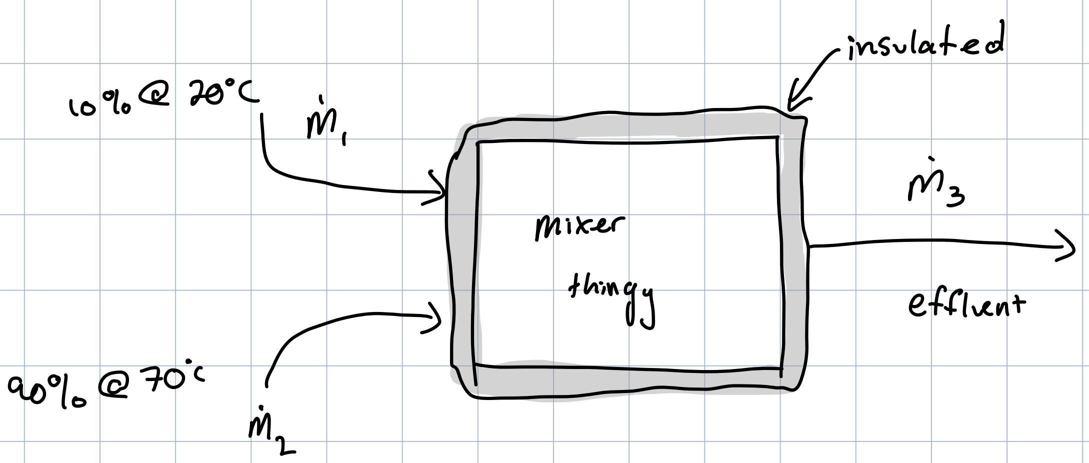
8.14

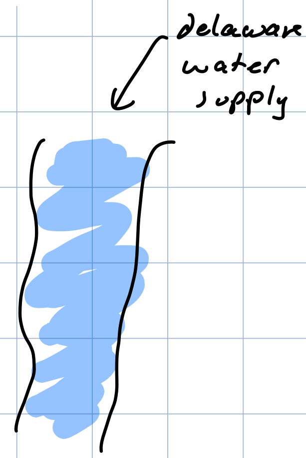
8.14 The temperature achieved when two fluid streams of differing temperature and/or composition are adiabatically mixed is termed the adiabatic mixing temperature. Compute the adiabatic mixing temperature for the following two cases:

a. Equal weights of aqueous solutions containing 10 wt % sulfuric acid at 20°C and 90 wt % sulfuric acid at 70°C are mixed.

b. Equal weights of aqueous solutions containing 10 wt % sulfuric acid at 20°C and 60 wt % sulfuric acid at 0°C are mixed.

Explain why the adiabatic mixing temperature is greater than that of either of the initial solutions in one of these cases, and intermediate between those of the initial solutions in the other case.





mass balance (overall)

$$\dot m_1 + \dot m_2 = \dot m_3$$

also $\dot m_1 = \dot m_2$

energy balance (overall) (Steady State)

$$\frac{dU}{dt} = 0 = \cancel{\dot Q} + \cancel{\dot W_s} + \sum_{i=1}^{3} \dot m_i \hat H_i$$

adiabatic

no $\dot W_s$

$$0 = \dot m_1 \hat H_1 + \dot m_2 \hat H_2 - \dot m_3 \hat H_3$$

now from mass balance

$$\dot m_1 = \dot m_2 = \dot m \quad , \quad \dot m_3 = 2\dot m$$

and applying to energy balance

$$0 = \dot{m}\left(\hat{H}_1 + \hat{H}_2\right) - 2\dot{m}\left(\hat{H}_3\right)$$

of course $\dot{m}$ cancels

$$0 = \hat{H}_1 + \hat{H}_2 - 2\hat{H}_3$$

$$\Longrightarrow \quad \hat{H}_3 = \frac{1}{2}\left(\hat{H}_1 + \hat{H}_2\right)$$

now we need to figure out the wt% of H_2SO_4 in the final stream using component balances

H_2SO_4 Mass Balance

$$0 = \sum_{i=1}^{3} x_{si}\dot{m}_i = x_{s1}\dot{m}_1 + x_{s2}\dot{m}_2 - x_{s3}\dot{m}_3$$

from the overall mass balance and $\dot{m}_1 = \dot{m}_2$ we know $\dot{m}_3 = 2\dot{m}_1 = 2\dot{m}_2$,

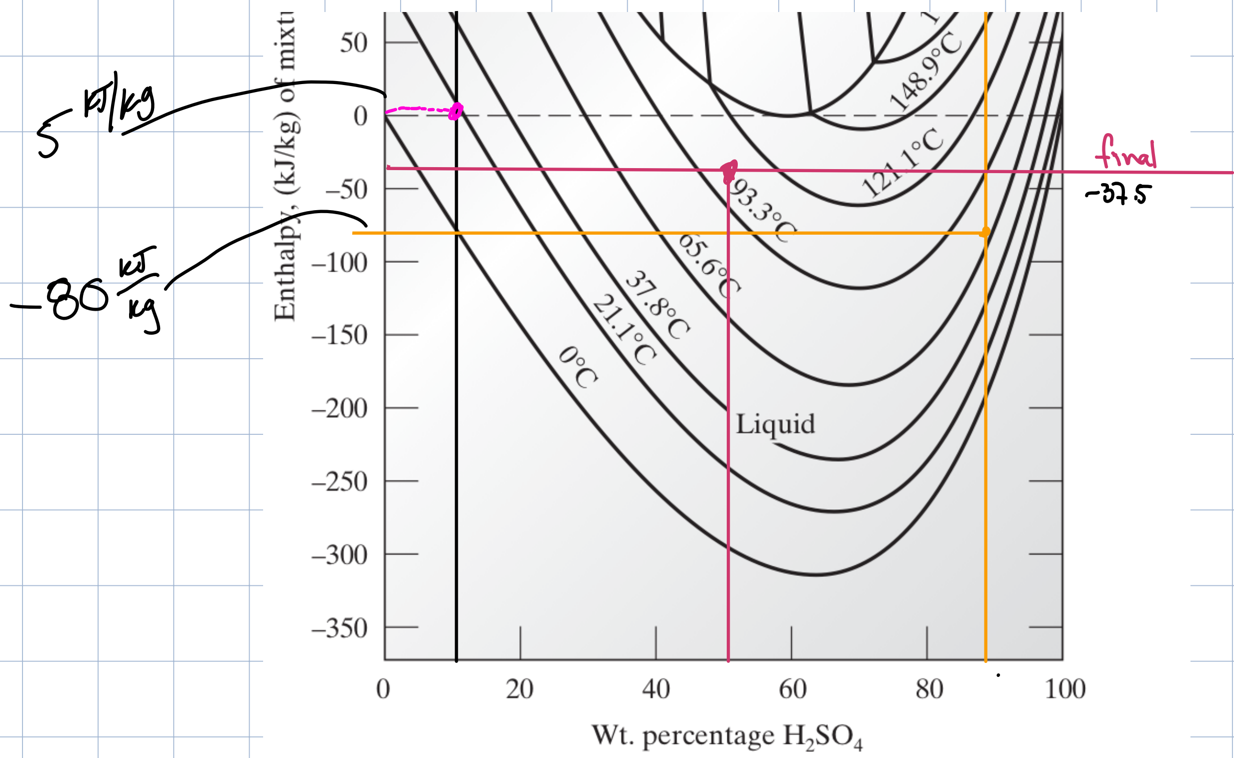
$$0 = x_{s1} + x_{s2} - 2x_{s3}$$

$$x_{s3} = \frac{1}{2}\left(x_{s1} + x_{s2}\right) = 0.50$$

now we may find $\hat{H}_3$ knowing $\hat{H}_1$ and $\hat{H}_2$ and use that and x_{s3} to find the final temp.

for (b)

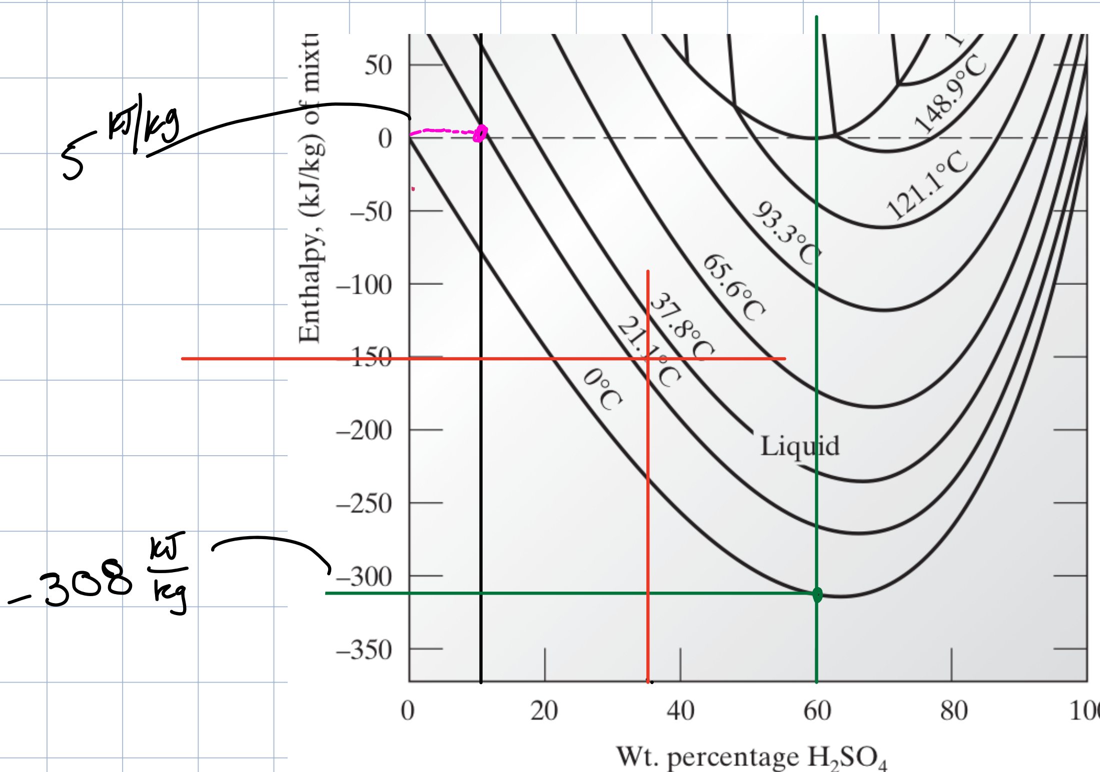
$$x_{s3} = \frac{1}{2}\left(x_{s1} + x_{s2}\right) = 0.35$$



$$\tilde{H}_3 = \frac{1}{2}(-80 + 5) = -37.5 \ \frac{kJ}{kg}$$

$$T_f \approx 103°C$$ in this color on the graph

(b)



$$\tilde{H}_3 = \frac{1}{2}(-308 + 5) = 151.5 \ kJ/kg$$

$T_f = 25\ °C$

(c)

T_f in a >> T of either stream, while T_f in (b) is essentially the same as the 60% stream

when the concentration difference is much larger, like (a), the enthalpy released from mixing is much larger than for (b)