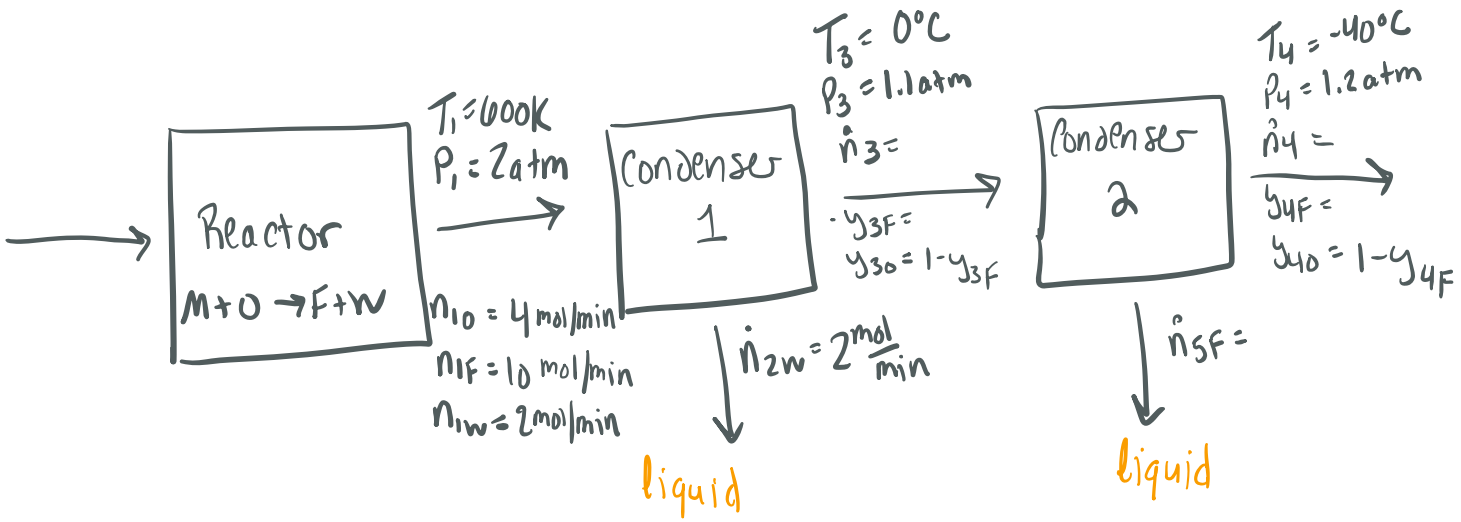
A)



Want to know $\dot{Q}$ (kJ/mol) condenser 2.

B)

DOF - condenser 1

2 unknowns ($\dot{n}_3$ y_{3F})
- 2 material balances (O, F)
0 additional EQs

0 DOF

DOF - condenser 2

5 unknowns ($\dot{n}_3$ y_{3F} $\dot{n}_{5F}$ $\dot{n}_4$ y_{4F})
- 2 material balances (O, F)
- 1 additional equations (Raoults/Antoine)

2 DOF

Material Balances - Condenser 1

O: $\dot{n}_{1O} = \dot{n}_3 y_{3O}$

F: $\dot{n}_{1F} = \dot{n}_3 y_{3F} = \dot{n}_3 (1 - y_{3O})$

How to solve

1. Solve O balance for $\dot{n}_3$ + plug into F. Calc y_{3O}
2. Use y_{3O} in O balance - calc $\dot{n}_3$

Mat. Balances - condenser 2

F: $\dot{n}_3 y_{3F} = \dot{n}_4 y_{4F} + \dot{n}_5$

O: $\dot{n}_3 y_{3O} = \dot{n}_4 y_{4O} = \dot{n}_4 (1 - y_{4F})$

$y_{4F} P = P_F^{sat} = 10^{\wedge}\left[A - \frac{B}{T_4 + C}\right]$ where A= B= C=

How to solve

1. Antoine Eq w/ T_4 to calc P_F^{sat}
2. Raoult's Law to calc y_{4F}
3. O balance to calc $\dot{n}_4$
4. F balance to calc $\dot{n}_5$
5. $y_{4O} = 1 - y_{4F}$

C) $\Delta \dot{E}_p + \Delta \dot{E}_K + \Delta \dot{H} = \dot{Q} - \dot{W}_S$ (all ΔĖp, ΔĖK, Ẇs = 0)

$$\dot{Q} = \Delta \dot{H} = \sum_{out} \dot{n}_i \hat{H}_i - \sum_{in} \dot{n}_i \hat{H}_i$$

$$\dot{Q} = \left[\dot{n}_4 y_{4F} \hat{H}_{4F} + \dot{n}_4 y_{4O} \hat{H}_{4O} + \dot{n}_5 \hat{H}_{5F} \right] - \left[\dot{n}_3 y_{3F} \hat{H}_{3F} + \dot{n}_3 y_{3O} \hat{H}_{3O} \right]$$

reference state so $\hat{H}_{3F} = \hat{H}_{3O} = 0$

→ Need to calculate $\hat{H}_{4F}, \hat{H}_{4O}, \hat{H}_{5F}, \hat{H}_{3F}, \hat{H}_{3O}$

→ Reference state F(g, 0°C, 1.1 atm)
O(g, 0°C, 1.1 atm)

D) Hypothetical path for $\hat{H}_{4F}$ (process state: F(-40°C, 1.2 atm, g)

F(g, 0°C, 1.1 atm) *Ref state
↓ ΔT constant P, phase $\int_{0°C}^{-40°C} Cp_{F,g}\, dT$
F(g, -40°C, 1.1 atm)
↓ ΔP, constant T, phase – nearly ideal ΔH=0
F(g, -40°C, 1.2 atm)

*we don't have the tools in this class to treat this as a real gas – this is the best approximation we can make

$$\hat{H}_{4F} = \int_{0}^{-40°C} Cp_{F,g}\, dT \quad \text{where} \quad Cp_{F,g} = 34.28 \times 10^{-3} + 4.268 \times 10^{-5} T - 8.694 \times 10^{-8} T^2$$

from B.2 and 40°C outside of range – this is the best approx. we have.

Hypothetical path for $\hat{H}_{4O}$ (process state: O(-40°C, 1.2 atm, g))

O(g, 0°C, 1.1 atm) *Ref state
↓ ΔT constant P, phase $\int_{0°C}^{-40°C} Cp_{O,g}\, dT$
O(g, -40°C, 1.1 atm)
↓ ΔP, constant T, phase nearly ideal gas ΔH=0
O(g, -40°C, 1.2 atm)

$$\hat{H}_{4O} = \int_{0°C}^{-40°C} Cp_{O,g}\, dT$$

where $Cp_{O,g} = 29.10 \times 10^{-3} + 1.158 \times 10^{-5} T - 0.6076 \times 10^{-8} T^2$

Hypothetical path for $\hat{H}_{SF}$ (process state: F | -40°C, 1.2 atm, ℓ))

F(g, 0°C, 1.1 atm) ← Ref state

↓ ΔP, constant T, phase — $\Delta\hat{H} = 0$ ideal gas

F(g, 0°C, 1 atm)

↓ ΔT, constant P, phase — $\int_{0°C}^{T_{boil}} Cp_{F,g}\, dT$ — Table B.2

F(g, T^{boil} = , 1 atm)

↓ Δphase, constant P, T — $-\Delta\hat{H}^{\circ}_{vap,F}$ = — Table B.1

F(ℓ, T^{boil} = , 1 atm)

↓ ΔP, constant T, phase — $\Delta\hat{H} = \hat{V}\Delta P = \frac{1\ kJ}{1.2\ L\cdot atm} \cdot \frac{MW_F}{\rho_F} \cdot (0.2\ atm)$

F(ℓ, T^{boil} = , 1.2 atm)

↓ ΔT, constant P, phase — $\Delta\hat{H} \int_{T_{boil}}^{-40°C} Cp_{F,\ell}\, dT$

F(ℓ, -40°C, 1.2 atm)

$$\hat{H}_{SF} = \int_{0°C}^{T_{boil}} Cp_{F,g}\, dT - \Delta\hat{H}^{\circ}_{vap,F} + \left(\frac{1\ kJ}{1.2\ L\cdot atm}\right)\frac{MW_F}{\rho_F}(0.2\ atm) + \int_{T_{boil}}^{-40°C} Cp_{F,\ell}\, dT$$

Where $Cp_{F,g}$ = same as above

$Cp_{F,\ell} = 105 \frac{kJ}{mol\,°C}$ (from problem statement)

$MW_F = 30.03$ (Table B.1)

$\rho_F = \rho_{H_2O} \cdot 0.815 = 815\ g/L$ (Table B.1)

$\Delta\hat{H}^{\circ}_{vap} = 24.148\ kJ$ (Table B.1)

Plug in all quantities to solve for $\hat{H}_{4F}$ $\hat{H}_{40}$ $\hat{H}_{sf}$. Plug them all into the $\dot{Q}$ (kJ/min) with all known molar flowrates.