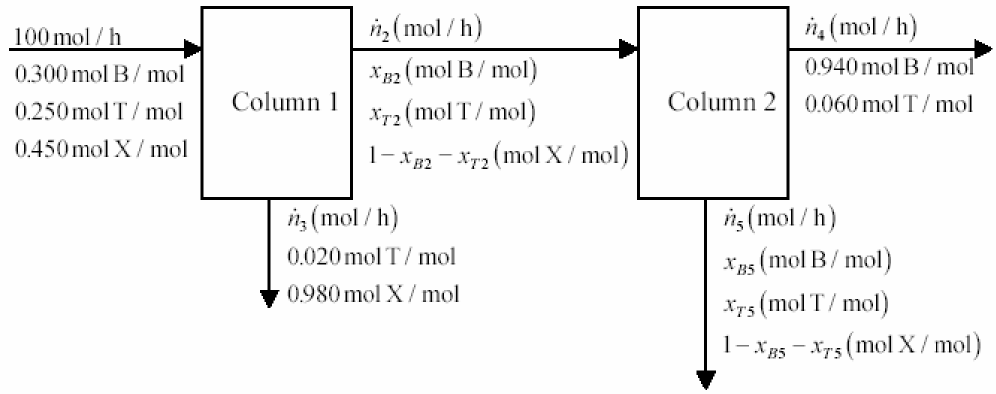
4.29 **a.**



Column 1
4 unknowns ($\dot{n}_2, \dot{n}_3, x_{B2}, x_{T2}$)
–3 balances
– 1 recovery of X in bot. (96%)
0 DF

Column 2:
4 unknowns ($\dot{n}_3, \dot{n}_4, \dot{n}_5, y_x$)
– 3 balances
– 1 recovery of B in top (97%)
0 DF

Column 1

96% X recovery: $0.96(0.450)(100) = 0.98\dot{n}_3$ (1)

Total mole balance: $100 = \dot{n}_2 + \dot{n}_3$ (2)

B balance: $0.300(100) = x_{B2}\dot{n}_2$ (3)

T balance: $0.250(100) = x_{T2}\dot{n}_2 + 0.020\dot{n}_3$ (4)

Column 2

97% B recovery: $0.97x_{B2}\dot{n}_2 = 0.940\dot{n}_4$ (5)

Total mole balance: $\dot{n}_2 = \dot{n}_4 + \dot{n}_5$ (6)

B balance: $x_{B2}\dot{n}_2 = 0.940\dot{n}_4 + x_{B5}\dot{n}_5$ (7)

T balance: $x_{T2}\dot{n}_2 = 0.060\dot{n}_4 + x_{T5}\dot{n}_5$ (8)

b.

$(1) \Rightarrow \dot{n}_3 = 44.1$ mol / h $\quad (2) \Rightarrow \dot{n}_2 = 55.9$ mol / h

$(3) \Rightarrow x_{B2} = 0.536$ mol B / mol $\quad (4) \Rightarrow x_{T2} = 0.431$ mol T / mol

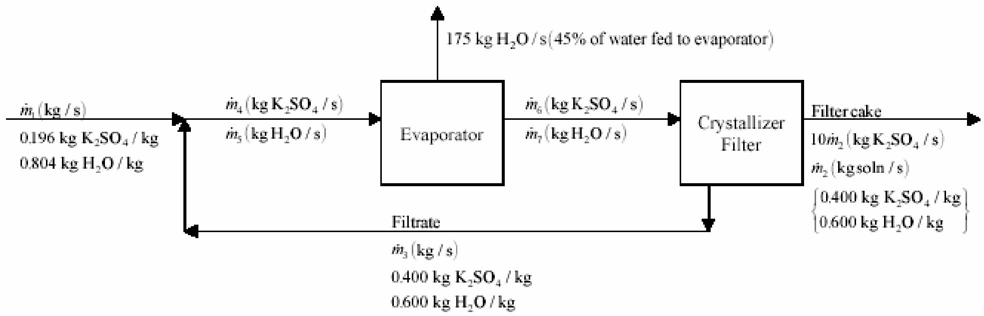
$(5) \Rightarrow \dot{n}_4 = 30.95$ mol / h $\quad (6) \Rightarrow \dot{n}_5 = 24.96$ mol / h

$(7) \Rightarrow x_{B5} = 0.036$ mol B / mol $\quad (8) \Rightarrow x_{T5} = 0.892$ mol T / mol

Overall benzene recovery: $\dfrac{0.940(30.95)}{0.300(100)} \times 100\% = 97\%$

Overall toluene recovery: $\dfrac{0.892(24.96)}{0.250(100)} \times 100 = 89\%$

4.34 a.



Let K = K_2SO_4, W = H_2 <u>Basis</u>: 175 kg W evaporated/s

<u>Overall process</u>: 2 unknowns ($\dot{m}_1, \dot{m}_2$)
<u>- 2 balances</u>
0 DF

<u>Mixing point</u>: 4 unknowns ($\dot{m}_1, \dot{m}_3, \dot{m}_4, \dot{m}_5$)
<u>- 2 balances</u>
2 DF

<u>Evaporator</u>: 4 unknowns ($\dot{m}_4, \dot{m}_5, \dot{m}_6, \dot{m}_7$)
– 2 balances
<u>– 1 percent evaporation</u>
1 DF

<u>Crystallizer</u>: 4 unknowns ($\dot{m}_2, \dot{m}_3, \dot{m}_6, \dot{m}_7$)
<u>– 2 balances</u>
2 DF

<u>Strategy</u>:

Overall balances $\Rightarrow \dot{m}_1, \dot{m}_2$
% evaporation $\Rightarrow \dot{m}_5$
Balances around mixing point $\Rightarrow \dot{m}_3, \dot{m}_4$
Balances around evaporator $\Rightarrow \dot{m}_6, \dot{m}_7$

} verify that each chosen subsystem involves no more than two unknown variables

Overall mass balance: $\underline{\dot{m}_1} = 175 + 10\underline{\dot{m}_2} + \underline{\dot{m}_2}$

Overall K balance: $0.196\dot{m}_1 = 10\dot{m}_2 + 0.400\dot{m}_2$

Production rate of crystals $= 10\dot{m}_2$

45% evaporation: 175 kg evaporated/min $= 0.450\dot{m}_5$

W balance around mixing point: $0.804\dot{m}_1 + 0.600\dot{m}_3 = \dot{m}_5$

Mass balance around mixing point: $\dot{m}_1 + \dot{m}_3 = \dot{m}_4 + \dot{m}_5$

K balance around evaporator: $\dot{m}_6 = \dot{m}_4$

W balance around evaporator: $\dot{m}_5 = 175 + \dot{m}_7$

Mole fraction of K in stream entering evaporator $= \dfrac{\dot{m}_4}{\dot{m}_4 + \dot{m}_5}$

b. Fresh feed rate: $\dot{m}_1 = 221 \text{ kg/s}$

Production rate of crystals $= 10\dot{m}_2 = 41.6 \text{ kg K(s)/s}$

Recycle ratio: $\dfrac{\dot{m}_3(\text{kg recycle/s})}{\dot{m}_1(\text{kg fresh feed/s})} = \dfrac{352.3}{220.8} = 1.60 \dfrac{\text{kg recycle}}{\text{kg fresh feed}}$

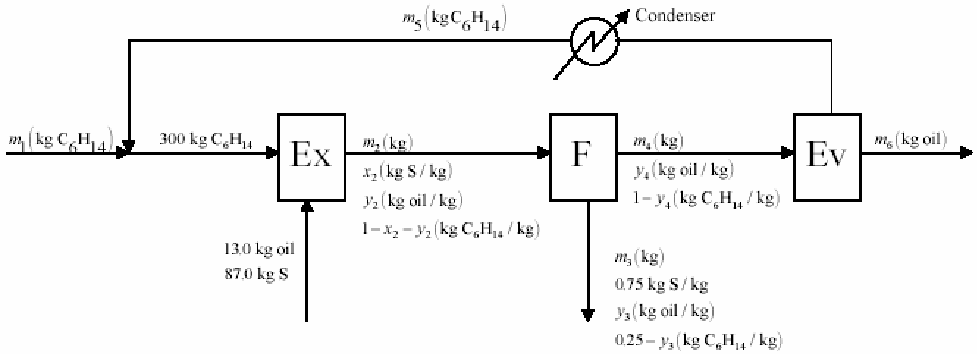
c. Scale to 75% of capacity.

Flow rate of stream entering evaporator $= 0.75(398 \text{ kg/s}) = 299 \text{ kg/s}$

46.3% K, 53.7% W

d. Drying. Principal costs are likely to be the heating cost for the evaporator and the dryer and the cooling cost for the crystallizer.

4.36 a. <u>Basis</u>: 100 kg beans fed



<u>Overall</u>: 4 unknowns (m_1, m_3, m_6, y_3)
− 3 balances
1 DF

<u>Extractor</u>: 3 unknowns (m_2, x_2, y_2)
− 3 balances
0 DF

<u>Mixing Pt</u>: 2 unknowns (m_1, m_5)
− 1 balance
1 DF

<u>Evaporator</u>: 4 unknowns (m_4, m_5, m_6, y_4)
− 2 balances
2 DF

<u>Filter</u>: 7 unknowns ($m_2, m_3, m_4, x_2, y_2, y_3, y_4$)
− 3 balances
− 1 oil/hexane ratio
3 DF

Start with extractor (0 degrees of freedom)

<u>Extractor mass balance</u>: $[300 + 87.0 + 13.0]$ kg $= \underline{\underline{m_2}}$

Extractor S balance: $87.0 \text{ kg S} = \underline{\underline{x_2}} m_2$

Extractor oil balance: $13.0 \text{ kg oil} = \underline{\underline{y_2}} m_2$

Filter S balance: $87.0 \text{ kg S} = 0.75 \underline{m_3}$

Filter mass balance: $m_2 (\text{kg}) = m_3 + \underline{m_4}$ Oil / hexane ratio in filter cake:

$$\frac{\underline{y_3}}{0.25 - \underline{y_3}} = \frac{y_2}{1 - x_2 - y_2}$$

Filter oil balance: $13.0 \text{ kg oil} = y_3 m_3 + \underline{y_4} m_4$

Evaporator hexane balance: $(1 - y_4) m_4 = \underline{\underline{m_5}}$

Mixing pt. Hexane balance: $\underline{\underline{m_1}} + m_5 = 300 \text{ kg } C_6H_{14}$

Evaporator oil balance: $y_4 m_4 = \underline{\underline{m_6}}$

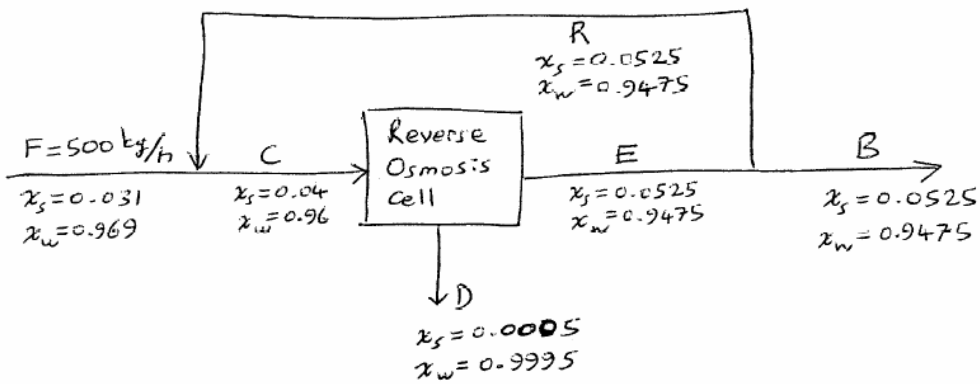
b. $$\text{Yield} = \frac{m_6}{100} = \frac{11.8 \text{ kg oil}}{100 \text{ kg beans fed}} = \underline{0.118 (\text{kg oil / kg beans fed})}$$

$$\text{Fresh hexane feed} = \frac{m_1}{100} = \frac{28 \text{ kg } C_6H_{14}}{100 \text{ kg beans fed}} = \underline{0.28 (\text{kg } C_6H_{14} \text{ / kg beans fed})}$$

$$\text{Recycle ratio} = \frac{m_5}{m_1} = \frac{272 \text{ kg } C_6H_{14} \text{ recycled}}{28 \text{ kg } C_6H_{14} \text{ fed}} = \underline{\underline{9.71 (\text{kg } C_6H_{14} \text{ recycled / kg } C_6H_{14} \text{ fed})}}$$

c. Lower heating cost for the evaporator and lower cooling cost for the condenser.

Q.4. a) $B = ?$, b) $D = ?$, c) $\frac{R}{R+B} = ?$



# of unknowns = 5 (D, B, R, C, E)
# of equations needed = 5 (from 3 independent systems)

	Overall System	Reverse Osmosis Cell	Separation Point	Mixing Point
unknowns	2 (D, B)	3 (C, E, D)	3 (E, B, R)	2 (R, C)
equations	2 balances	2 balances	1 balance	2 balances
DF	0	1	2	0

Start with Overall System or Mixing Point.

ⓐ & ⓑ Overall System

Total Balance: $500 = D + B$

Salt Balance: $(0.031)500 = (0.0005)D + (0.0525)B$

$\Rightarrow$ $B = 293.3$ kg/h , $D = 206.7$ kg/h

ⓒ Mixing Point

Total Balance: $R + 500 = C$

Salt Balance: $(0.0525)R + (0.031)500 = (0.04)C$

$\Rightarrow$ $R = 360$ kg/h , $C = 860$ kg/h

Separation Point

Total Balance: $E = R + B = 360 + 293.3 = 653.3$ kg/h

$$\Rightarrow \frac{R}{E} = \frac{R}{R+B} = \frac{360}{653.3} = 0.551 \ (55.1 \text{ wt\%})$$