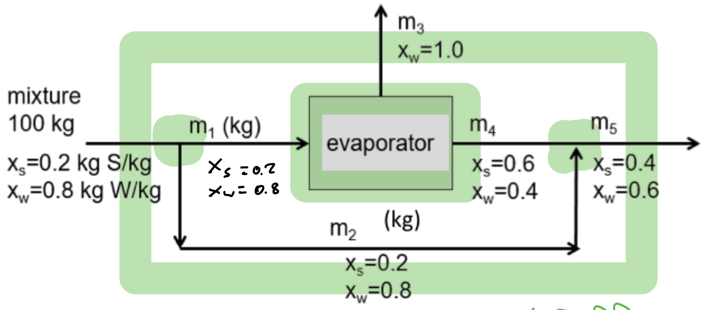
Conceptual Questions

1. (4 points) Which balance would result in zero degrees of freedom?



4 Diff Subsystems ☺

~~a.~~ Evaporator
b. Overall
~~c.~~ Splitting point
~~d.~~ Mixing point

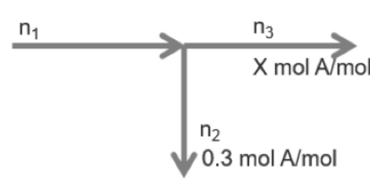
Evaporator
3 Unknowns (m_1, m_3, m_4)
− 2 Indep Mat Bal (2 species)
− 0 Additional EQs
1 DoF

Splitting Point
2 Unknowns (m_1, m_2)
− 1 Indep Mat Balance (splitting point)
− 0 Additional EQs
1 DoF

Overall
2 Unknowns (m_3, m_5)
− 2 Indep Mat Bal (2 species)
− 0 Additional EQs
0 DoF ✓

Mixing Point
3 Unknowns (m_2, m_4, m_5)
− 2 Additional Material Balances (2 species)
− 0 Additional EQs
1 DoF

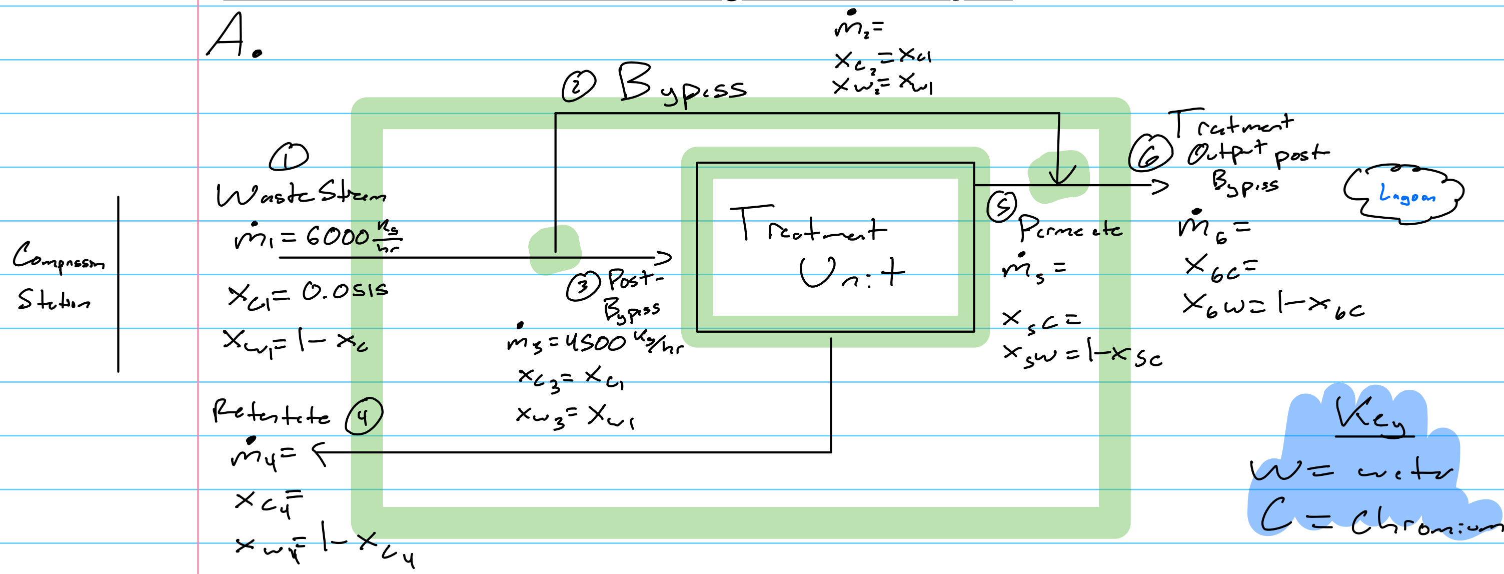
2. (3 points) The mole percent of A in stream 3 is ____________ the mole percent of A in stream 1.
   a. Greater than
   b. Less than
   c. Equal to



Splitting Point; Mass Flowrates change but mol Ratios stay consistent in the different streams ☺

Hexavalent Chromium for Heating Process Analysis

A.



Additional Info:

$$\left.\begin{aligned} \dot{m}_4 x_{c4} &= 0.95\, \dot{m}_3 x_{c3} \\ \dot{m}_5 x_{5c} &= 0.05\, \dot{m}_3 x_{c3} \end{aligned}\right\} \text{equivalent}$$

Want to Know

(i) $\dot{m}$ into lagoon: $\dot{m}_6$

(ii) x_c into lagoon: x_{6c}

DoF Analysis

Splitting Point

1 Unknowns ($\dot{m}_2$)
− 1 Material Balance (Splitting Point)
− 0 Additional EQs
0 DoF ☺

Mixing Point

5 Unknowns ($\dot{m}_2, \dot{m}_5, x_{5c}, \dot{m}_6, x_{6c}$)
− 2 Material Balances (2 species)
− 0 Additional EQs
3 DoF ☹

Treatment Unit

4 Unknowns ($\dot{m}_5, x_{5c}, \dot{m}_4, x_{4c}$)
− 2 Material Balance (2 species)
− 1 Additional EQs (★)
1 DoF ☹

Overall

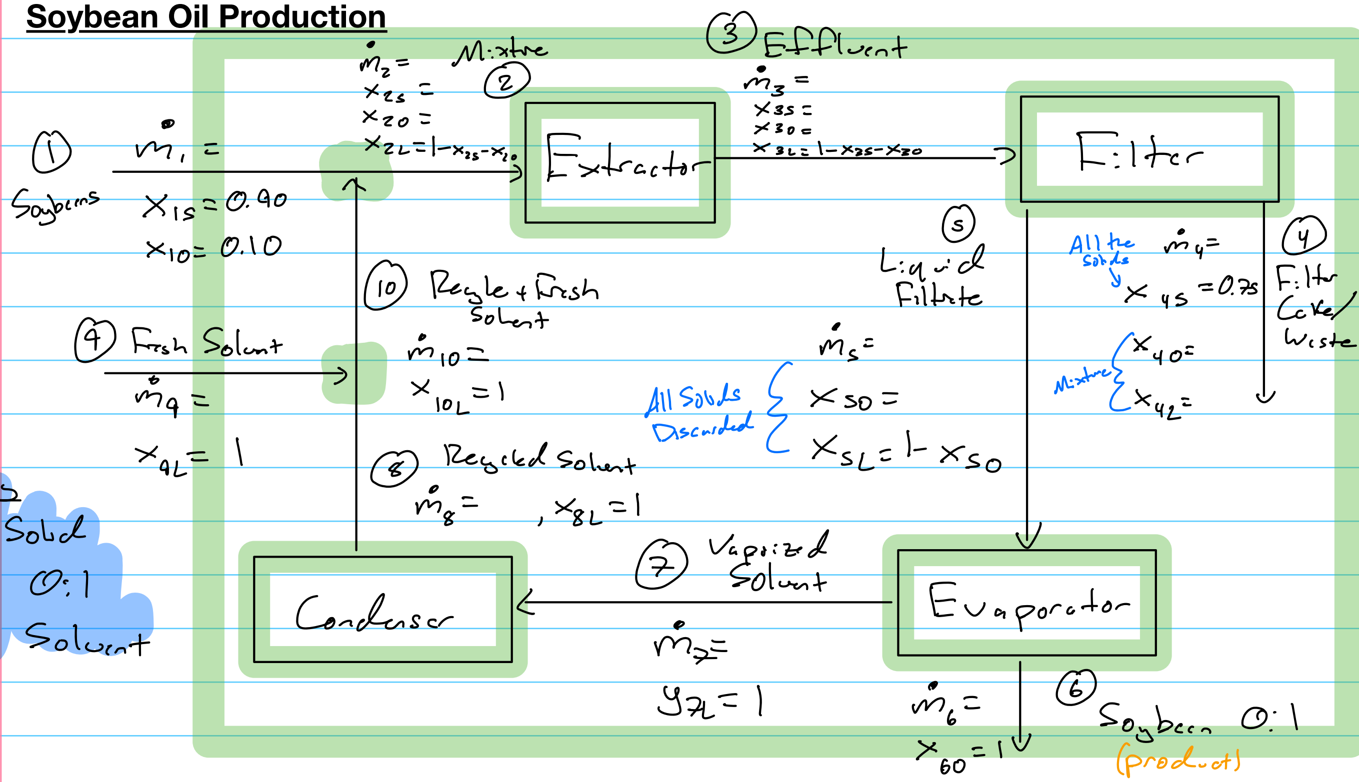
4 Unknowns ($\dot{m}_4, x_{4c}, \dot{m}_6, x_{6c}$)
− 2 Material Balance (2 species)
− 0 Additional EQs
2 DoF

Can only solve Splitting Point for $\dot{m}_2$, which isn't used in any other equation! This doesn't bring any other DoFs to 0, so the problem is $\boxed{\text{unsolvable!}}$ This is solvable if $\dot{m}_5$ is given, as the Treatment unit would then go to 0 DoF, which we could then solve for $\dot{m}_4$ and x_{4c} and use those in 'Overall' to get 0 DoF and solve for $\dot{m}_6$ and x_{6c}, as required.

Hexavalent Chromium for Heating Environmental Analysis

B. It is necessary to treat the wastewater before sending it to the lagoon in order to protect both the wildlife living there and also the humans that live around the lagoon as well. Failing to treat the water allows it to seep into the soil at high concentrations, which contaminates the drinking water for animals and potentially humans depending on where their water is coming from. In the US, the EPA (environmental protection agency) would place limits on the amount of contamination for emissions as to prevent groundwater contamination, which is what Erin Brockovich was a whistleblower for regarding the company Pacific Gas & Electric (PG&E) in 1993.

Soybean Oil Production



Key
S = Solid
O = Oil
L = Solvent

Additional Equations

1. $3\dot{m}_1 = \dot{m}_{10}$ — 3 kg Solvent : Kg Beans
2. $x_{4S} + x_{4O} + x_{4L} = 1$ — def of a mass fraction ($x_{4S} = 0.75$)
   $x_{4O} + x_{4L} = 0.25$
3. $\dfrac{x_{3O}}{x_{3L}} = \dfrac{x_{4O}}{x_{4L}}$

Want to Know

Yield of Soy Oil: $\dfrac{\dot{m}_6}{\dot{m}_1}$

Solvent Recycle Ratio: $\dfrac{\dot{m}_8}{\dot{m}_9}$

DoF Analysis

Solvent/Soybean Mixing

5 Unknowns ($\dot{m}_1, \dot{m}_2, x_{2S}, x_{2O}, \dot{m}_{10}$)
− 3 Indep. Mat. Balances (3 species)
− 1 Additional EQs (1)
1 DoF

Fresh/Recycled Solvent Mixing

3 Unknowns ($\dot{m}_8, \dot{m}_9, \dot{m}_{10}$)
− 1 Indep. Mat. Balances (1 species)
− 0 Additional EQs
2 DoF

Overall

6 Unknowns ($\dot{m}_1, \dot{m}_4, x_{4O}, x_{4L}, \dot{m}_6, \dot{m}_9$)
− 3 Indep. Mat. Balances (3 species)
− 1 Additional EQs (2)
2 DoF

Filter

8 Unknowns ($\dot{m}_3, x_{3S}, x_{3O}, \dot{m}_4, x_{4O}, x_{4L}, \dot{m}_5, x_{5O}$)
3 Indep. Mat. Balances (3 species)
2 Additional EQs (2, 3)
3 DoF

Soybean Oil Production (Continued)

DoF Analysis Continued

Extractor

6 Unknowns ($\dot{m}_2, x_{2S}, x_{2O}, \dot{m}_3, x_{3S}, x_{3O}$)
− 3 Mat Balances (3 species)
− 0 Additional EQs
3 DoF

Evaporator

4 Unknowns ($\dot{m}_5, x_{5O}, \dot{m}_6, \dot{m}_7$)
− 2 Mat Balances (2 species)
− 0 Additional EQs
2 DoF

Condenser

2 Unknowns ($\dot{m}_7, \dot{m}_8$)
− 1 Mat Balances (1 species)
− 0 Additional EQs
1 DoF

Plan

(i) Assume a Basis for $\dot{m}_1 = 100 \frac{kg}{hr}$
(ii) Solve Solvent/Soybean Mixing to get $\dot{m}_2, x_{2S}, x_{2O}, \dot{m}_{10}$
(iii) Solve Extractor for $\dot{m}_3, x_{3S}, x_{3O}$
(iv) Solve Filter for $\dot{m}_4, x_{4O}, x_{4L}, \dot{m}_5, x_{5O}$
(vi) Solve Evaporator for $\dot{m}_6, \dot{m}_7$ // Can now solve for yield
(vii) Solve Condenser for $\dot{m}_8$
(viii) Solve Fresh/Recycled Solvent Mixing for $\dot{m}_9$ // Can now solve ratio

Material Balances

Conservation of Mass: in − out + $\cancel{\text{generation} - \text{consumption}}$ = $\cancel{\text{accumulation}}$ — 0 No Rxns; 0 Assume batch/steady-state

→ in = out ← True for all!

0 DoF w/ Basis

Solvent/Soybean Mixing

S: $\dot{m}_1 x_{1S} = \dot{m}_2 x_{2S}$
O: $\dot{m}_1 x_{1O} = \dot{m}_2 x_{2O}$
L: $\dot{m}_{10} x_{10L} = \dot{m}_2 x_{2L}$
Total: $\dot{m}_1 + \dot{m}_{10} = \dot{m}_2$

How to Solve:
(i) Solve L to solve for $\dot{m}_{10}$
(ii) Solve Total balance for $\dot{m}_2$
(iii) Solve S Balance for x_{2S}
(iv) Solve O Balance for x_{2O}

0 DoF w/ solved values

Extractor

S: $\dot{m}_2 x_{2S} = \dot{m}_3 x_{3S}$
O: $\dot{m}_2 x_{2O} = \dot{m}_3 x_{3O}$
L: $\dot{m}_2 x_{2L} = \dot{m}_3 x_{3L}$
Total: $\dot{m}_2 = \dot{m}_3$

How to Solve:
(i) Solve Total Balance for $\dot{m}_3$
(ii) Solve S Balance for x_{3S}
(iii) Solve O Balance for x_{3O}

Soybean Oil Production (Continued)

Filter ← 0 DoF from solved values

S: $\dot{m}_3 x_{3S} = \dot{m}_4 x_{4S}$

O: $\dot{m}_3 x_{3O} = \dot{m}_4 x_{4O} + \dot{m}_5 x_{5O}$

L: $\dot{m}_3 x_{3L} = \dot{m}_4 x_{4L} + \dot{m}_5 x_{5L}$

Total: $\dot{m}_3 = \dot{m}_4 + \dot{m}_5$

How to Solve:
(i) Solve S Balance for $\dot{m}_4$
(ii) Solve Total Balance for $\dot{m}_5$
(iii) Solve L Balance for x_{4L}
(iv) Use ∅ to solve for x_{4O}
(v) Use O Balance to solve for x_{5O}

Evaporator ← 0 DoF from solved values

O: $\dot{m}_5 x_{5O} = \dot{m}_6 x_{6O}$

L: $\dot{m}_5 x_{5L} = \dot{m}_7 y_{7L}$

Total: $\dot{m}_5 = \dot{m}_6 + \dot{m}_7$

How to Solve:
(i) Solve L Balance for $\dot{m}_7$
(ii) Solve Total Balance for $\dot{m}_6$

Condenser ← 0 DoF as we know $\dot{m}_7$

Only 1 species

Total: $\dot{m}_7 = \dot{m}_8$

How to Solve:
(i) Solve Total Balance for $\dot{m}_8$

Fresh/Recycled Solvent Mix ← 0 DoF, only don't know $\dot{m}_9$

Only 1 species

Total: $\dot{m}_8 + \dot{m}_9 = \dot{m}_{10}$

How to Solve:
(i) Solve Total Balance for $\dot{m}_9$

Without solving Overall Material Balances, we have found $\dot{m}_1$ (basis), $\dot{m}_6$, $\dot{m}_8$, $\dot{m}_9$. We can then solve

Yield of Soy Oil: $\dfrac{\dot{m}_6}{\dot{m}_1}$ & Solvent Recycle Ratio: $\dfrac{\dot{m}_8}{\dot{m}_9}$

as required.

Unit 1 & 2 Total Reflection

1. (3 points) We have now concluded units 1 & 2 on unit conversions, dimensional homogeneity and the general procedure for nonreactive single- and multi-unit processes with recycle and bypass.
    a. Is there anything about the content that you still find confusing?
    b. What (if anything) about the class is prohibiting your learning?
    c. What (if anything) about the class is helping your learning?

A. I don’t think Im having trouble with any of the concepts in particular anymore. Having the experience of the first Homework of this unit was instrumental in my increase of confidence regarding the material. The only thing I am still working on is interpreting the given information in the problem statement, as it can sometimes be hard for me to piece together all of the information in the problem statement. I also seem to struggle with where to implement certain equations, as I’m not always sure if equations (not conversation of mass related) can be placed on the PFD or are just stated as additional EQs/relationships.

B. There is nothing in the class that is necessarily prohibiting my learning. Though I did comment on (in the HW2A reflection) doing more challenging examples in class, I think I really just needed to get over the hump of that first homework so I could know what to expect and how to attack problems on my own. The examples in class are definitely very involved, but I do still believe that there is a noticeable difficulty jump from the in class work to the assigned homework.

C. The heavy emphasis on examples is very helpful. It gives a framework for getting to the desired answers, while also reinforcing key techniques and illustrating what might be asked/looked for in exams. Though the most recent lecture on 9/18 isn’t on this material, I did like how we talked a lot about the “Jargon” for most of the lecture. This effectively outlines the verbiage that might be seen in future problem statements. The class seems very geared towards the success of the students, and I appreciate that.