
Component Flows	(mol/ hr)					
(M)	70	70	—	—	—	—
D	30	f_{D2}	f_{D3}	f_{D4}	—	f_{D6}
S	—	—	f_{S3}	f_{S4}	—	—
N	—	—	—	—	f_{N5}	f_{N6}

PROCESS SPECS as f_{ijjs}

$$0.90 f_{D4} = f_{D6}$$

$$\frac{f_{D2}}{f_{M2}} = \frac{f_{D2}}{70} = \frac{0.01}{0.99} \quad \therefore f_{D2} = 0.71$$

$$\frac{f_{D3}}{f_{S3}} = \frac{0.005}{0.995}$$

PROCESS SPECS as $x_{ij}'s$

$$0.90 (x_{D4} F_4) = x_{D6} F_{N6}$$

Degrees of Freedom for $x_{ij} + F_j$'s

	A1O1	S1O1	Overall
Streams	1, 2, 3, 4	3, 4, 5, 6	1, 2, 5, 6
Unknowns	$F_2 F_3 F_4$ $x_{D4} x_{S4}$ (5)	$F_3 F_4 F_5 F_6$ $x_{D4} x_{S4} x_{D6} x_{N6}$ (8)	$F_2 F_5 F_6$ $x_{D6} x_{N6}$ (5)
MB	3 (M, D, S)	3 (D, S, N)	3 (M, D, N)
Σx_i	1	2	1
Proc Spec	0	1	0
Basis	-	-	-
d.F.	1	2	1

$$\text{Process Spec: } 0.90(x_{D4}F_4) = x_{D6}F_6$$

→ you write Σx_{ij} 's and MB's

Degrees of Freedom for f_{ij} 's and F_j 's

	A1O1	S1O1	Overall
Streams	1, 2, 3, 4	3, 4, 5, 6	1, 2, 5, 6
Unknowns	F_2, F_3, F_4, f_{D2} $f_{D3} f_{D4} f_{S3} F_{SA}$ (7)	$F_3 F_4 F_5 F_6$ $f_{D3} f_{D4} f_{S3} f_{N3} = f_{SA}$ $f_{N5} = f_{N6}, f_{D6}$ (9)	$F_2 F_5 F_6 f_{D2} f_{N5}$ f_{D6} (6)
MB	1 (D)	1 (D)	1 (D)
Σf_{ij} 's	3	4	3
Proc Spec	2	2	1
Basis	-	-	-
d.F.	1	2	1

$$\text{Process Spec's: } 0.90 f_{D4} = f_{D6}$$

$$\frac{f_{D3}}{f_{M3}} = \frac{0.005}{0.995}$$

$$\frac{f_{D2}}{70} = \frac{0.01}{0.99}$$

you write
 Σf_{ij} 's and
MB's

DEGREES OF FREEDOM - f_{ij} 's only, leave f_{S4} and f_{N6} as variables

	Absorber	Stripper	Overall
Streams	1, 2, 3, 4	3, 4, 5, 6	1, 2, 5, 6
Unknowns	f_{D3}, f_{S3} f_{D4}, f_{S4}	f_{D3}, f_{S3} f_{N5} f_{D4}, f_{S4} f_{D6}, f_{N6}	f_{N5} f_{D6}, f_{N6}
	(4)	(7)	(3)
Material balances	32	3	2
xi Process Spec	1	2	0
d.f.	1	2	1

So d.f. analysis is the same!

Write CO₂ balances:

$$\text{Absorber: } 30 + f_{D3} = 0.71 + f_{D4}$$

$$f_{D4} - f_{D3} = 29.29 \frac{\text{mol}}{\text{hr}} = \text{CO}_2 \text{ absorbed}$$

$$\text{Stripper: } f_{D4} = f_{D6} + f_{D3}$$

$$f_{D4} - f_{D3} = f_{D6} = 29.29 \frac{\text{mol}}{\text{hr}}$$

$$\text{Overall: } \frac{30 \text{ mol}}{\text{hr}} = 0.71 \frac{\text{mol}}{\text{hr}} + 29.29 \frac{\text{mol}}{\text{hr}} \checkmark$$

Write N₂ balances:

$$\text{Stripper: } f_{N5} = f_{N6}$$

$$\text{Overall: } f_{N5} = f_{N6}$$

Solvent balances:

$$\text{Absorber and Stripper: } f_{S3} = f_{S4}$$

Apply process spec.

$$0.90 f_{D4} = f_{D4} = 29.29 \frac{\text{mol}}{\text{hr}} \quad \therefore f_{D4} = 32.54 \frac{\text{mol}}{\text{hr}}$$

$$f_{D4} - f_{D6} = f_{D3} = (32.54 - 29.29) \frac{\text{mol}}{\text{hr}} = 3.25 \frac{\text{mol}}{\text{hr}}$$

$$\frac{f_{D3}}{f_{S3}} = \frac{0.005}{0.995} \quad \therefore f_{S3} = 647.63 \frac{\text{mol}}{\text{hr}} = f_{S4}$$

Regroup MB Table

everything is known except the nitrogen flows: $f_{N5} = f_{N6}$, so 1 d.f. means one unknown in terms of component flows.

	1	2	3	4	5	6	
CH ₄ (M)	0.70	0.99	-	-	-	-	
CD ₂ (D)	0.30	0.01	0.005	0.048	-	x_{D6}	
CH ₃ OH(S)	-	-	0.995	0.952	-	-	
N ₂ (N)	-	-	-	-	1.0	x_{N6}	
Total Stream flows (mol/hr)	100	70.71	650.9	680.17	F_5	F_6	
Component flows (mol/hr)							
CH ₄ (M)	70	70	-	-	-	-	
CD ₂ (D)	30	0.71	3.25	32.54	-	29.29	
CH ₃ OH(S)	-	-	647.63	647.63	-	-	
N ₂ (N)	-	-	-	-	F_{N5}	F_{N5}	

Note that in terms of x_{ij} 's and F 's, there remain 4 unknowns (x_{D6} , x_{N6} , F_5 and F_6) and 3 equations (CO₂ balance, N₂ balance, Σx_{ij}).

MOEAL OF THE STORY

- 1) Component flows are another way to solve the problem. They lead to the same final answer as the mole or mass fraction solution.
- 2) The degrees of freedom are the same, regardless of when they are calculated, or what approach is used.
- 3) With one degree of freedom, one variable will remain unknown.
- 4) A process spec can be used whenever all of the variables in the p.s. belong to the list of streams for that vessel.