$\mathcal{ME}354$
Thermodynamics 2

Quiz #2 - T02:

Name:	____________________
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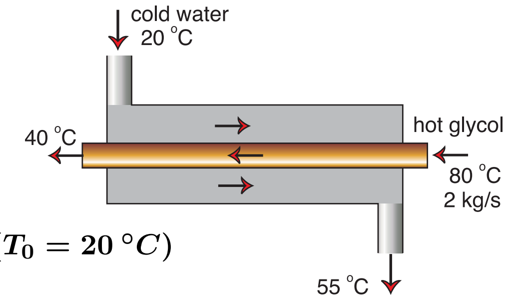
Problem: An adiabatic heat exchanger is to cool ethylene glycol ($c_p = 2.56\ kJ/kg \cdot {}^\circ C$) flowing at a rate of $2\ kg/s$ from 80 to $40\ {}^\circ C$ by water ($c_p = 4.18\ kJ/kg \cdot {}^\circ C$) that enters at $20\ {}^\circ C$ and leaves at $55\ {}^\circ C$. Determine:

(a) the rate of heat transfer $[kW]$ and
(b) the rate of exergy destruction $[kW]$ in the heat exchanger ($T_0 = 20\ {}^\circ C$)



Assumptions

1. SS-SF
2. heat loss to the surroundings is negligible
3. $KE = PE \to 0$
4. properties are constant

Part a)

The rate of heat transfer can be determined from a heat balance between the two flow streams.

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}h_{in} = \dot{Q}_{out} + \dot{m}h_{out}$$ 1 mark

$$\dot{Q}_{out} = \dot{m}c_p(T_{in} - T_{out}) \quad \text{(since KE=PE=0)}$$

The rate of heat transfer out of the glycol is

$$\dot{Q}_{out} = [\dot{m}c_p(T_{in} - T_{out})]_{glycol} = (2\ kg/s)(2.56\ kJ/kg \cdot {}^\circ C)(80 - 40)\ {}^\circ C = 204.8\ kW \Leftarrow$$

2 marks

Part b)

Applying the second law to the entire heat exchanger we get

$$\dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen} = \Delta \dot{S}_{system} \nearrow^0 \quad \text{(SS)}$$

$$\dot{m}_{glycol}s_1 + \dot{m}_{water}s_3 - \dot{m}_{glycol}s_2 + \dot{m}_{water}s_4 + \dot{S}_{gen} = 0$$ 1 mark

$$\dot{m}_{glycol}(s_2 - s_1) + \dot{m}_{water}(s_4 - s_3) = \dot{S}_{gen}$$

The mass flow rate of the water can be determined by noting that $\dot{Q}_{out,glycol} = \dot{Q}_{in,water}$, therefore

$$\dot{m}_{water} = \frac{\dot{Q}_{in,water}}{c_p(T_{out} - T_{in})} = \frac{204.8\ kJ/s}{(4.18\ kJ/kg \cdot {}^\circ C)(55 - 20)\ {}^\circ C} = 1.4\ kg/s$$ 2 marks

For an incompressible substance

$$\Delta s = c_p \ln \frac{T_2}{T_1}$$

1 mark

Therefore

$$\begin{aligned}
\dot{S}_{gen} &= \dot{m}_{glycol} c_p \ln \frac{T_2}{T_1} + \dot{m}_{water} c_p \ln \frac{T_4}{T_3} \\
&= (2\ kg/s)\left(2.56\ \frac{kJ}{kg \cdot K}\right) \ln \frac{40 + 273.15}{80 + 273.15} + (1.4\ kg/s)\left(4.18\ \frac{kJ}{kg \cdot K}\right) \ln \frac{55 + 273.15}{20 + 273.15} \\
&= 0.045\ kW/K
\end{aligned}$$

2 marks

The exergy destroyed is found as

$$\dot{X}_{des} = T_0 \dot{S}_{gen} = (293.15\ K)(0.045\ kW/K) = 13.1\ kW \Leftarrow$$

1 mark