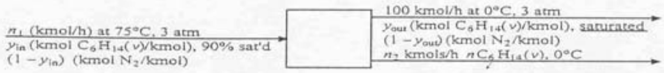
CHE 203

HW # 4

8.48

Basis: $$\frac{746.7\ \text{m}^3\ \text{outlet gas/h}}{} \left| \frac{3\ \text{atm}}{1\ \text{atm}} \right| \frac{1\ \text{kmol}}{22.4\ \text{m}^3(\text{STP})} = 100.0\ \text{kmol/h}$$



Antoine: $\log p_v^* = 6.87776 - \frac{1171.530}{224.336+T}$ $\quad p_v^*(0^\circ\text{C}) = 45.24$ mm Hg, $p_v^*(75^\circ\text{C}) = 920.44$ mm Hg

$$y_{out} = \frac{p_v^*(0^\circ\text{C})}{P} = \frac{45.24}{3(760)} = 0.0198\ \text{kmol}\ C_6H_{14}/\text{kmol}\,,$$

$$y_{in} = \frac{0.90 p_v^*(75^\circ\text{C})}{P} = \frac{(0.90)(920.44)}{3(760)} = 0.363\,\frac{\text{kmol}\ C_6H_{14}}{\text{kmol}}$$

N_2 balance: $\dot{n}_1(1-0.363) = 100(1-0.0198) \Rightarrow \dot{n}_1 = 153.9$ kmol/h

C_6H_{14} balance: $(153.9)(0.363) = (100)(0.0198) + \dot{n}_2 \Rightarrow \dot{n}_2 = 53.89$ kmol $C_6H_{14}(l)$/h

Percent Condensation: (53.89 kmol/h condense)/(0.363×153.9)(kmol/h in feed) × 100% = 96.5%

References: N_2(25°C), n-C_6H_{14}(l, 0°C)

Substance	n_{in}	$\hat{H}_{in}$	n_{out}	$\hat{H}_{out}$	
N_2	98000	1.46	98000	−0.726	$\dot{n}$ in mol/h
$n-C_6H_{14}(r)$	55800	44.75	2000	33.33	$\hat{H}$ in kJ/mol
$n-C_6H_{14}(l)$	–	–	53800	0.0	

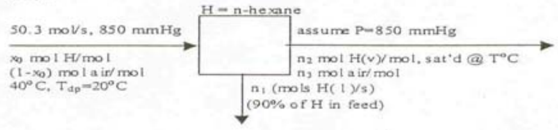
N_2: $\hat{H} = \overline{C}_p(T-25)$, $\quad$ **$n-C_6H_{14}(v)$:** $\hat{H} = \int_0^{68.7} C_{pl}\,dT + \Delta\hat{H}_v(68.7) + \int_{68.7}^{T} C_{pv}\,dT$

Energy balance: $$Q = \Delta \underset{\underset{\sum_{out} n_i \hat{H}_i - \sum_{in} n_i \hat{H}_i}{\Uparrow}}{H} = (-2.64 \times 10^6\ \text{kJ/h})(1\ \text{h}/3600\ \text{s}) \Rightarrow \underline{-733\ \text{kW}}$$

8.50 a.

$$\begin{array}{c|c|c|c|c|c|c} 3\text{ m} & \pi\times(35)^2\text{ cm}^2 & 1\text{ m}^2 & 273\text{ K} & 850\text{ mmHg} & 1\text{ kg}\cdot\text{mol} & 10^3\text{ mol} \\ \hline \text{s} & & 10^4\text{ cm}^2 & (273+40)\text{K} & 760\text{ mmHg} & 22.4\text{ m}^3(\text{STP}) & 1\text{ kg}\cdot\text{mol} \end{array}$$

$= 50.3\ \text{mol/s}$



Degree-of-freedom analysis

  5 unknowns (n_1, n_2, n_3, x_0 and T)
− 2 independent material balances
− 1 saturation condition
− 1 60% recovery equation
− 1 energy balance
  0 degrees of freedom

All unknowns can be calculated.

b.

Antoine equation, Table B.4

$$\underline{(T_{dp})_{feed} = 25\ °\text{C}} \Rightarrow x_0 = \frac{p^*_H(25°\text{C})}{P} = \frac{151\text{ mm Hg}}{850\text{ mm Hg}} = 0.178\ \text{mol H/mol}$$

60% recovery $\Rightarrow n_1 = \dfrac{0.600 \mid (50.3)(0.178)\text{ mols H feed}}{\mid \text{s}} = 5.37\ \text{mols H}(l)/\text{s}$

$$n_2 = (0.400)(50.3)(0.178) = 3.58\ \text{mols H}(v)/\text{s}$$

Air balance: $n_3 = (50.3)(1-0.178) = 41.3$ mols air/s

Mole fraction of hexane in outlet gas:

$$\frac{n_2}{n_2+n_3} = \frac{3.58}{(3.58+41.3)} = \frac{p^*_H(T)}{850\text{ mm Hg}} \Rightarrow p^*_H(T) = 67.8\text{ mm Hg}$$

Antoine equation: $p^*_H = 67.8\text{ mm Hg} \Rightarrow \underline{T = 7.8\ °\text{C}}$

Reference states: $C_6H_{14}(l, 7.8°\text{C})$, air (25°C)

Substance	$\dot{n}_{in}$	$\hat{H}_{in}$	$\dot{n}_{out}$	$\hat{H}_{out}$
$C_6H_{14}O(v)$	8.95	37.5	3.58	32.7
$C_6H_{14}O(l)$	—	—	5.37	0
Air	41.3	0.435	41.3	−0.499

$\dot{n}$ in mol/s
$\hat{H}$ in kJ/mol

$C_6H_{14}O(v)$: $\hat{H} = \int_{7.8}^{68.74} C_{pl}\,dT + \Delta\hat{H}_v(68.74\ °\text{C}) + \int_{68.74}^{T} C_{pv}\,dT$, C_p from Table B.2, $\Delta\hat{H}_v$ from Table B.1

Air: $\hat{H}$ from Table B.8

Energy balance: $Q = \Delta H = \sum_{out}\dot{n}_i\hat{H}_i - \sum_{in}\dot{n}_i\hat{H}_i = \dfrac{-257\ \text{kJ/s} \mid 1\text{ kW cooling}}{\mid -1\ \text{kJ/s}} = \underline{\underline{257\text{ kW}}}$

c. $\left.u\cdot A = u'\cdot A';\ A = \dfrac{\pi\cdot D^2}{4};\ D' = \dfrac{1}{2}D\right\} \Rightarrow u' = 4\cdot u = \underline{\underline{12.0\text{ m/s}}}$

8.69 (a) For 24°C and 50% relative humidity, from Figure 8.4-1,
Absolute humidity = $\underline{0.0093 \text{ kg water / kg DA}}$, Humid volume ≈ $\underline{0.856 \text{ m}^3 \text{ / kg DA}}$
Specific enthalpy = (48 - 0.2) kJ / kg DA = $\underline{47.8 \text{ kJ / kg DA}}$, Dew point = $\underline{13^\circ\text{C}}$, $T_{wb} = \underline{17^\circ\text{C}}$

(b) $\underline{24^\circ\text{C}}$ (T_{db})

(c) $\underline{13^\circ\text{C}}$ (Dew point)

(d) Water evaporates, causing your skin temperature to drop. $\underline{T_{\text{skin}} \approx 13^\circ\text{C}}$ (T_{wb}). At 98% R.H. the rate of evaporation would be lower, T_{skin} would be closer to T_{ambient}, and you would not feel as cold.

8.70 $V_{\text{room}} = 141 \text{ ft}^3$. DA = dry air.

$$m_{\text{DA}} = \frac{140 \text{ ft}^3}{} \Big| \frac{\text{lb-mol}\cdot{}^\circ\text{R}}{0.7302 \text{ ft}^3\cdot\text{atm}} \Big| \frac{29 \text{ lb}_m \text{ DA}}{\text{lb-mol}} \Big\| \frac{1 \text{ atm}}{550\ {}^\circ\text{R}} = 10.1 \text{ lb}_m \text{ DA}$$

$$h_a = \frac{0.205 \text{ lb}_m \text{ H}_2\text{O}}{10.1 \text{ lb}_m \text{ DA}} = 0.0203 \text{ lb}_m \text{ H}_2\text{O / lb}_m \text{ DA}$$

From the psychrometric chart, $T_{db} = 90^\circ\text{F}$, $h_a = 0.0903$

⇓

$\underline{\text{h}_r = 67\%}$ $\underline{\text{T}_{wb} = 80.5^\circ\text{F}}$ $\underline{\hat{\text{V}} = 14.3 \text{ ft}^3 \text{ / lb}_m \text{ DA}}$

$\underline{\text{T}_{\text{dew point}} = 77.3^\circ\text{F}}$ $\underline{\hat{\text{H}} = 44.0 - 0.11 \cong 43.9 \text{ Btu / lb}_m}$

8.72 a. $T_{db} = 40^\circ\text{C},\ T_{\text{dew point}} = 20^\circ\text{C} \overset{\text{Fig. 8.4-1}}{\Longrightarrow} \underline{h_r = 33\%, h_a = 0.0148 \text{ kg H}_2\text{O/kg dry air}}$

$\underline{T_{wb} = 25.5^\circ\text{C}}$

b. Mass of dry air: $m_{da} = \frac{2.00 \text{ L}}{} \Big| \frac{1 \text{ m}^3}{10^3 \text{ L}} \Big| \frac{1 \text{ kg dry air}}{0.92 \text{ m}^3} = 2.2 \times 10^{-3} \text{ kg dry air}$

↑ from Fig. 8.4-1

Mass of water: $\frac{2.2 \times 10^{-3} \text{ kg dry air}}{} \Big| \frac{0.0148 \text{ kg H}_2\text{O}}{1 \text{ kg dry air}} \Big| \frac{10^3 \text{ g}}{1 \text{ kg}} = \underline{0.033 \text{ g H}_2\text{O}}$

c. $\hat{H}(40^\circ\text{C}, 33\% \text{ relative humidity}) \approx (78.0 - 0.65) \text{ kJ/kg dry air} = 77.4 \text{ kJ/kg dry air}$

$\hat{H}(20^\circ\text{C}, \text{saturated}) \approx 57.5 \text{ kJ/kg dry air}$ (both values from Fig. 8.4-1)

$$\Delta \dot{H}_{40\to 20} = \frac{2.2 \times 10^{-3} \text{ kg dry air}}{} \Big| \frac{(57.5 - 77.4) \text{ kJ}}{\text{kg dry air}} \Big| \frac{10^3 \text{ J}}{1 \text{ kJ}} = \underline{-44 \text{ J}}$$

d. Energy balance: closed system

$$n = \frac{2.2 \times 10^{-3} \text{ kg dry air}}{} \Big| \frac{10^3 \text{ g}}{1 \text{ kg}} \Big| \frac{1 \text{ mol}}{29 \text{ g}} + \frac{0.033 \text{ g H}_2\text{O}}{} \Big| \frac{1 \text{ mol}}{18 \text{ g}} = 0.078 \text{ mol}$$

$$Q = \Delta U = n\Delta\hat{U} = n(\Delta\hat{H} - R\Delta T) = \Delta H - nR\Delta T$$

$$= -44 \text{ J} - \frac{0.078 \text{ mol}}{} \Big| \frac{8.314 \text{ J}}{\text{mol}\cdot\text{K}} \Big| \frac{(20-40)^\circ\text{C}}{} \Big| \frac{1 \text{ K}}{1^\circ\text{C}} = \underline{-31 \text{ J}} \text{(23 J transferred from the air)}$$