ENGI 9630 – Problem Set 1.

5.3 Compound A is converted into Product B in a zero order reaction. When will 100 mg/L of A be 90% consumed if K = 2.0 mg/L-min.?

zero order: $C_t = C_0 - kt$; $k = \frac{C_0 - C_t}{t}$

$$t = \frac{C_0 - C_t}{k} = \frac{100\ \text{mg/L} - 10\ \text{mg/L}}{2.0\ \text{mg/L}\cdot\text{min}} = \underline{\underline{45\ \text{mins.}}}$$

5.4 and **5.5** When does 90% of 100 mg/L of reactant A become converted into product B in a first order reaction if K = 0.06 min⁻¹? (same for plug flow).

first order: $\frac{C_t}{C_0} = e^{-kt} = \frac{10\ \text{mg/L}}{100\ \text{mg/L}} = 0.1$

$$\ln 0.1 = -kt \ ; \quad \frac{\ln 0.1}{-k} = t = \frac{-2.3026}{-0.06\ \text{min}^{-1}} = \underline{\underline{38.38\ \text{min}}}$$

5.6 When will the reaction in problem 5.4 occur if it takes place in a CSTR?

$$\frac{C_t}{C_0} = \frac{1}{1 + K\Theta} \ ; \quad \frac{C_0}{C_t} = 1 + K\Theta \ ; \quad \frac{C_0}{C_t} - 1 = K\Theta$$

$$\Theta = \frac{\left(C_0/C_t - 1\right)}{K} = \frac{\left(100\ \text{mg/L} / 10\ \text{mg/L} - 1\right)}{0.06\ \text{min}^{-1}} = \underline{\underline{150\ \text{mins.}}}$$

$\boxed{5.8}$ 5000 kg/h stream A from 20°C to 50°C. has $C = 4{,}500\ J/kg\cdot°C$. It will be heated with stream B that cools from 80° to 40°C and has $C = 2{,}700\ J/kg\cdot°C$. What is mass flow of B?

A: $H = W \cdot C \cdot \Delta T$.

$$= (5000\ kg/h)(4{,}500\ J/kg\cdot°C)(50-20°C) = 675{,}000{,}000\ J/h.$$

B: $H = W \cdot C \cdot \Delta T$.

$$W = \frac{H}{C \cdot \Delta T} = \frac{675{,}000{,}000\ J/h}{(2{,}700\ J/kg\cdot°C)(80-40°C)} = \underline{\underline{6250\ kg/h\ \text{stream B}}}$$

$\boxed{5.9}$ $\Theta_m = 80°C$; Heat transfer coefficient, $U = 2.6\ kW/m^2\cdot°C$, Heat that needs to be transferred $= Q =$ $3 \times 10^8\ J/h$. What surface area of heat exchanger is needed?

$(1W = 1J/s)$

$$Q = U \cdot A \cdot \Delta T_m$$

$$A = \frac{Q}{U \cdot \Delta T_m} = \frac{(3 \times 10^8\ J/h)(h/3600\ s)}{(2.6\ kW/m^2\cdot°C)(80°C)(1000\ W/kW)}$$

$$= \underline{\underline{0.400\ m^2}}$$

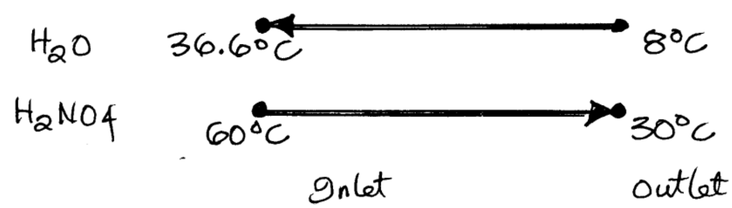
$\boxed{5.10}$ 20 kg/s H_2NO_4 from 60°C to 30°C, $C = 6000$ J/kg·K
30 kg/s H_2O at 8°C, and $C = 4{,}200$ J/kg·K
Heat transfer coefficient, $U = 500$ W/m²·K (between 2 fluids)
Find Area, A for countercurrent heat exchanger.

H_2NO_4: $H = W \cdot C \cdot \Delta T$

$$= (20\ \text{kg/s})(6000\ \text{J/kg·K})(60-30°C) = 3{,}600{,}000\ \text{J/s}.$$

$$H_2O: \quad \Delta T = \frac{H}{W \cdot C} = \frac{3{,}600{,}000\ \text{J/s}}{(30\ \text{kg/s})(4{,}200\ \text{J/kg·K})} = 28.57°C.$$

Final temperature $= 8°C + 28.57°C = 36.57°C$



$\theta_1 = 60 - 36.6 = 23.4°C.$

$\theta_2 = 30 - 8 = 22°C$

$$\theta_m = \frac{\theta_1 - \theta_2}{\ln(\theta_1/\theta_2)} = \frac{23.4 - 22.0}{\ln(23.4/22.0)} = \frac{1.4}{0.0617} = 22.7°C.$$

$$Q = U \cdot A \cdot \theta_m$$

$$A = \frac{Q}{U \cdot \theta_m} = \frac{3{,}600{,}000\ \text{J/s}}{(500\ \text{W/m}^2\text{·K})(22.7°C)} = \underline{\underline{317\ m^2}}$$