Conceptual Questions

1.

DOF - evaporator

4 unknowns (m_1 m_2 m_3 m_4)
- 2 ind. mat. balances

2 DOF

DOF - splitting point

2 unknowns (m_1 m_2)
- 1 ind. mat. balance

1 DOF

DOF - mixing point

3 unknowns (m_4 m_5 m_2)
-2 ind. mat balances

1 DOF

DOF - overall

2 unknowns (m_3 m_5)
-2 ind. mat. balances

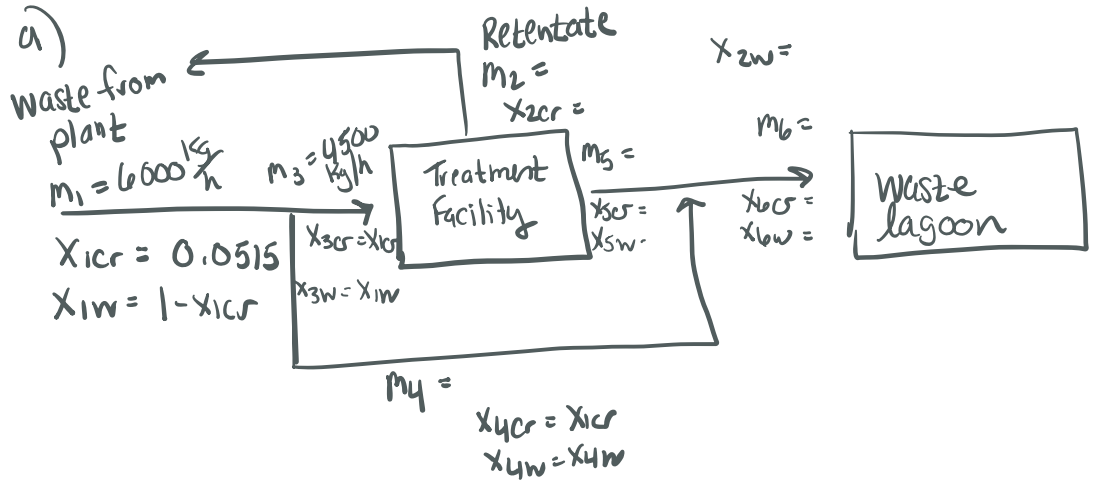
0 DOF

b. overall

2. **C. Equal to**

Problem 3: Hexavalent Chromium

a)



want to know:

x_{6cr}, m_6

additional equations:

(*) $0.95 m_3 x_{3cr} = m_2 x_{2cr}$

DOF - Treatment Facility

6 unknowns (m_2 x_{2cr} m_5 x_{5cr} x_{2w} x_{5w})
- 2 ind. mat. balances
- 3 add equations ($\Sigma x_{5i} = 1$, $\Sigma x_{2i} = 1$, (*))

1 DOF

DOF - overall

6 unknowns (m_2 x_{2w} x_{2cr} m_6 x_{6cr} x_{6w})
- 2 balances
- 2 additional eqs ($\Sigma x_{6i} = 1$, $\Sigma x_{2i} = 1$)

2 DOF

DOF - splitting

-1 unknowns (m_4)
-1 balance
-0 add. equations

0 DOF * can start here

DOF - mixing

7 unknowns (m_5 x_{5cr} x_{5w} x_{6cr} x_{6w} m_4 m_6)
- 2 balances
- 2 add-equations ($\Sigma x_{5i} = 1$, $\Sigma x_{6i} = 1$)

3 DOF

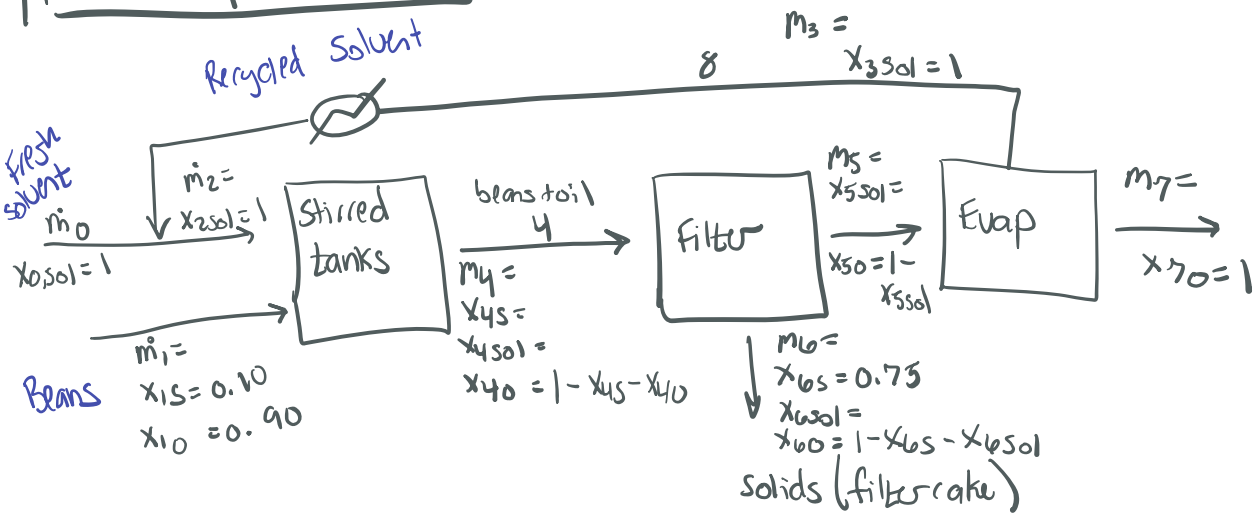
Plan of attack: splitting → mixing in

not enough info to solve—
can stop here. Need to
know at least 1 more process
variable.

b) Hexavalent chromium can harm aquatic life and cause cancer in local populations. In the US, the EPA regulates industrial emissions.

Problem 4: Soybeans

S = solids, BO = beanoil, Sol = solvent



Want to know: Yield: $\frac{m_7}{\dot{m}_1}$ Recycle Ratio: $\frac{m_3}{\dot{m}_0}$

Additional EQs: (**) $\frac{m_4 \cdot x_{4sol}}{m_4 \cdot x_{4O}} = \frac{m_4 \cdot x_{6sol}}{m_4 \cdot x_{6O}}$, $\frac{\dot{m}_2}{\dot{m}_1} = 3$ (*)

DOF on all subsystems (mixing, stirred tank, filter, evap, overall)

Overall

5 unknowns ($\dot{m}_0$ $\dot{m}_1$, $\dot{m}_6$, $\dot{m}_7$, x_{6sol})
- 3 ind. mat balances
- 0 additional equations

2 DOF

Mixing

3 unknowns ($\dot{m}_0$ $\dot{m}_2$ $\dot{m}_3$)
- 1 ind. mat balances
- 0 additional equations

2 DOF

Stirred tank

5 unknowns ($\dot{m}_2$ $\dot{m}_1$ $\dot{m}_4$ x_{4s} x_{4sol})
- 3 ind. mat balances (sol, s, 0)
- 1 additional equations (*)

1 DOF

filter

7 unknowns ($\dot{m}_4$ x_{4s} x_{4sol} $\dot{m}_6$ x_{6sol} $\dot{m}_5$ x_{5sol})
- 3 ind. mat balances
- 1 additional equations (**)

4 DOF

Evaporator

4 unknowns ($\dot{m}_3$, $\dot{m}_7$, $\dot{m}_5$, x_{5sol})
- 2 ind. mat balances
- 0 additional equations

2 DOF

*We have not yet assumed a basis, but we are allowed to do so because there is no $\dot{m}$, $\dot{V}$, or $\dot{n}$ on the PFD.

Assume a basis for $\dot{m}_1$ which brings my DOF at the extractor to 0.

Plan to solve:
- Assume basis, $\dot{m}_1 = 100$ kg/h
- Solve extractor
- Solve filter
- Solve evaporator (m_3, m_7)
- Solve mixing (m_0)

Material balances

given or assumed basis

calculated in stirred tank

calculated from filter

calc in evaporator

Stirred Tanks

solvent: $\dot{m}_2 = \dot{m}_4 x_{4sol}$

$\frac{\dot{m}_2}{\dot{m}_1} = 3$ (*)

oil: $\dot{m}_1 x_{1o} = \dot{m}_4 x_{4o}$

solids: $\dot{m}_1 x_{1s} = \dot{m}_4 x_{4s}$

total: $\dot{m}_2 + \dot{m}_1 = \dot{m}_4$

How to solve

1. use basis ($\dot{m}_1$) in (*), calc $\dot{m}_2$
2. use total balance, calc $\dot{m}_4$
3. Calc x_{4sol} from solvent balance
4. calc x_{4o} from oil balance
5. calc x_{4s} from solids balance

Filter

solvent: $\dot{m}_4 x_{4sol} = \dot{m}_6 x_{6sol} + \dot{m}_5 x_{5sol}$

oil: $\dot{m}_4 x_{4o} = \dot{m}_5 x_{5o} + \dot{m}_6 x_{6o}$

solids: $\dot{m}_4 x_{4s} = \dot{m}_6 x_{6s}$

total: $\dot{m}_4 = \dot{m}_5 + \dot{m}_6$

(**) $\frac{x_{4sol}}{x_{4o}} = \frac{x_{6sol}}{x_{6o}}$ additional EQ

How to solve

1. Calculate $\dot{m}_6$ from solids balance
2. Calc. $\dot{m}_5$ from total
3. In the oil balance, write x_{5o} in terms of x_{5sol}: $x_{5o} = 1 - x_{5sol}$

   write $x_{6o} = 1 - x_{6s} - x_{6sol}$
4. Solve oil balance for x_{5sol} + plug into solvent balance - calc. x_{6sol}
5. use (**) to calc x_{6o}
6. use oil balance to calc x_{5o}

Evaporator

Solvent: $\dot{m}_5 x_{5sol} = \dot{m}_3 + \dot{m}_6 x_{6sol}$

Oil: $\dot{m}_5 x_{5o} = \dot{m}_7$

total: $\dot{m}_5 = \dot{m}_3 + \dot{m}_7$

How to solve

1. Calc $\dot{m}_3$ from solvent balance
2. Calc $\dot{m}_7$ from oil balance

Mixing Point

total: $\dot{m}_0 + \dot{m}_3 = \dot{m}_2$

How to solve

1. use total to calc $\dot{m}_0$

we now know $\dot{m}_3$, $\dot{m}_7$, $\dot{m}_0$, and $\dot{m}_1$ — therefore, can calculate

yield: $\dot{m}_7/\dot{m}_1$

recycle ratio: $\dot{m}_3/\dot{m}_0$