HW #2

7.16. (a) $\Delta E_k = 0$ ($u_1 = u_2 = 0$)

$\Delta E_p = 0$ (no elevation change)

$\Delta P = 0$ (the pressure is constant since restraining force is constant, and area is constrant)

$W_s = P\Delta V$ (the only work done is expansion work)

$\hat{H} = 34980 + 35.5T$ (J / mol), $V_1 = 785\ \text{cm}^3$, $T_1 = 400$ K, P = 125 kPa, Q = 83.8 J

$$n = \frac{PV}{RT} = \frac{125\times10^3\ \text{Pa}}{8.314\ \text{m}^3\ \text{Pa / mol}\cdot\text{K}}\left|\frac{785\ \text{cm}^3}{400\ \text{K}}\right|\frac{1\ \text{m}^3}{10^6\ \text{cm}^3} = 0.0295\ \text{mol}$$

$$Q = \Delta H = n(\hat{H}_2 - \hat{H}_1) = 0.0295\ \text{mol}[34980 + 35.5T_2 - 34980 - 35.5(400\text{K})]\ (\text{J / mol})$$

$$83.8\ \text{J} = 0.0295[35.5T_2 - 35.5(400)] \Rightarrow \underline{T_2 = 480\ \text{K}}$$

$$i)\ V = \frac{nRT}{P} = \frac{0.0295\ \text{mol}}{125\times10^3\ \text{Pa}}\left|\frac{8.314\ \text{m}^3\cdot\text{Pa}}{\text{mol}\cdot\text{K}}\right|\frac{10^6\ \text{cm}^3}{1\ \text{m}^3}\left|\frac{480\ \text{K}}{}\right. = \underline{941\ \text{cm}^3}$$

$$ii)\ W = P\Delta V = \frac{125\times10^3\ \text{N}}{\text{m}^2}\left|\frac{(941-785)\text{cm}^3}{}\right|\frac{1\ \text{m}^3}{10^6\ \text{cm}^3} = \underline{19.5\ \text{J}}$$

$$iii)\ Q = \Delta U + P\Delta V \Rightarrow \Delta U = Q - \Delta PV = 83.8\ \text{J} - 19.5\ \text{J} = \underline{64.3\ \text{J}}$$

(b) $\underline{\Delta E_p = 0}$

7.18 (b) $\Delta\dot{H} + \Delta\dot{E}_k + \Delta\dot{E}_p = \dot{Q} - \dot{W}_s$ (The system is the liquid stream.)

⇓ $\Delta\dot{E}_k = 0$ (no change in $\dot{m}$ and u)
$\Delta\dot{E}_p = 0$ (no elevation change)
$\dot{W}_s = 0$ (no moving parts or generated currents)

$\underline{\Delta\dot{H} = \dot{Q},\ \dot{Q} > 0}$

(c) $\Delta\dot{H} + \Delta\dot{E}_k + \Delta\dot{E}_p = \dot{Q} - \dot{W}_s$ (The system is the water)

⇓ $\Delta\dot{H} = 0$ (T and P – constant)
$\Delta\dot{E}_k = 0$ (no change in $\dot{m}$ and u)
$\dot{Q} = 0$ (no ΔT between system and surroundings)

$\underline{\Delta\dot{E}_p = -\dot{W}_s,\ \dot{W}_s > 0\ \text{(for water system)}}$

(d) $\Delta\dot{H} + \Delta\dot{E}_k + \Delta\dot{E}_p = \dot{Q} - \dot{W}_s$ (The system is the oil)

⇓ $\Delta\dot{E}_k = 0$ (no velocity change)

$\underline{\Delta\dot{H} + \Delta\dot{E}_p = \dot{Q} - \dot{W}_s}$ $\dot{Q} < 0$ (friction loss); $\dot{W}_s < 0$ (pump work).

(e) $\Delta\dot{H} + \Delta\dot{E}_k + \Delta\dot{E}_p = \dot{Q} - \dot{W}_s$ (The system is the reaction mixture)

⇓ $\Delta\dot{E}_k = \Delta\dot{E}_p = 0$ (given)
$\Delta\dot{W}_s = 0$ (no moving parts or generated current)

$\underline{\Delta\dot{H} = \dot{Q},\ \dot{Q}\ \text{pos. or neg. depends on reaction}}$

7.21 (a) $\hat{H} = aT + b \quad a = \dfrac{\hat{H}_2 - \hat{H}_1}{T_2 - T_1} = \dfrac{129.8 - 25.8}{50 - 30} = 5.2$

$b = \hat{H}_1 - aT_1 = 25.8 - (5.2)(30) = -130.2 \quad \Rightarrow \underline{\underline{\hat{H}(\text{kJ/kg}) = 5.2T(°\text{C}) - 130.2}}$

$\hat{H} = 0 \Rightarrow T_{ref} = \dfrac{130.2}{5.2} = \underline{\underline{25°\text{C}}}$

Table B.1 $\Rightarrow (S.G.)_{C_6H_{14}(l)} = 0.659 \Rightarrow \hat{V} = \dfrac{1 \text{ m}^3}{659 \text{ kg}} = 1.52 \times 10^{-3} \text{ m}^3/\text{kg}$

$\hat{U}(\text{kJ/kg}) = \hat{H} - P\hat{V} = (5.2T - 130.2)\text{kJ / kg}$

$$- \frac{1 \text{ atm}}{} \left| \frac{1.0132 \times 10^5 \text{ N / m}^2}{1 \text{ atm}} \right| \frac{1.52 \times 10^{-3} \text{ m}^3}{1 \text{ kg}} \left| \frac{1 \text{ J}}{1 \text{ N} \cdot \text{m}} \right| \frac{1 \text{ kJ}}{10^3 \text{ J}}$$

$\Rightarrow \underline{\underline{\hat{U}(\text{kJ/kg}) = 5.2T - 130.4}}$

(b) $\underline{\text{Energy balance:}}$ $Q = \Delta U = \dfrac{20 \text{ kg}}{} \left| \dfrac{[(5.2 \times 20 - 130.4) - (5.2 \times 80 - 130.4)] \text{ kJ}}{1 \qquad \text{kg}} \right. = -6240 \text{ kJ}$

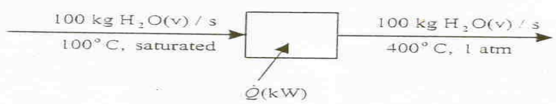
$\underline{\Delta E_k, \Delta E_p, W = 0}$

$\underline{\text{Average rate of heat removal}} = \dfrac{6240 \text{ kJ}}{5 \text{ min}} \left| \dfrac{1 \text{ min}}{60 \text{ s}} \right. = \underline{\underline{20.8 \text{ kW}}}$

7.24 (a) $\Delta\dot{H} + \Delta\dot{E}_k + \Delta\dot{E}_p = \dot{Q} - \dot{W}_s; \ \Delta\dot{E}_k, \ \Delta\dot{E}_p, \ \dot{W}_s = 0 \Rightarrow \Delta\dot{H} = \dot{Q}$

$\hat{H}(400°\text{C}, 1 \text{ atm}) = 3278 \text{ kJ/kg}$ (Table B.6)

$\hat{H}(100°\text{C}, \text{sat'd} \Rightarrow 1 \text{ atm}) = 2676 \text{ kJ/kg}$ (Table B.5)



$\dot{Q} = \dfrac{100 \text{ kg}}{\text{s}} \left| \dfrac{(3278 - 2676.0)\text{kJ}}{\text{kg}} \right| \dfrac{10^3 \text{ J}}{1 \text{ kJ}} = \underline{\underline{6.02 \times 10^7 \text{ J/s}}}$

(b) $\Delta U + \Delta E_k + \Delta E_p = Q - W; \ \Delta E_k, \ \Delta E_p, \ W = 0 \Rightarrow \Delta U = Q$

$\hat{U}(100°\text{C}, 1 \text{ atm}) = 2507 \text{ kJ/kg} \quad \hat{U}(400°\text{C}, 1 \text{ atm}) = 2968 \text{ kJ/kg}$ (Tables B.5 & B.7)

$\Rightarrow Q = \Delta U = m\Delta\hat{U} = 100 \text{ kg}[(2968 - 2507) \text{ kJ/kg}](10^3 \text{ J/kJ}) = \underline{\underline{4.61 \times 10^7 \text{ J}}}$

The difference is the net energy needed to move the fluid through the system (flow work).

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HW # 2

7.31 Basis: 1 kg of 30°C stream

(a) $T_f = \frac{1}{3}(30^\circ C) + \frac{2}{3}(90^\circ C) = \underline{70^\circ C}$

(b) Internal Energy of feeds: $\left.\begin{array}{l}\hat{U}(30^\circ C, \text{ liq.}) = 125.7 \text{ kJ/kg} \\ \hat{U}(90^\circ C, \text{ liq.}) = 376.9 \text{ kJ/kg}\end{array}\right\}$

(Table B.5 - neglecting effect of P on $\hat{H}$)

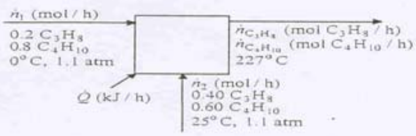
Energy Balance: $Q - W = \Delta U + \Delta E_p + \Delta E_k \xrightarrow{Q=W=\Delta E_p=\Delta E_k=0} \Delta U = 0$

$\Rightarrow 3\hat{U}_f - (1 \text{ kg})(125.7 \text{ kJ / kg}) - (2 \text{ kg})(376.9 \text{ kJ / kg}) = 0$

$\Rightarrow \underline{\hat{U}_f = 293.2 \text{ kJ/kg}} \Rightarrow \underline{T_f = 70.05^\circ C}$ (Table B.5)

$\text{Diff.} = \frac{70.05 - 70.00}{70.05} \times 100\% = \underline{0.07\%}$ (Any answer of this magnitude is acceptable).

7.40 Basis: Given feed rates



Molar flow rates of feed streams:

$$\dot{n}_1 = \frac{300 \text{ L}}{\text{hr}} \left| \frac{1.1 \text{ atm}}{1 \text{ atm}} \right| \frac{1 \text{ mol}}{22.4 \text{ L(STP)}} = 14.7 \text{ mol/h}$$

$$\dot{n}_2 = \frac{200 \text{ L}}{\text{hr}} \left| \frac{273 \text{ K}}{298 \text{ K}} \right| \frac{1.1 \text{ atm}}{1 \text{ atm}} \left| \frac{1 \text{ mol}}{22.4 \text{ L(STP)}} \right. = 9.00 \text{ mol/h}$$

Propane balance $\Rightarrow$ $\dot{n}_{C_3H_8} = \frac{14.7 \text{ mol}}{\text{h}} \left| \frac{0.20 \text{ mol } C_3H_8}{\text{mol}} \right. + \frac{9.00 \text{ mol}}{\text{h}} \left| \frac{0.40 \text{ mol } C_3H_8}{\text{mol}} \right.$

$= 6.54 \text{ mol } C_3H_8/\text{h}$

Total mole balance: $\dot{n}_{C_4H_{10}} = (14.7 + 9.00 - 6.54) \text{ mol } C_4H_{20}/\text{h} = 17.16 \text{ mol } C_4H_{20}/\text{h}$

Energy balance: $\Delta\dot{E}_p, \dot{W}_s = 0$, neglect $\Delta\dot{E}_k \Rightarrow \dot{Q} = \Delta\dot{H}$

$$\dot{Q} = \Delta\dot{H} = \sum_{out} \dot{N}_i \hat{H}_i - \sum_{in} \dot{N}_i \hat{H}_i = \frac{6.54 \text{ mol } C_3H_8}{\text{h}} \left| \frac{20.685 \text{ kJ}}{\text{mol}} \right. + \frac{17.16 \text{ mol } C_4H_{10}}{\text{h}} \left| \frac{27.442 \text{ kJ}}{\text{mol}} \right.$$

$$- \frac{(0.40 \times 9.00) \text{ mol } C_3H_8}{\text{h}} \left| \frac{1.772 \text{ kJ}}{\text{mol}} \right. - \frac{(0.60 \times 9.00) \text{ mol } C_4H_{10}}{\text{h}} \left| \frac{2.394 \text{ kJ}}{\text{mol}} \right. = \underline{587 \text{ kJ/h}}$$

($\hat{H}_i = 0$ for components of 1st feed stream)

7.53 **(a).** $\dot{V}(\text{m}^3/\text{s}) = A_1(\text{m}^2)u_1(\text{m/s}) = A_2(\text{m}^2)u_2(\text{m/s}) \Rightarrow u_2 = u_1 \dfrac{A_1}{A_2} \xrightarrow{A_1=4A_2} \underline{\underline{u_2 = 4u_1}}$

(b). Bernoulli equation ($\Delta z = 0$)

$$\frac{\Delta P}{\rho} + \frac{\Delta u^2}{2} = 0 \Rightarrow \Delta P = P_2 - P_1 = -\frac{\rho\left(u_2^2 - u_1^2\right)}{2}$$

Multiply both sides by -1

Substitute $u_2^2 = 16u_1^2$

Multiply top and bottom of right - hand side by A_1^2

note $\dot{V}^2 = A_1^2 u_1^2$

$$\underline{\underline{P_1 - P_2 = \frac{15\rho\dot{V}^2}{2A_1^2}}}$$

(c) $P_1 - P_2 = (\rho_{Hg} - \rho_{H_2O})gh = \dfrac{15\rho_{H_2O}\dot{V}^2}{2A_1^2} \Rightarrow \dot{V}^2 = \dfrac{2A_1^2 gh}{15}\left(\dfrac{\rho_{Hg}}{\rho_{H_2O}} - 1\right)$

$$\dot{V}^2 = \frac{2\left[\pi(7.5)^2\right]^2 \text{cm}^4}{15}\left|\frac{1 \quad \text{m}^4}{10^8 \ \text{cm}^4}\right|\frac{9.8066 \text{ m}}{\text{s}^2}\left|\ 38 \text{ cm}\ \right|\frac{1 \text{ m}}{10^2 \text{ cm}}\left|(13.6-1)\right. = 1.955\times10^{-3} \ \frac{\text{m}^6}{\text{s}^2}$$

$\Rightarrow \dot{V} = 0.044 \ \text{m}^3/\text{s} = \underline{\underline{44 \ \text{L/s}}}$