CHAPTER THREE

3.1 **(a)** $$m = \begin{array}{c|c} 16\times 6\times 2\ \text{m}^3 & 1000\ \text{kg} \\ \hline & \text{m}^3 \end{array} \approx (2\times 10)(5)(2)\left(10^3\right) \approx \underline{\underline{2\times 10^5\ \text{kg}}}$$

(b) $$\dot{m} = \begin{array}{c|c|c|c} 8\ \text{oz} & 1\ \text{qt} & 10^6\ \text{cm}^3 & 1\ \text{g} \\ \hline 2\ \text{s} & 32\ \text{oz} & 1056.68\ \text{qt} & \text{cm}^3 \end{array} \approx \frac{4\times 10^6}{(3\times 10)\left(10^3\right)} \approx \underline{\underline{1\times 10^2\ \text{g/s}}}$$

(c) Weight of a boxer $\approx$ 220 lb_m

$$W_{\max} \geq \begin{array}{c|c} 12\times 220\ \text{lb}_\text{m} & 1\ \text{stone} \\ \hline & 14\ \text{lb}_\text{m} \end{array} \approx \underline{\underline{220\ \text{stones}}}$$

(d) dictionary

$$V = \frac{\pi D^2 L}{4} = \begin{array}{c|c|c|c|c|c} \frac{3.14}{4} & 4.5^2\ \text{ft}^2 & 800\ \text{miles} & 5880\ \text{ft} & 7.4805\ \text{gal} & 1\ \text{barrel} \\ \hline & & & 1\ \text{mile} & 1\ \text{ft}^3 & 42\ \text{gal} \end{array}$$

$$\approx \frac{3\times 4\times 5\times\left(8\times 10^2\right)\times\left(5\times 10^3\right)\times 7}{4\times 4\times 10} \approx \underline{\underline{1\times 10^7\ \text{barrels}}}$$

(e) $$(i)V \approx \begin{array}{c|c} 6\ \text{ft}\times 1\ \text{ft}\times 0.5\ \text{ft} & 28{,}317\ \text{cm}^3 \\ \hline & 1\ \text{ft}^3 \end{array} \approx 3\times 3\times 10^4 \approx \underline{\underline{1\times 10^5\text{cm}^3}}$$

$$(ii)V \approx \begin{array}{c|c|c} 150\ \text{lb}_\text{m} & 1\ \text{ft}^3 & 28{,}317\ \text{cm}^3 \\ \hline & 62.4\ \text{lb}_\text{m} & 1\ \text{ft}^3 \end{array} \approx \frac{150\times 3\times 10^4}{60} \approx \underline{\underline{1\times 10^5\ \text{cm}^3}}$$

(f) $\underline{\underline{SG \approx 1.05}}$

3.2 **(a)** $$\text{(i)} \begin{array}{c|c|c} 995\ \text{kg} & 1\ \text{lb}_\text{m} & 0.028317\ \text{m}^3 \\ \hline \text{m}^3 & 0.45359\ \text{kg} & 1\ \text{ft}^3 \end{array} = \underline{\underline{62.12\ \text{lb}_\text{m}/\text{ft}^3}}$$

$$\text{(ii)} \begin{array}{c|c} 995\ \text{kg}/\text{m}^3 & 62.43\ \text{lb}_\text{m}/\text{ft}^3 \\ \hline & 1000\ \text{kg}/\text{m}^3 \end{array} = \underline{\underline{62.12\ \text{lb}_\text{m}/\text{ft}^3}}$$

(b) $$\rho = \rho_{H_2O}\times SG = 62.43\ \text{lb}_\text{m}/\text{ft}^3\times 5.7 = \underline{\underline{360\ \text{lb}_\text{m}/\text{ft}^3}}$$

3.3 **(a)** $$\begin{array}{c|c|c} 50\ \text{L} & 0.70\times 10^3\ \text{kg} & 1\ \text{m}^3 \\ \hline & \text{m}^3 & 10^3\ \text{L} \end{array} = \underline{\underline{35\ \text{kg}}}$$

(b) $$\begin{array}{c|c|c|c} 1150\ \text{kg} & \text{m}^3 & 1000\ \text{L} & 1\ \text{min} \\ \hline \text{min} & 0.7\times 1000\ \text{kg} & 1\ \text{m}^3 & 60\ \text{s} \end{array} = \underline{\underline{27\ \text{L/s}}}$$

(c) $$\begin{array}{c|c|c} 10\ \text{gal} & 1\ \text{ft}^3 & 0.70\times 62.43\ \text{lb}_\text{m} \\ \hline 2\ \text{min} & 7.481\ \text{gal} & 1\ \text{ft}^3 \end{array} \cong \underline{\underline{29\ \text{lb}_\text{m}/\text{min}}}$$

3.3 (cont'd)

(d) Assuming that 1 cm^3 kerosene was mixed with V_g (cm^3) gasoline

$$V_g\left(\text{cm}^3\text{gasoline}\right) \Rightarrow 0.70V_g\left(\text{g gasoline}\right)$$

$$1\left(\text{cm}^3 \text{ kerosene}\right) \Rightarrow 0.82\left(\text{g kerosene}\right)$$

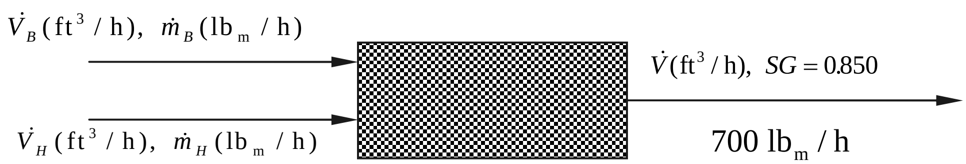
$$SG = \frac{\left(0.70V_g + 0.82\right)\left(\text{g blend}\right)}{V_g + 1\left(\text{cm}^3 \text{ blend}\right)} = 0.78 \;\Rightarrow\; V_g = \frac{0.82-0.78}{0.78-0.70} = 0.50 \text{ cm}^3$$

$$\underline{\text{Volumetric ratio}} = \frac{V_{\text{gasoline}}}{V_{\text{kerosene}}} = \frac{0.50 \text{ cm}^3}{1 \text{ cm}^3} = \underline{\underline{0.50 \text{ cm}^3 \text{ gasoline / cm}^3 \text{ kerosene}}}$$

3.4 In France: $\begin{array}{c|c|c|c} 50.0 \text{ kg} & \text{L} & 5 \text{ Fr} & \$1 \\ \hline & 0.7 \times 1.0 \text{ kg} & 1\text{L} & 5.22 \text{ Fr} \end{array} = \underline{\underline{\$68.42}}$

In U.S.: $\begin{array}{c|c|c|c} 50.0 \text{ kg} & \text{L} & 1 \text{ gal} & \$1.20 \\ \hline & 0.70 \times 1.0 \text{ kg} & 3.7854 \text{ L} & 1 \text{ gal} \end{array} = \underline{\underline{\$22.64}}$

3.5



(a) $\dot{V} = \begin{array}{c|c} 700 \text{ lb}_m & \text{ft}^3 \\ \hline \text{h} & 0.850 \times 62.43 \text{ lb}_m \end{array} = 13.19 \text{ ft}^3 / \text{h}$

$$\dot{m}_B = \begin{array}{c|c} \dot{V}_B\left(\text{ft}^3\right) & 0.879 \times 62.43 \text{ lb}_m \\ \hline \left(\text{h}\right) & \text{ft}^3 \end{array} = 54.88\dot{V}_B \; \left(\text{kg / h}\right)$$

$$\dot{m}_H = \left(\dot{V}_H\right)\left(0.659 \times 62.43\right) = 41.14\dot{V}_H \; \left(\text{kg / h}\right)$$

$$\dot{V}_B + \dot{V}_H = 13.19 \text{ ft}^3 / \text{h}$$

$$\dot{m}_B + \dot{m}_H = 54.88\dot{V}_B + 41.14\dot{V}_H = 700 \text{ lb}_m$$

$$\Rightarrow \quad \dot{V}_B = \underline{\underline{11.4 \text{ ft}^3 / \text{h}}} \Rightarrow \dot{m}_B = \underline{\underline{628 \text{ lb}_m / \text{h benzene}}}$$

$$\dot{V}_H = \underline{\underline{1.74 \text{ ft}^3 / \text{h}}} \Rightarrow \dot{m}_H = \underline{\underline{71.6 \text{ lb}_m / \text{h hexane}}}$$

(b) – No buildup of mass in unit.
– ρ_B and ρ_H at inlet stream conditions are equal to their tabulated values (which are strictly valid at 20$^\text{o}$C and 1 atm.)
– Volumes of benzene and hexane are additive.
– Densitometer gives correct reading.

3.6 **(a)** $V = \dfrac{195.5 \text{ kg } \mathrm{H_2SO_4}}{} \Bigg| \dfrac{1 \text{ kg solution}}{0.35 \text{kg } \mathrm{H_2SO_4}} \Bigg| \dfrac{\text{L}}{1.2563 \times 1.000 \text{ kg}} = \underline{\underline{445 \text{ L}}}$

(b)

$$V_{\text{ideal}} = \frac{195.5 \text{ kg } \mathrm{H_2SO_4}}{} \Bigg| \frac{\text{L}}{1.8255 \times 1.00 \text{ kg}}$$

$$+ \frac{195.5 \text{ kg } \mathrm{H_2SO_4}}{} \Bigg| \frac{0.65 \text{ kg } \mathrm{H_2O}}{0.35 \text{ kg } \mathrm{H_2SO_4}} \Bigg| \frac{\text{L}}{1.000 \text{ kg}} = 470 \text{ L}$$

$\underline{\%\ \text{error}} = \dfrac{470 - 445}{445} \times 100\% = \underline{\underline{5.6\%}}$

3.7 Buoyant force $(\text{up}) \underset{\Downarrow}{=}$ Weight of block (down)

Mass of oil displaced + Mass of water displaced = Mass of block

$\rho_{\text{oil}}\ (0.542)V + \rho_{\mathrm{H_2O}}\ (1 - 0.542)V = \rho_{\text{c}}\ V$

From Table B.1: $\rho_c = 2.26 \text{ g/cm}^3$, $\rho_w = 1.00 \text{ g/cm}^3 \Rightarrow \rho_{oil} = 3.325 \text{ g/cm}^3$

$m_{\text{oil}} = \rho_{\text{oil}} \times V = 3.325 \text{ g/cm}^3 \times 35.3 \text{ cm}^3 = 117.4 \text{ g}$

$m_{\text{oil + flask}} = 117.4 \text{ g} + 124.8 \text{ g} = \underline{\underline{242 \text{ g}}}$

3.8 Buoyant force $(\text{up}) =$ Weight of block (down)

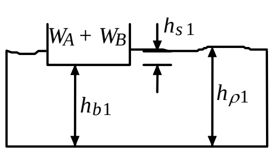
$\Rightarrow W_{\text{displaced liquid}} = W_{\text{block}} \Rightarrow (\rho V g)_{\text{disp. Liq}} = (\rho V g)_{\text{block}}$

$\underline{\text{Expt. 1}}$: $\rho_w(1.5A)g = \rho_B(2A)g \Rightarrow \rho_B = \rho_w \times \dfrac{1.5}{2}$

$$\xRightarrow{\rho_w = 1.00 \text{ g/cm}^3} \rho_B = 0.75 \text{ g/cm}^3 \Rightarrow \underline{\underline{(SG)_B = 0.75}}$$

$\underline{\text{Expt. 2}}$: $\rho_{\text{soln}}(A)g = \rho_B(2A)g \Rightarrow \rho_{\text{soln}} = 2\rho_B = 1.5 \text{ g/cm}^3 \Rightarrow \underline{\underline{(SG)_{\text{soln}} = 1.5}}$

3.9



Before object is jettisoned

Let $\rho_w =$ density of water. $\underline{\text{Note: } \rho_A > \rho_w}$ (object sinks)

$\underline{\text{Volume displaced}}$: $V_{d1} = A_b h_{si} = A_b\left(h_{p1} - h_{b1}\right)$ (1)

$\underline{\text{Archimedes}} \Rightarrow \underbrace{\rho_w V_{d1} g}_{\text{weight of displaced water}} = W_A + W_B$

Subst. (1) for V_{d1}, solve for $\left(h_{p1} - h_{b1}\right)$

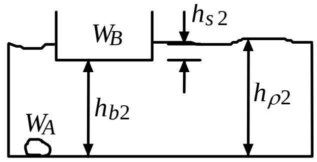
$$h_{p1} - h_{b1} = \frac{W_A + W_B}{p_w g A_b} \qquad (2)$$

$\underline{\text{Volume of pond water}}$: $V_w = A_p h_{p1} - V_{d1} \overset{(i)}{\Rightarrow} V_w = A_p h_{p1} - A_b\left(h_{p1} - h_{b1}\right)$

$$\xRightarrow[\text{for } b_{p1} - h_{b1}]{\text{subst. (2)}} V_w = A_p h_{p1} - \frac{W_A + W_B}{p_w g} \Rightarrow h_{p1} = \frac{V_w}{A_p} + \frac{W_A + W_B}{p_w g A_p} \qquad (3)$$

$$\xRightarrow[\text{(2), solve for } h_{b1}]{\text{subst. (3) for } h_{p1} \text{ in}} h_{b1} = \frac{V_w}{A_p} + \frac{\left(W_A + W_B\right)}{p_w g}\left[\frac{1}{A_p} - \frac{1}{A_b}\right] \qquad (4)$$

3.9 (cont'd)



After object is jettisoned

Let $V_A =$ volume of jettisoned object $= \dfrac{W_A}{\rho_A g}$ (5)

<u>Volume displaced by boat</u>: $V_{d2} = A_b\left(h_{p2} - h_{b2}\right)$ (6)

<u>Archimedes</u> $\Rightarrow \rho_W V_{d2} g \underset{\Downarrow}{=} W_B$

Subst. for V_{d2}, solve for $\left(h_{p2} - h_{b2}\right)$

$$h_{p2} - h_{b2} = \frac{W_B}{p_w g A_b} \qquad (7)$$

<u>Volume of pond water</u>: $V_w = A_p h_{p2} - V_{d2} - V_A \xrightarrow{(5),\,(6)\ \&\ (7)} V_w = A_p h_{p2} - \dfrac{W_B}{p_w g} - \dfrac{W_A}{p_A g}$

$$\underset{h_{p2}}{\overset{\text{solve for}}{\Rightarrow}} h_{p2} = \frac{V_w}{A_p} + \frac{W_B}{p_w g A_p} + \frac{W_A}{p_A g A_p} \qquad (8)$$

$$\underset{\text{for } h_{p2} \text{ in } (7),\text{ solve for } h_{b2}}{\overset{\text{subst. } (8)}{\Rightarrow}} h_{b2} = \frac{V_w}{A_p} + \frac{W_B}{p_w g A_p} + \frac{W_A}{p_A g A_p} - \frac{W_B}{p_w g A_b} \qquad (9)$$

(a) <u>Change in pond level</u>

$$h_{p2} - h_{p1} \overset{(8)-(3)}{=} \frac{W_A}{A_p g}\left[\frac{1}{p_A} - \frac{1}{p_W}\right] = \frac{W_A\left(p_W - p_A\right)}{p_A p_W g A_p} \xrightarrow{\rho_W < \rho_A} < 0$$

$\Rightarrow$ <u>the pond level falls</u>

(b) <u>Change in boat level</u>

$$h_{p2} - h_{p1} \overset{(9)-(4)}{=} \frac{W_A}{A_p g}\left[\frac{1}{p_A A_p} - \frac{1}{p_W A_p} + \frac{1}{p_W A_b}\right] \overset{(5)}{=} \overbrace{\left(\frac{V_A}{A_p}\right)}^{>0}\left[1 + \overbrace{\left(\frac{p_A}{p_W}\left(\frac{A_p}{A_b} - 1\right)\right)}^{>0}\right] > 0$$

$\Rightarrow$ <u>the boat rises</u>

3.10 (a) $\rho_{\text{bulk}} = \begin{array}{c|c} 2.93 \text{ kg CaCO}_3 & 0.70 \text{ L CaCO}_3 \\ \hline \text{L CaCO}_3 & \text{L total} \end{array} = \underline{\underline{2.05 \text{ kg / L}}}$

(b) $W_{bag} = \rho_{bulk} V g = \begin{array}{c|c|c|c} 2.05 \text{ kg} & 50 \text{ L} & 9.807 \text{ m / s}^2 & 1 \text{ N} \\ \hline \text{L} & & & 1 \text{ kg} \cdot \text{m / s}^2 \end{array} = \underline{\underline{1.00 \times 10^3 \text{ N}}}$

<u>Neglected the weight of the bag itself and of the air in the filled bag.</u>

(c) The limestone would fall short of filling three bags, because
– the powder would pack tighter than the original particles.
– you could never recover 100% of what you fed to the mill.

3.11 **(a)** $W_b = m_b g = \dfrac{122.5\text{ kg}}{} \left| \dfrac{9.807\text{ m/s}^2}{} \right| \dfrac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2} = \underline{\underline{1202\text{ N}}}$

$$V_b = \frac{W_b - W_I}{\rho_w g} = \frac{(1202\text{ N - }44.0\text{ N})}{0.996\text{ kg/L}\times 9.807\text{ m/s}^2} \left| \frac{1\text{ kg}\cdot\text{m/s}^2}{1\text{ N}} \right. = \underline{\underline{119\text{ L}}}$$

$$\rho_b = \frac{m_b}{V_b} = \frac{122.5\text{ kg}}{119\text{ L}} = \underline{\underline{1.03\text{ kg/L}}}$$

(b)

$$m_f + m_{nf} = m_b \qquad (1)$$

$$x_f = \frac{m_f}{m_b} \Rightarrow m_f = m_b x_f \qquad (2)$$

$$(1),(2) \Rightarrow m_{nf} = m_b\left(1 - x_f\right) \qquad (3)$$

$$V_f + V_{nf} = V_b \Rightarrow \frac{m_f}{\rho_f} + \frac{m_{nf}}{\rho_{nf}} = \frac{m_b}{\rho_b}$$

$$\overset{(2),(3)}{\Rightarrow} m_b\left(\frac{x_f}{\rho_f} + \frac{1-x_f}{\rho_{nf}}\right) = \frac{m_b}{\rho_b} \Rightarrow x_f\left(\frac{1}{\rho_f} - \frac{1}{\rho_{nf}}\right) = \frac{1}{\rho_b} - \frac{1}{\rho_{nf}} \quad \Rightarrow x_f = \underline{\underline{\frac{1/\rho_b - 1/\rho_{nf}}{1/\rho_f - 1/\rho_{nf}}}}$$

(c) $x_f = \dfrac{1/\rho_b - 1/\rho_{nf}}{1/\rho_f - 1/\rho_{nf}} = \dfrac{1/1.03 - 1/1.1}{1/0.9 - 1/1.1} = \underline{\underline{0.31}}$

(d) $V_f + V_{nf} + V_{lungs} + V_{other} = V_b$

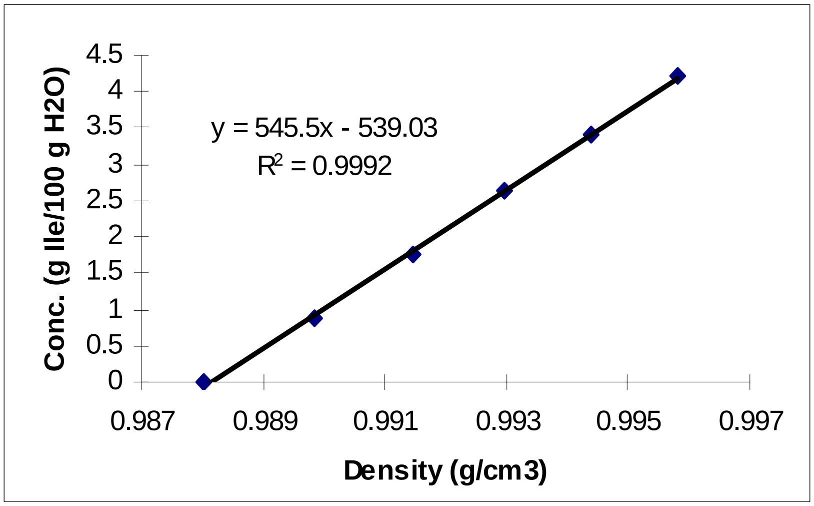
$$\frac{m_f}{\rho_f} + \frac{m_{nf}}{\rho_{nf}} + V_{lungs} + V_{other} = \frac{m_b}{\rho_b}$$

$$\xrightarrow[m_{nf} = m_b(1-x_f)]{m_f = m_b x_f} m_b\left(\frac{x_f}{\rho_f} - \frac{1-x_f}{\rho_{nf}}\right) + (V_{lungs} + V_{other}) = m_b\left(\frac{1}{\rho_b} - \frac{1}{\rho_{nf}}\right)$$

$$\Rightarrow x_f\left(\frac{1}{\rho_f} - \frac{1}{\rho_{nf}}\right) = \frac{1}{\rho_b} - \frac{1}{\rho_{nf}} - \frac{V_{lungs} + V_{other}}{m_b}$$

$$\Rightarrow x_f = \frac{\left(\dfrac{1}{\rho_b} - \dfrac{1}{\rho_{nf}}\right) - \left(\dfrac{V_{lungs} + V_{other}}{m_b}\right)}{\left(\dfrac{1}{\rho_f} - \dfrac{1}{\rho_{nf}}\right)} = \frac{\left(\dfrac{1}{1.03} - \dfrac{1}{1.1}\right) - \left(\dfrac{1.2 + 0.1}{122.5}\right)}{\left(\dfrac{1}{0.9} - \dfrac{1}{1.1}\right)} = \underline{\underline{0.25}}$$

3.12 (a)



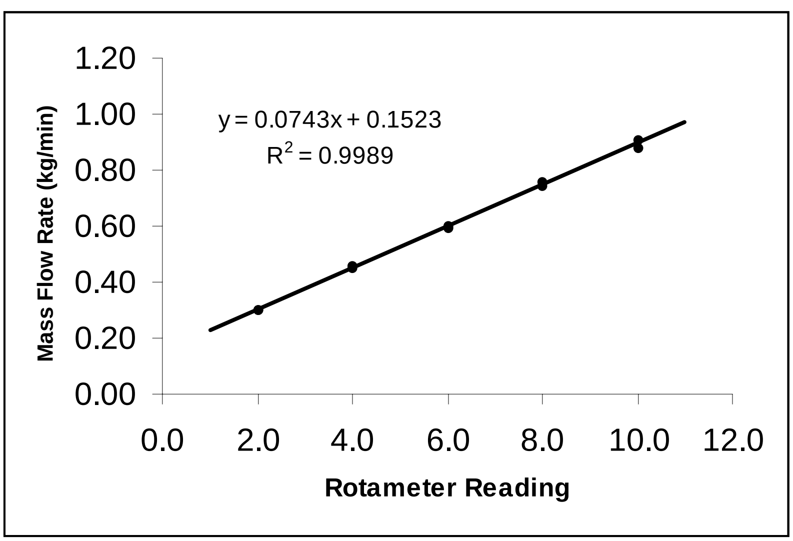
From the plot above, $r = 545.5\rho - 539.03$

(b) For $\rho = 0.9940\ \text{g}/\text{cm}^3$, $\quad r = 3.197\ \text{g Ile}/100\text{g H}_2\text{O}$

$$\dot{m}_{Ile} = \frac{150\ \text{L}}{\text{h}}\left|\frac{0.994\ \text{g}}{\text{cm}^3}\right|\frac{1000\ \text{cm}^3}{\text{L}}\left|\frac{3.197\ \text{g Ile}}{103.197\ \text{g sol}}\right|\frac{1\ \text{kg}}{1000\ \text{g}} = \underline{\underline{4.6\ \text{kg Ile}/\text{h}}}$$

(c) The measured solution density is 0.9940 g ILE/cm^3 solution *at 50°C*. For the calculation of Part (b) to be correct, the density would have to be changed to its equivalent at 47°C. Presuming that the dependence of solution density on *T* is the same as that of pure water, the solution density at 47°C would be higher than 0.9940 g ILE/cm^3. The ILE mass flow rate calculated in Part (b) is therefore <u>too low</u>.

3.13 (a)



3.13 (cont'd)

From the plot, $R = 5.3 \Rightarrow \dot{m} = 0.0743(5.3) + 0.1523 = \underline{\underline{0.55 \text{ kg / min}}}$

(b)

Rotameter Reading	Collection Time (min)	Collected Volume (cm3)	Mass Flow Rate (kg/min)	Difference Duplicate (D_i)	Mean D_i
2	1	297	0.297		
2	1	301	0.301	0.004	
4	1	454	0.454		
4	1	448	0.448	0.006	
6	0.5	300	0.600		
6	0.5	298	0.596	0.004	0.0104
8	0.5	371	0.742		
8	0.5	377	0.754	0.012	
10	0.5	440	0.880		
10	0.5	453	0.906	0.026	

$$\overline{D}_i = \frac{1}{5}(0.004 + 0.006 + 0.004 + 0.012 + 0.026) = \underline{\underline{0.0104 \text{ kg / min}}}$$

<u>95% confidence limits</u>: $(0.610 \pm 1.74\overline{D}_i)$ kg / min $= \underline{\underline{0.610 \pm 0.018 \text{ kg / min}}}$

There is roughly a 95% probability that the true flow rate is between 0.592 kg / min and 0.628 kg / min.

3.14 **(a)** $\dfrac{15.0 \text{ kmol } C_6H_6 \,\big|\, 78.114 \text{ kg } C_6H_6}{\big|\, \text{kmol } C_6H_6} = \underline{\underline{1.17 \times 10^3 \text{ kg } C_6H_6}}$

(b) $\dfrac{15.0 \text{ kmol } C_6H_6 \,\big|\, 1000 \text{ mol}}{\big|\, \text{kmol}} = \underline{\underline{1.5 \times 10^4 \text{ mol } C_6H_6}}$

(c) $\dfrac{15{,}000 \text{ mol } C_6H_6 \,\big|\, \text{lb-mole}}{\big|\, 453.6 \text{ mol}} = \underline{\underline{33.07 \text{ lb-mole } C_6H_6}}$

(d) $\dfrac{15{,}000 \text{ mol } C_6H_6 \,\big|\, 6 \text{ mol C}}{\big|\, 1 \text{ mol } C_6H_6} = \underline{\underline{90{,}000 \text{ mol C}}}$

(e) $\dfrac{15{,}000 \text{ mol } C_6H_6 \,\big|\, 6 \text{ mol H}}{\big|\, 1 \text{ mol } C_6H_6} = \underline{\underline{90{,}000 \text{ mol H}}}$

(f) $\dfrac{90{,}000 \text{ mol C} \,\big|\, 12.011 \text{ g C}}{\big|\, \text{mol C}} = \underline{\underline{1.08 \times 10^6 \text{ g C}}}$

(g) $\dfrac{90{,}000 \text{ mol H} \,\big|\, 1.008 \text{ g H}}{\big|\, \text{mol H}} = \underline{\underline{9.07 \times 10^4 \text{ g H}}}$

(h) $\dfrac{15{,}000 \text{ mol } C_6H_6 \,\big|\, 6.022 \times 10^{23}}{\big|\, \text{mol}} = \underline{\underline{9.03 \times 10^{27} \text{ molecules of } C_6H_6}}$

3.15 **(a)** $\dot{m} = \frac{175 \text{ m}^3}{\text{h}} \left| \frac{1000 \text{ L}}{\text{m}^3} \right| \frac{0.866 \text{ kg}}{\text{L}} \left| \frac{1 \text{ h}}{60 \text{ min}} \right. = \underline{\underline{2526 \text{ kg / min}}}$

(b) $\dot{n} = \frac{2526 \text{ kg}}{\text{min}} \left| \frac{1000 \text{ mol}}{92.13 \text{ kg}} \right| \frac{1 \text{ min}}{60 \text{ s}} = \underline{\underline{457 \text{ mol / s}}}$

(c) Assumed density (SG) at T, P of stream is the same as the density at 20°C and 1 atm

3.16 **(a)** $\frac{200.0 \text{ kg mix}}{} \left| \frac{0.150 \text{ kg } CH_3OH}{\text{kg mix}} \right| \frac{\text{kmol } CH_3OH}{32.04 \text{ kg } CH_3OH} \left| \frac{1000 \text{ mol}}{1 \text{ kmol}} \right. = \underline{\underline{936 \text{ mol } CH_3OH}}$

(b) $\dot{m}_{mix} = \frac{100.0 \text{ lb-mole MA}}{\text{h}} \left| \frac{74.08 \text{ lb}_m \text{ MA}}{1 \text{ lb-mole MA}} \right| \frac{1 \text{ lb}_m \text{ mix}}{0.850 \text{ lb}_m \text{ MA}} = \underline{\underline{8715 \text{ lb}_m \text{ / h}}}$

3.17 $\overline{M} = \frac{0.25 \text{ mol } N_2}{} \left| \frac{28.02 \text{ g } N_2}{\text{mol } N_2} \right. + \frac{0.75 \text{ mol } H_2}{} \left| \frac{2.02 \text{ g } H_2}{\text{mol } H_2} \right. = 8.52 \text{ g/mol}$

$\dot{m}_{N_2} = \frac{3000 \text{ kg}}{\text{h}} \left| \frac{\text{kmol}}{8.52 \text{ kg}} \right| \frac{0.25 \text{ kmol } N_2}{\text{kmol feed}} \left| \frac{28.02 \text{ kg } N_2}{\text{kmol } N_2} \right. = \underline{\underline{2470 \text{ kg } N_2/\text{h}}}$

3.18 $M_{\text{suspension}} = 565 \text{ g} - 65 \text{ g} = 500 \text{ g}$, $M_{CaCO_3} = 215 \text{ g} - 65 \text{ g} = 150 \text{ g}$

(a) $\dot{V} = \underline{\underline{455 \text{ mL/min}}}$, $\dot{m} = \underline{\underline{500 \text{ g/min}}}$

(b) $\rho = \dot{m} / \dot{V} = 500 \text{ g} / 455 \text{ mL} = \underline{\underline{1.10 \text{ g/mL}}}$

(c) $150 \text{ g } CaCO_3 / 500 \text{ g suspension} = \underline{\underline{0.300 \text{ g } CaCO_3/\text{g suspension}}}$

3.19 Assume 100 mol mix.

$$m_{C_2H_5OH} = \frac{10.0 \text{ mol } C_2H_5OH}{} \left| \frac{46.07 \text{ g } C_2H_5OH}{\text{mol } C_2H_5OH} \right. = 461 \text{ g } C_2H_5OH$$

$$m_{C_4H_8O_2} = \frac{75.0 \text{ mol } C_4H_8O_2}{} \left| \frac{88.1 \text{ g } C_4H_8O_2}{\text{mol } C_4H_8O_2} \right. = 6608 \text{ g } C_4H_8O_2$$

$$m_{CH_3COOH} = \frac{15.0 \text{ mol } CH_3COOH}{} \left| \frac{60.05 \text{ g } CH_3COOH}{\text{mol } CH_3COOH} \right. = 901 \text{ g } CH_3COOH$$

$$x_{C_2H_5OH} = \frac{461 \text{ g}}{461 \text{ g} + 6608 \text{ g} + 901 \text{ g}} = \underline{\underline{0.0578 \text{ g } C_2H_5OH \text{ / g mix}}}$$

$$x_{C_4H_8O_2} = \frac{6608 \text{ g}}{461 \text{ g} + 6608 \text{ g} + 901 \text{ g}} = \underline{\underline{0.8291 \text{ g } C_4H_8O_2 \text{ / g mix}}}$$

$$x_{CH_3COOH} = \frac{901 \text{ g}}{461 \text{ g} + 6608 \text{ g} + 901 \text{ g}} = \underline{\underline{0.113 \text{ g } CH_3COOH \text{ / g mix}}}$$

$$\overline{MW} = \frac{461 \text{ g} + 6608 \text{ g} + 901 \text{ g}}{100 \text{ mol}} = \underline{\underline{79.7 \text{ g / mol}}}$$

$$m = \frac{25 \text{ kmol EA}}{} \left| \frac{100 \text{ kmol mix}}{75 \text{ kmol EA}} \right| \frac{79.7 \text{ kg mix}}{1 \text{ kmol mix}} = \underline{\underline{2660 \text{ kg mix}}}$$

3.20 (a)

Unit	*Function*
Crystallizer	Form solid gypsum particles from a solution
Filter	Separate particles from solution
Dryer	Remove water from filter cake

(b) $$m_{\text{gypsum}} = \frac{1 \text{ L slurry}}{} \bigg| \frac{0.35 \text{ kg } CaSO_4 \cdot 2H_2O}{\text{L slurry}} = \underline{\underline{0.35 \text{ kg } CaSO_4 \cdot 2H_2O}}$$

$$V_{\text{gypsum}} = \frac{0.35 \text{ kg } CaSO_4 \cdot 2H_2O}{} \bigg| \frac{\text{L } CaSO_4 \cdot 2H_2O}{2.32 \text{ kg } CaSO_4 \cdot 2H_2O} = \underline{\underline{0.151 \text{ L } CaSO_4 \cdot 2H_2O}}$$

$$CaSO_4 \text{ in gypsum: } m = \frac{0.35 \text{ kg } gypsum}{} \bigg| \frac{136.15 \text{ kg } CaSO_4}{172.18 \text{ kg } gypsum} = \underline{\underline{0.277 \text{ kg } CaSO_4}}$$

$$CaSO_4 \text{ in soln.: } m = \frac{(1-0.151) \text{ L sol}}{} \bigg| \frac{1.05 \text{ kg}}{\text{L}} \bigg| \frac{0.209 \text{ kg } CaSO_4}{100.209 \text{ kg sol}} = \underline{\underline{0.00186 \text{ kg } CaSO_4}}$$

(c) $$m = \frac{0.35 \text{ kg gypsum}}{} \bigg| \frac{0.05 \text{ kg sol}}{0.95 \text{ kg gypsum}} \bigg| \frac{0.209 \text{ g } CaSO_4}{100.209 \text{ g sol}} = 3.84 \times 10^{-5} \text{ kg } CaSO_4$$

$$\underline{\%\text{recovery}} = \frac{0.277 \text{ g} + 3.84 \times 10^{-5} \text{ g}}{0.277 \text{ g} + 0.00186 \text{ g}} \times 100\% = \underline{\underline{99.3\%}}$$

3.21

$$\left.\begin{array}{l} \underline{\text{CSA}}: \dfrac{45.8 \text{ L}}{\text{min}} \bigg| \dfrac{0.90 \text{ kg}}{\text{L}} \bigg| \dfrac{\text{kmol}}{75 \text{ kg}} = 0.5496 \dfrac{\text{kmol}}{\text{min}} \\ \underline{\text{FB}}: \dfrac{55.2 \text{ L}}{\text{min}} \bigg| \dfrac{0.75 \text{ kg}}{\text{L}} \bigg| \dfrac{\text{kmol}}{90 \text{ kg}} = 0.4600 \dfrac{\text{kmol}}{\text{min}} \end{array}\right\} \Rightarrow \frac{0.5496}{0.4600} = 1.2 \ \underline{\underline{\frac{\text{mol CSA}}{\text{mol FB}}}}$$

<u>She was wrong.</u>
<u>The mixer would come to a grinding halt and the motor would overheat.</u>

3.22 (a) $$\frac{150 \text{ mol EtOH}}{} \bigg| \frac{46.07 \text{ g EtOH}}{\text{mol EtOH}} = 6910 \text{ g EtOH}$$

$$\frac{6910 \text{ g EtOH}}{} \bigg| \frac{0.600 \text{ g } H_2O}{0.400 \text{ g EtOH}} = 10365 \text{ g } H_2O$$

$$V = \frac{6910 \text{ g EtOH}}{} \bigg| \frac{\text{L}}{789 \text{ g EtOH}} + \frac{10365 \text{ g } H_2O}{} \bigg| \frac{\text{L}}{1000 \text{ g } H_2O} = 19.123 \text{ L} \Rightarrow \underline{\underline{19.1 \text{ L}}}$$

$$SG = \frac{(6910+10365) \text{ g}}{19.1 \text{ L}} \bigg| \frac{\text{L}}{1000 \text{ g}} = \underline{\underline{0.903}}$$

(b) $$V' = \frac{(6910+10365) \text{ g mix}}{} \bigg| \frac{\text{L}}{935.18 \text{ g}} = 18.472 \text{ L} \Rightarrow \underline{\underline{18.5 \text{ L}}}$$

$$\underline{\%\text{error}} = \frac{(19.123-18.472) \text{ L}}{18.472 \text{ L}} \times 100\% = \underline{\underline{3.5\%}}$$

3.23 $\overline{M} = \dfrac{0.09 \text{ mol CH}_4}{} \left| \dfrac{16.04 \text{ g}}{\text{mol}} \right. + \dfrac{0.91 \text{ mol Air}}{} \left| \dfrac{29.0 \text{ g Air}}{\text{mol}} \right. = 27.83 \text{ g/mol}$

$$\frac{700 \text{ kg}}{\text{h}} \left| \frac{\text{kmol}}{27.83 \text{ kg}} \right| \frac{0.090 \text{ kmol CH}_4}{1.00 \text{ kmol mix}} = 2.264 \text{ kmol CH}_4/\text{h}$$

$$\frac{2.264 \text{ kmol CH}_4}{\text{h}} \left| \frac{0.91 \text{ kmol air}}{0.09 \text{ kmol CH}_4} \right. = 22.89 \text{ kmol air/h}$$

$$\underline{5\% \text{ CH}_4} \Rightarrow \frac{2.264 \text{ kmol CH}_4}{\text{h}} \left| \frac{0.95 \text{ kmol air}}{0.05 \text{ kmol CH}_4} \right. = 43.01 \text{ kmol air/h}$$

<u>Dilution air required</u>: $\dfrac{(43.01 - 22.89) \text{ kmol air}}{\text{h}} \left| \dfrac{1000 \text{ mol}}{1 \text{ kmol}} \right. = \underline{\underline{20200 \text{ mol air/h}}}$

<u>Product gas</u>: $\dfrac{700 \text{ kg}}{\text{h}} + \dfrac{20.20 \text{ kmol Air}}{\text{h}} \left| \dfrac{29 \text{ kg Air}}{\text{kmol Air}} \right. = 1286 \text{ kg/h}$

$$\frac{43.01 \text{ kmol Air}}{\text{h}} \left| \frac{0.21 \text{ kmol O}_2}{1.00 \text{ kmol Air}} \right| \frac{32.00 \text{ kg O}_2}{1 \text{ kmol O}_2} \left| \frac{\text{h}}{1286 \text{ kg total}} \right. = \underline{\underline{0.225 \frac{\text{kg O}_2}{\text{kg}}}}$$

3.24 $x_i = \dfrac{m_i}{M}$, $\rho_i = \dfrac{m_i}{V_i}$, $\overline{\rho} = \dfrac{\text{M}}{\text{V}}$

A: $\sum x_i \rho_i = \sum \dfrac{m_i}{M} \dfrac{m_i}{V_i} = \dfrac{1}{M} \sum \dfrac{m_i^2}{V_i} \neq \overline{\rho}$ Not helpful.

B: $\sum \dfrac{x_i}{\rho_i} = \sum \dfrac{m_i}{M} \dfrac{V_i}{m_i} = \dfrac{1}{M} \sum V_i = \dfrac{V}{M} = \dfrac{1}{\overline{\rho}}$ Correct.

$$\frac{1}{\overline{\rho}} = \sum \frac{x_i}{\rho_i} = \frac{0.60}{0.791} + \frac{0.25}{1.049} + \frac{0.15}{1.595} = 1.091 \quad \Rightarrow \overline{\rho} = \underline{\underline{0.917 \text{ g/cm}^3}}$$

3.25 (a) Basis: $100 \text{ mol N}_2 \Rightarrow 20 \text{ mol CH}_4 \Rightarrow \begin{cases} 20 \times \dfrac{80}{25} = 64 \text{ mol CO}_2 \\ 20 \times \dfrac{40}{25} = 32 \text{ mol CO} \end{cases}$

$$N_{total} = 100 + 20 + 64 + 32 = 216 \text{ mol}$$

$x_{\text{CO}} = \dfrac{32}{216} = \underline{\underline{0.15 \text{ mol CO/mol}}}$, $x_{\text{CO}_2} = \dfrac{64}{216} = \underline{\underline{0.30 \text{ mol CO}_2\text{/mol}}}$

$x_{\text{CH}_4} = \dfrac{20}{216} = \underline{\underline{0.09 \text{ mol CH}_4\text{/mol}}}$, $x_{\text{N}_2} = \dfrac{100}{216} = \underline{\underline{0.46 \text{ mol N}_2\text{/mol}}}$

(b) $\overline{M} = \sum y_i M_i = 0.15 \times 28 + 0.30 \times 44 + 0.09 \times 16 + 0.46 \times 28 = \underline{\underline{32 \text{ g/mol}}}$

3.26 (a)

Samples	Species	MW	k	Peak Area	Mole Fraction	Mass Fraction	moles	mass
1	CH4	16.04	0.150	3.6	0.156	0.062	0.540	8.662
	C2H6	30.07	0.287	2.8	0.233	0.173	0.804	24.164
	C3H8	44.09	0.467	2.4	0.324	0.353	1.121	49.416
	C4H10	58.12	0.583	1.7	0.287	0.412	0.991	57.603
2	CH4	16.04	0.150	7.8	0.249	0.111	1.170	18.767
	C2H6	30.07	0.287	2.4	0.146	0.123	0.689	20.712
	C3H8	44.09	0.467	5.6	0.556	0.685	2.615	115.304
	C4H10	58.12	0.583	0.4	0.050	0.081	0.233	13.554
3	CH4	16.04	0.150	3.4	0.146	0.064	0.510	8.180
	C2H6	30.07	0.287	4.5	0.371	0.304	1.292	38.835
	C3H8	44.09	0.467	2.6	0.349	0.419	1.214	53.534
	C4H10	58.12	0.583	0.8	0.134	0.212	0.466	27.107
4	CH4	16.04	0.150	4.8	0.333	0.173	0.720	11.549
	C2H6	30.07	0.287	2.5	0.332	0.324	0.718	21.575
	C3H8	44.09	0.467	1.3	0.281	0.401	0.607	26.767
	C4H10	58.12	0.583	0.2	0.054	0.102	0.117	6.777
5	CH4	16.04	0.150	6.4	0.141	0.059	0.960	15.398
	C2H6	30.07	0.287	7.9	0.333	0.262	2.267	68.178
	C3H8	44.09	0.467	4.8	0.329	0.380	2.242	98.832
	C4H10	58.12	0.583	2.3	0.197	0.299	1.341	77.933

(b)

```
REAL A(10), MW(10), K(10), MOL(10), MASS(10), MOLT, MASST
INTEGER N, ND, ID, J
READ (5, *) N
CN-NUMBER OF SPECIES
READ (5, *) (MW(J), K(J), J = 1, N)
READ (5, *) ND
DO 20 ID = 1, ND
    READ (5, *)(A(J), J = 1, N)
    MOLT = 0.0
    MASST = 0.0
    DO 10 J = 1, N
      MOL(J) =
      MASS(J) = MOL(J) * MW(J)
      MOLT = MOLT + MOL(J)
      MASST = MASST + MASS(J)
    10          CONTINUE
    DO 15 J = 1, N
      MOL(J) = MOL(J)/MOLT
      MASS(J) = MASS(J)/MASST
    15          CONTINUE
    WRITE (6, 1) ID, (J, MOL(J), MASS (J), J = 1, N)
20  CONTINUE
1   FORMAT (' SAMPLE:  `, I3, /,
    * ' SPECIES MOLE FR. MASS FR.', /,
```

3.26 (cont'd)

```
* 10(3X, I3, 2(5X, F5.3), /), /)
END
$DATA
*
   4
16.04   0.150
30.07   0.287
44.09   0.467
58.12   0.583
   5
3.6   2.8   2.4   1.7
7.8   2.4   5.6   0.4
3.4   4.5   2.6   0.8
4.8   2.5   1.3   0.2
6.4   7.9   4.8   2.3
[OUTPUT]
SAMPLE:        1
 SPECIES    MOLE FR    MASS FR
      1         0.156        0.062
      2         0.233        0.173
      3         0.324        0.353
      4         0.287        0.412
SAMPLE: 2
(ETC.)
```

3.27 (a)

$$\frac{(8.7\times10^6\times0.40)\text{ kg C}}{}\left|\frac{44\text{ kg }CO_2}{12\text{ kg C}}\right.=1.28\times10^7\text{ kg }CO_2\Rightarrow2.9\times10^5\text{ kmol }CO_2$$

$$\frac{(1.1\times10^6\times0.26)\text{ kg C}}{}\left|\frac{28\text{ kg CO}}{12\text{ kg C}}\right.=6.67\times10^5\text{ kg CO}\Rightarrow2.38\times10^4\text{ kmol CO}$$

$$\frac{(3.8\times10^5\times0.10)\text{ kg C}}{}\left|\frac{16\text{ kg }CH_4}{12\text{ kg C}}\right.=5.07\times10^4\text{ kg }CH_4\Rightarrow3.17\times10^3\text{ kmol }CH_4$$

$$m=\frac{(1.28\times10^7+6.67\times10^5+5.07\times10^4)\text{ kg}}{}\left|\frac{1\text{ metric ton}}{1000\text{ kg}}\right.=\underline{\underline{13{,}500\ \frac{\text{metric tons}}{\text{yr}}}}$$

$$\overline{M}=\sum y_iM_i=0.915\times44+0.075\times28+0.01\times16=\underline{\underline{42.5\text{ g / mol}}}$$

3.28 (a) Basis: 1 liter of solution

$$\frac{1000\text{ mL}}{}\left|\frac{1.03\text{ g}}{\text{mL}}\right|\frac{5\text{ g }H_2SO_4}{100\text{ g}}\left|\frac{\text{mol }H_2SO_4}{98.08\text{ g }H_2SO_4}\right.=0.525\text{ mol / L}\Rightarrow\underline{\underline{0.525\text{ molar solution}}}$$

3.28 (cont'd)

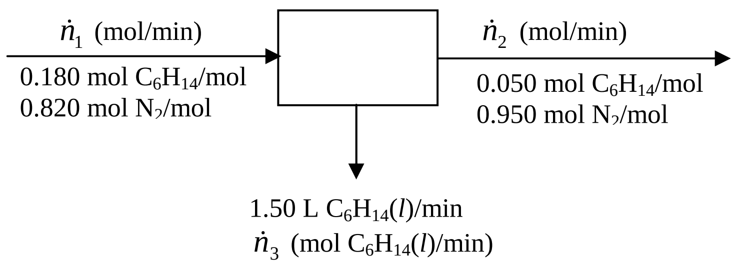
(b) $t = \dfrac{V}{\dot{V}} = \begin{array}{c|c|c|c} 55 \text{ gal} & 3.7854 \text{ L} & \text{min} & 60 \text{ s} \\ \hline & \text{gal} & 87 \text{ L} & \text{min} \end{array} = \underline{\underline{144 \text{ s}}}$

$\begin{array}{c|c|c|c|c|c} 55 \text{ gal} & 3.7854 \text{ L} & 10^3 \text{ mL} & 1.03 \text{ g} & 0.0500 \text{ g } H_2SO_4 & 1 \text{ lbm} \\ \hline & \text{gal} & 1 \text{ L} & \text{mL} & \text{g} & 453.59 \text{ g} \end{array} = \underline{\underline{23.6 \text{ lb}_m \; H_2SO_4}}$

(c) $u = \dfrac{\dot{V}}{A} = \begin{array}{c|c|c|c} 87 \text{ L} & \text{m}^3 & 1 \text{ min} & \\ \hline \text{min} & 1000 \text{ L} & 60 \text{ s} & (\pi \times 0.06^2 \ / \ 4) \text{ m}^2 \end{array} = 0.513 \text{ m / s}$

$t = \dfrac{L}{u} = \dfrac{45 \text{ m}}{0.513 \text{ m / s}} = \underline{\underline{88 \text{ s}}}$

3.29 (a)



$\dot{n}_3 = \begin{array}{c|c|c} 1.50 \text{ L} & 0.659 \text{ kg} & 1000 \text{ mol} \\ \hline \text{min} & \text{L} & 86.17 \text{ kg} \end{array} = 11.47 \text{ mol / min}$

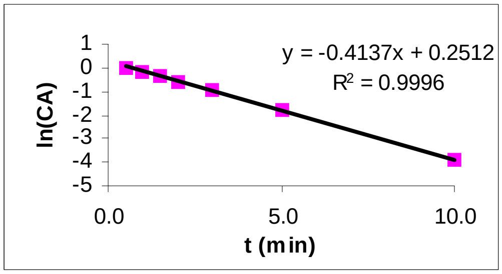
$$\left.\begin{array}{l} \underline{\text{Hexane balance}}: \ 0.180\dot{n}_1 = 0.050\dot{n}_2 + 11.47 \text{ (mol } C_6H_{14} \text{ / min)} \\ \underline{\text{Nitrogen balance}}: \ 0.820\dot{n}_1 = 0.950\dot{n}_2 \text{ (mol } N_2 \text{ / min)} \end{array}\right\} \overset{\text{solve}}{\Rightarrow} \left\{\begin{array}{l} \dot{n}_1 = 83.8 \text{ mol / min} \\ \underline{\underline{\dot{n}_2 = 72.3 \text{ mol / min}}} \end{array}\right.$$

(b) $\underline{\text{Hexane recovery}} = \dfrac{\dot{n}_3}{\dot{n}_1} \times 100\% = \dfrac{11.47}{0.180(83.8)} \times 100\% = \underline{\underline{76\%}}$

3.30 $\begin{array}{c|c|c|c} 30 \text{ mL} & 1 \text{ L} & 0.030 \text{ mol} & 172 \text{ g} \\ \hline & 10^3 \text{ mL} & 1 \text{ L} & 1 \text{ mol} \end{array} = \underline{\underline{0.155 \text{ g Nauseum}}}$

3.31 (a) kt is dimensionless $\Rightarrow k\ (\text{min}^{-1})$

(b) A semilog plot of C_A vs. t is a straight line $\Rightarrow \ln C_A = \ln C_{AO} - kt$



$$\underline{\underline{k = 0.414\ \text{min}^{-1}}}$$

$$\ln C_{AO} = 0.2512 \Rightarrow \underline{\underline{C_{AO} = 1.286\ \text{lb-moles/ft}^3}}$$

(c) $$C_A\left(\frac{\text{1b-moles}}{\text{ft}^3}\right) = C'_A \frac{\text{mol}}{\text{liter}}\left|\frac{28.317\ \text{liter}}{1\ \text{ft}^3}\right|\frac{2.26462\ \text{lb-moles}}{1000\ \text{mol}} = 0.06243C'_A$$

$$t(\text{min}) = \frac{t'(s)}{}\left|\frac{1\ \text{min}}{60\ \text{s}}\right. = t'/60$$

$$\Big\Downarrow\ C_A = C_{A0}\exp(-kt)$$

$$0.06243C'_A = 1.334\exp(-0.419t'/60) \overset{\text{drop primes}}{\Rightarrow} \underline{\underline{C_A(\text{mol / L}) = 21.4\exp(-0.00693t)}}$$

$$t = 200\ \text{s} \Rightarrow C_A = \underline{\underline{5.30\ \text{mol / L}}}$$

3.32 (a) $$\frac{2600\ \text{mm Hg}}{}\left|\frac{14.696\ \text{psi}}{760\ \text{mm Hg}}\right. = \underline{\underline{50.3\ \text{psi}}}$$

(b) $$\frac{275\ \text{ft}\ H_2O}{}\left|\frac{101.325\ \text{kPa}}{33.9\ \text{ft}\ H_2O}\right. = \underline{\underline{822.0\ \text{kPa}}}$$

(c) $$\frac{3.00\ \text{atm}}{}\left|\frac{1.01325\times10^5\ \text{N/m}^2}{1\ \text{atm}}\right|\frac{1^2\ \text{m}^2}{100^2\ \text{cm}^2} = \underline{\underline{30.4\ \text{N/cm}^2}}$$

(d) $$\frac{280\ \text{cm Hg}}{}\left|\frac{10\ \text{mm}}{1\ \text{cm}}\right|\frac{1.01325\times10^6\ \text{dynes/cm}^2}{760\ \text{mm Hg}}\left|\frac{100^2\ \text{cm}^2}{1^2\ \text{m}^2}\right. = \underline{\underline{3.733\times10^{10}\ \frac{\text{dynes}}{\text{m}^2}}}$$

(e) $$1\ \text{atm} - \frac{20\ \text{cm Hg}}{}\left|\frac{10\ \text{mm}}{1\ \text{cm}}\right|\frac{1\ \text{atm}}{760\ \text{mm Hg}} = 0.737\ \text{atm}$$

3.32 (cont'd)

(f) $\dfrac{25.0\text{ psig}}{} \left| \dfrac{760\text{ mm Hg (gauge)}}{14.696\text{ psig}} \right. = \underline{\underline{1293\text{ mm Hg (gauge)}}}$

(g) $\dfrac{(25.0+14.696)\text{psi}}{} \left| \dfrac{760\text{ mm Hg}}{14.696\text{ psi}} \right. = \underline{\underline{2053\text{ mm Hg (abs)}}}$

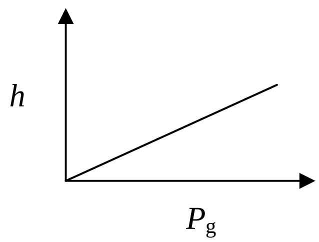
(h) $325\text{ mm Hg} - 760\text{ mm Hg} = \underline{\underline{-435\text{ mm Hg (gauge)}}}$

(i) Eq. (3.4-2) $\Rightarrow h = \dfrac{P}{\rho g} = \dfrac{35.0\text{ lb}_f}{\text{in}^2} \left| \dfrac{144\text{ in}^2}{1\text{ ft}^2} \right| \dfrac{\text{ft}^3}{1.595\text{x}62.43\text{ lb}_m} \left| \dfrac{\text{s}^2}{32.174\text{ ft}} \right| \dfrac{32.174\text{ lb}_m \cdot \text{ft}}{\text{s}^2 \cdot \text{lb}_f} \left| \dfrac{100\text{ cm}}{3.2808\text{ ft}} \right.$

$= \underline{\underline{1540\text{ cm CCl}_4}}$

3.33 (a) $P_g = \rho g h = \dfrac{0.92 \times 1000\text{ kg}}{\text{m}^3} \left| \dfrac{9.81\text{ m/s}^2}{} \right| \dfrac{h\text{ (m)}}{} \left| \dfrac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2} \right| \dfrac{1\text{ kPa}}{10^3\text{ N/m}^2}$

$\Rightarrow h\text{ (m)} = 0.111 P_g\text{ (kPa)}$



$P_g = 68\text{ kPa} \Rightarrow h = 0.111 \times 68 = \underline{\underline{7.55\text{ m}}}$

$m_{oil} = \rho V = \left(0.92 \times 1000\ \dfrac{\text{kg}}{\text{m}^3}\right) \times \left(7.55 \times \pi \times \dfrac{16^2}{4}\ \text{m}^3\right) = \underline{\underline{1.4 \times 10^6\ \text{kg}}}$

(b) $P_g + P_{atm} = P_{top} + \rho g h$

$\Downarrow$

$68 + 101 = 115 + \left[(0.92 \times 1000) \times (9.81)/10^3\right] h \ \Rightarrow h = \underline{\underline{5.98\text{ m}}}$

3.34 (a) Weight of block = Sum of weights of displaced liquids

$(h_1 + h_2) A \rho_b g = h_1 A \rho_1 g + h_2 A \rho_2 g \Rightarrow \rho_b = \dfrac{\rho_1 h_1 + \rho_2 h_2}{h_1 + h_2}$

(b)

$P_{\text{top}} = P_{\text{atm}} + \rho_1 g h_0\ ,\ P_{\text{bottom}} = P_{\text{atm}} + \rho_1 g (h_0 + h_1) + \rho_2 g h_2\ ,\ W_{\text{b}} = \rho_b (h_1 + h_2) A$

$\Rightarrow F_{\text{down}} = (P_{\text{atm}} + \rho_1 g h_0) A + \rho_b (h_1 + h_2) A,\ F_{\text{up}} = [P_{\text{atm}} + \rho_1 g (h_0 + h_1) + \rho_2 g h_2] A$

$F_{\text{down}} = F_{\text{up}} \Rightarrow \rho_b (h_1 + h_2) A = \rho_1 g h_1 A + \rho_2 g h_2 A \Rightarrow W_{\text{block}} = W_{\text{liquid displaced}}$

3.35 $\Delta P = (P_{atm} + \rho gh) - P_{inside}$

$$= 1\text{ atm} - 1\text{ atm} + \frac{(1.05)1000\text{ kg}}{\text{m}^3}\bigg|\frac{9.8066\text{ m}}{\text{s}^2}\bigg|\frac{150\text{ m}}{}\bigg|\frac{1^2\text{ m}^2}{100^2\text{ cm}^2}\bigg|\frac{1\text{ N}}{1\text{ kg}\cdot\text{m/s}^2}$$

$$F = \frac{154\text{ N}}{\text{cm}^2}\bigg|\frac{65\text{ cm}^2}{} = \underline{\underline{1.00\times10^4\text{ N}}} \times \left(\frac{0.22481\text{ lb}_f}{1\text{ N}}\right) = \underline{\underline{2250\text{ lb}_f}}$$

3.36 $$m = \rho V = \frac{1.4\times62.43\text{ lb}_m}{\text{ft}^3}\bigg|\frac{1\text{ ft}^3}{7.481\text{ gal}}\bigg|\frac{2.3\times10^6\text{ gal}}{} = \underline{\underline{2.69\times10^7\text{ lb}_m}}$$

$$P = P_0 + \rho gh$$

$$= 14.7\frac{\text{lb}_f}{\text{in}^2} + \frac{1.4\times62.43\text{ lb}_m}{\text{ft}^3}\bigg|\frac{32.174\text{ ft}}{\text{s}^2}\bigg|\frac{30\text{ ft}}{}\bigg|\frac{1\text{ lb}_f}{32.174\text{ lb}_m\cdot\text{ft/s}^2}\bigg|\frac{1^2\text{ ft}^2}{12^2\text{ in}^2}$$

$$= \underline{\underline{32.9\text{ psi}}}$$

— Structural flaw in the tank.
— Tank strength inadequate for that much force.
— Molasses corroded tank wall

3.37 (a) $$m_{head} = \frac{\pi\times24^2\times3\text{ in}^3}{4}\bigg|\frac{1\text{ ft}^3}{12^3\text{ in}^3}\bigg|\frac{8.0\times62.43\text{ lb}_m}{\text{ft}^3} = 392\text{ lb}_m$$

$$W = m_{head}g = \frac{392\text{ lb}_m}{}\bigg|\frac{32.174\text{ ft}/s^2}{}\bigg|\frac{1\text{ lb}_f}{32.174\text{ lb}_m\cdot\text{ft/s}^2} = 392\text{ lb}_f$$

$$F_{net} = F_{gas} - F_{atm} - W = \frac{[(30+14.7)]\text{lb}_f}{\text{in}^2}\bigg|\frac{\pi\times20^2\text{ in}^2}{4}$$

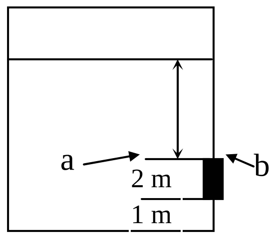
$$-\frac{14.7\text{ lb}_f}{\text{in}^2}\bigg|\frac{\pi\times24^2\text{ in}^2}{4} - 392\text{ lb}_f = \underline{\underline{7.00\times10^3\text{ lb}_f}}$$

The head would blow off.

Initial acceleration: $$a = \frac{F_{net}}{m_{head}} = \frac{7.000\times10^3\text{ lb}_f}{392\text{ lb}_m}\bigg|\frac{32.174\text{ lb}_m\cdot\text{ft/s}^2}{1\text{ lb}_f} = \underline{\underline{576\text{ ft/s}^2}}$$

(b) <u>Vent the reactor through a valve to the outside or a hood before removing the head.</u>

3.38 (a)



$P_a = \rho gh + P_{atm}$, $P_b = P_{atm}$

If the inside pressure on the door equaled P_a, the force on the door would be $F = A_{door}(P_a - P_b) = \rho ghA_{door}$

Since the pressure at every point on the door is greater than P_a, Since the pressure at every point on the door is greater than P_a, $F > \rho ghA_{\text{door}}$

(b) Assume an average bathtub 5 ft long, 2.5 ft wide, and 2 ft high takes about 10 min to fill.

$$\dot{V}_{tub} = \frac{V}{t} \approx \frac{5\times 2.5\times 2\ \text{ft}^3}{10\ \text{min}} = 2.5\ \text{ft}^3/\text{min} \Rightarrow \dot{V} = 5\times 2.5 = 12.5\ \text{ft}^3/\text{min}$$

(i) For a full room, $h = 7$ m

$$\Rightarrow F > \frac{1000\ \text{kg}}{\text{m}^3}\left|\frac{9.81\ \text{m}}{\text{s}^2}\right|\frac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2}\left|7\ \text{m}\right|2\ \text{m}^2 \Rightarrow \underline{\underline{F > 1.4\times 10^5\ \text{N}}}$$

<u>The door will break before the room fills</u>

(ii) If the door holds, it will take

$$t_{\text{fill}} = \frac{V_{\text{room}}}{\dot{V}} = \frac{(5\times 15\times 10)\ \text{m}^3}{12.5\ \text{ft}^3/\text{min}}\left|\frac{35.3145\ \text{ft}^3}{1\ \text{m}^3}\right|\frac{1\ \text{h}}{60\ \text{min}} = \underline{\underline{31\ \text{h}}}$$

<u>He will not have enough time.</u>

3.39 (a) $$\left(P_g\right)_{tap} = \frac{25\ \text{m}\ H_2O}{}\left|\frac{101.3\ \text{kPa}}{10.33\ \text{m}\ H_2O}\right. = \underline{\underline{245\ \text{kPa}}}$$

$$\left(P_g\right)_{junction} = \frac{(25+5)\ \text{m}\ H_2O}{}\left|\frac{101.3\ \text{kPa}}{10.33\ \text{m}\ H_2O}\right. = \underline{\underline{294\ \text{kPa}}}$$

(b) <u>Air in the line. (lowers average density of the water.)</u>

(c) <u>The line could be clogged, or there could be a leak between the junction and the tap.</u>

3.40 $P_{abs} = \underline{\underline{800\ \text{mm Hg}}}$

$P_{gauge} = \underline{\underline{25\ \text{mm Hg}}}$

$P_{atm} = 800 - 25 = \underline{\underline{775\ \text{mm Hg}}}$

3.41 **(a)** $P_1 + \rho_A g(h_1 + h_2) = P_2 + \rho_B g h_1 + \rho_C g h_2$

$$\Rightarrow \underline{\underline{P_1 - P_2 = (\rho_B - \rho_A) g h_1 + (\rho_C - \rho_A) g h_2}}$$

(b) $$P_1 = 121 \text{ kPa} + \left[\frac{(1.0 - 0.792) \text{ g}}{\text{cm}^3} \bigg| \frac{981 \text{ cm}}{\text{s}^2} \bigg| \frac{30.0 \text{ cm}}{} + \frac{(1.37 - 0.792) \text{ g}}{\text{cm}^3} \bigg| \frac{981 \text{ cm}}{\text{s}^2} \bigg| \frac{24.0 \text{ cm}}{} \right]$$

$$\times \left(\frac{1 \text{ dyne}}{1 \text{ g} \cdot \text{cm/s}^2} \right) \left(\frac{101.325 \text{ kPa}}{1.01325 \times 10^6 \text{ dynes/cm}^2} \right) = \underline{\underline{123.0 \text{ kPa}}}$$

3.42 **(a)** Say ρ_t (g/cm^3) = density of toluene, ρ_m (g/cm^3) = density of manometer fluid

$$\rho_t g(500 - h + R) = \rho_m g R \Rightarrow R = \frac{500 - h}{\dfrac{\rho_m}{\rho_t} - 1}$$

(i) Hg: $\rho_t = 0.866,\ \rho_m = 13.6,\ h = 150 \text{ cm} \Rightarrow R = \underline{\underline{23.8 \text{ cm}}}$

(ii) H_2O: $\rho_t = 0.866,\ \rho_m = 1.00,\ h = 150 \text{ cm} \Rightarrow R = \underline{\underline{2260 \text{ cm}}}$

Use mercury, because the water manometer would have to be too tall.

(b) If the manometer were simply filled with toluene, the level in the glass tube would be at the level in the tank.
Advantages of using mercury: smaller manometer; less evaporation.

(c) The nitrogen blanket is used to avoid contact between toluene and atmospheric oxygen, minimizing the risk of combustion.

3.43 $$P_{\text{atm}} = \rho_f g(7.23 \text{ m}) \Rightarrow \rho_f = \frac{P_{\text{atm}}}{7.23 \text{ g}}$$

$$P_a - P_b = (\rho_f - \rho_w) g(26 \text{ cm}) = \left(\frac{P_{\text{atm}}}{7.23 \text{ m}} - \rho_w g \right)(26 \text{ cm})$$

$$= \left(\frac{756 \text{ mmHg}}{7.23 \text{ m}} \bigg| \frac{1 \text{ m}}{100 \text{ cm}} - \frac{1000 \text{ kg}}{\text{m}^3} \bigg| \frac{9.81 \text{ m/s}^2}{} \bigg| \frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \bigg| \frac{760 \text{ mmHg}}{1.01325 \times 10^5 \text{ N/m}^2} \bigg| \frac{1 \text{ m}}{100 \text{ cm}} \right)(26 \text{ cm})$$

$$\Rightarrow P_a - P_b = \underline{\underline{8.1 \text{ mm Hg}}}$$

3.44 **(a)** $$\Delta h = 900 - h_1 = \frac{7.5 \text{ psi}}{} \bigg| \frac{760 \text{ mm Hg}}{14.696 \text{ psi}} = 388 \text{ mm Hg} \Rightarrow h_1 = 900 - 388 = \underline{\underline{512 \text{ mm}}}$$

(b) $$\Delta h = 388 - 25 \times 2 = 338 \text{ mm} \Rightarrow P_g = \frac{338 \text{ mm Hg}}{} \bigg| \frac{14.696 \text{ psi}}{760 \text{ mm Hg}} = \underline{\underline{6.54 \text{ psig}}}$$

3.45 (a) $h = L \sin\theta$

(b) $h = (8.7 \text{ cm})\sin(15°) = 2.3 \text{ cm } H_2O = \underline{\underline{23 \text{ mm } H_2O}}$

3.46 (a) $P = P_{atm} - P_{oil} - P_{Hg}$

$$= 765 - 365 - \begin{array}{c|c|c|c|c} 920 \text{ kg} & 9.81 \text{ m/s}^2 & 0.10 \text{ m} & 1 \text{ N} & 760 \text{ mm Hg} \\ \hline \text{m}^3 & & & 1 \text{ kg}\cdot\text{m/s}^2 & 1.01325\times10^5 \text{ N/m}^2 \end{array}$$

$$= \underline{\underline{393 \text{ mm Hg}}}$$

(b) — Nonreactive with the vapor in the apparatus.
— Lighter than and immiscible with mercury.
— Low rate of evaporation (low volatility).

3.47 (a) Let ρ_f = manometer fluid density (1.10 g/cm^3), ρ_{ac} = acetone density (0.791 g/cm^3)

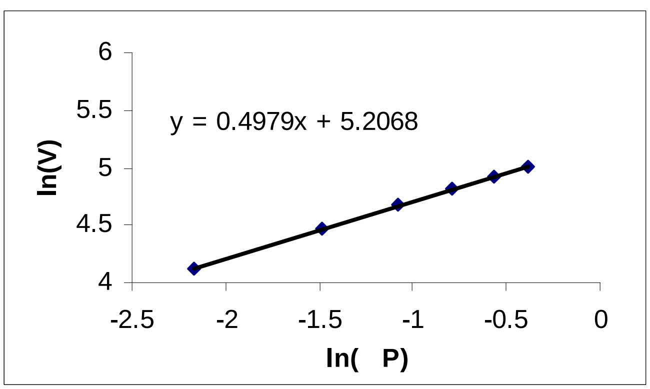
<u>Differential manometer formula</u>: $\Delta P = (\rho_f - \rho_{ac})gh$

$$\Delta P(\text{mm Hg}) = \begin{array}{c|c|c|c|c|c} (1.10-0.791)\text{g} & 981 \text{ cm} & \text{h (mm)} & 1 \text{ cm} & 1 \text{ dyne} & 760 \text{ mm Hg} \\ \hline \text{cm}^3 & \text{s}^2 & & 10 \text{ mm} & 1 \text{ g}\cdot\text{cm/s}^2 & 1.01325\times10^6 \text{ dyne/cm}^2 \end{array}$$

$$= 0.02274 \text{ h(mm)}$$

$\dot{V}$(mL/s)	62	87	107	123	138	151
h(mm)	5	10	15	20	25	30
ΔP(mm Hg)	0.114	0.227	0.341	0.455	0.568	0.682

(b) $\ln\dot{V} = n\ln(\Delta P) + \ln K$



From the plot above, $\ln \dot{V} = 0.4979 \ln(\Delta P) + 5.2068$

$\Rightarrow \underline{\underline{n = 0.4979 \approx 0.5}}$, $\ln K = 5.2068 \Rightarrow \underline{\underline{K = 183 \dfrac{\text{ml/s}}{(\text{mm Hg})^{0.5}}}}$

3.47 (cont'd)

(c) $h = 23 \Rightarrow \Delta P = (0.02274)(23) = 0.523 \text{ mm Hg} \Rightarrow \dot{V} = 183(0.523)^{0.5} = \underline{\underline{132 \text{ mL/s}}}$

$$\frac{132 \text{ mL}}{\text{s}}\bigg|\frac{0.791 \text{ g}}{\text{mL}} = \underline{\underline{104 \text{ g/s}}} \qquad \frac{104 \text{ g}}{\text{s}}\bigg|\frac{1 \text{ mol}}{58.08 \text{ g}} = \underline{\underline{1.80 \text{ mol/s}}}$$

3.48 (a) $T = 85^\circ\text{F} + 459.7 = \underline{\underline{544^\circ\text{R}}} / 1.8 = \underline{\underline{303 \text{ K}}} - 273 = \underline{\underline{30^\circ\text{C}}}$

(b) $T = -10^\circ\text{C} + 273 = \underline{\underline{263 \text{ K}}} \times 1.8 = \underline{\underline{474^\circ\text{R}}} - 460 = \underline{\underline{14^\circ\text{F}}}$

(c) $\Delta T = \dfrac{85^\circ\text{C}}{}\bigg|\dfrac{1.0^\circ\text{K}}{1.0^\circ\text{C}} = \underline{\underline{85^\circ\text{K}}};\quad \dfrac{85^\circ\text{C}}{}\bigg|\dfrac{1.8^\circ\text{F}}{1^\circ\text{C}} = \underline{\underline{153^\circ\text{F}}};\quad \dfrac{85^\circ\text{C}}{}\bigg|\dfrac{1.8^\circ\text{R}}{1.0^\circ\text{C}} = \underline{\underline{153^\circ\text{R}}}$

(d) $\dfrac{150^\circ\text{R}}{}\bigg|\dfrac{1^\circ\text{F}}{1^\circ\text{R}} = \underline{\underline{150^\circ\text{F}}};\quad \dfrac{150^\circ\text{R}}{}\bigg|\dfrac{1.0^\circ\text{K}}{1.8^\circ\text{R}} = \underline{\underline{83.3^\circ\text{K}}};\quad \dfrac{150^\circ\text{R}}{}\bigg|\dfrac{1.0^\circ\text{C}}{1.8^\circ\text{R}} = \underline{\underline{83.3^\circ\text{C}}}$

3.49 (a) $T = 0.0940 \times 1000^\circ\text{FB} + 4.00 = 98.0^\circ\text{C} \Rightarrow \text{T} = 98.0 \times 1.8 + 32 = \underline{\underline{208^\circ\text{F}}}$

(b) $\Delta T\ (^\circ\text{C}) = 0.0940\Delta T\ (^\circ\text{FB}) = \underline{\underline{0.94^\circ\text{C}}} \Rightarrow \Delta T\ (\text{K}) = \underline{\underline{0.94 \text{ K}}}$

$$\Delta T\ (^\circ\text{F}) = \frac{0.94^\circ\text{C}}{}\bigg|\frac{1.8^\circ\text{F}}{1.0^\circ\text{C}} = \underline{\underline{1.69^\circ\text{F}}} \Rightarrow \Delta T\ (^\circ\text{R}) = \underline{\underline{1.69^\circ\text{R}}}$$

(c) $T_1 = 15^\circ\text{C} \Rightarrow 100^\circ\text{L}\,;\quad T_2 = 43^\circ\text{C} \Rightarrow 1000^\circ\text{L}$

$$T\ (^\circ\text{C}) = aT\ (^\circ\text{L}) + b$$

$$a = \frac{(43-15)^\circ\text{C}}{(1000-100)^\circ\text{L}} = 0.0311\left(\frac{^\circ\text{C}}{^\circ\text{L}}\right); \qquad b = 15 - 0.0311 \times 100 = 11.9^\circ\text{C}$$

$$\Rightarrow \begin{array}{l} \underline{\underline{T\ (^\circ\text{C}) = 0.0311T\ (^\circ\text{L}) + 11.9}} \quad \text{and} \\ T\ (^\circ\text{L}) = \dfrac{1}{0.0311}\left[0.0940T(^\circ\text{FB}) + 4.00 - 11.9\right] = \underline{\underline{3.023T(^\circ\text{FB}) - 254}} \end{array}$$

(d) $T_{bp} = -88.6^\circ\text{C} \Rightarrow \underline{\underline{184.6 \text{ K}}} \Rightarrow \underline{\underline{332.3^\circ\text{R}}} \Rightarrow \underline{\underline{-127.4^\circ\text{F}}} \Rightarrow \underline{\underline{-985.1^\circ\text{FB}}} \Rightarrow \underline{\underline{-3232^\circ\text{L}}}$

(e) $\Delta T = 50.0^\circ\text{L} \Rightarrow \underline{\underline{1.56^\circ\text{C}}} \Rightarrow \underline{\underline{16.6^\circ\text{FB}}} \Rightarrow \underline{\underline{1.56 \text{ K}}} \Rightarrow \underline{\underline{2.8^\circ\text{F}}} \Rightarrow \underline{\underline{2.8^\circ\text{R}}}$

3.50 $\left(T_b\right)_{H_2O} = 100°\text{C} \quad \left(T_m\right)_{AgCl} = 455°\text{C}$

(a) $V(\text{mV}) = aT(°\text{C}) + b$

$$\begin{aligned} 5.27 &= 100a + b \\ 24.88 &= 455a + b \end{aligned} \Rightarrow \begin{aligned} a &= 0.05524 \ \text{mV}/°\text{C} \\ b &= -0.2539 \ \text{mV} \end{aligned}$$

$$\underline{\underline{V(\text{mV}) = 0.05524T(°\text{C}) - 0.2539}}$$

$$\Downarrow$$

$$\underline{\underline{T(°\text{C}) = 18.10V(\text{mV}) + 4.596}}$$

(b) $10.0\ \text{mV} \to 13.6\ \text{mV} \Rightarrow 185.6°\text{C} \to 250.8°\text{C} \Rightarrow \dfrac{dT}{dt} = \dfrac{(250.8 - 185.6)°\text{C}}{20\ \text{s}} = \underline{\underline{3.26\ °\text{C/s}}}$

3.51 **(a)** $\ln T = \ln K + n \ln R \quad \left[T = KR^n\right]$

$$n = \frac{\ln(250.0/110.0)}{\ln(40.0/20.0)} = 1.184$$

$$\ln K = \ln\ 110.0 - 1.184(\ln 20.0) = 1.154 \Rightarrow K = 3.169 \Rightarrow \underline{\underline{T = 3.169R^{1.184}}}$$

(b) $R = \left(\dfrac{320}{3.169}\right)^{1/1.184} = \underline{\underline{49.3}}$

(c) Extrapolation error, thermocouple reading wrong.

3.52 **(a)** $PV = 0.08206nT$

$$P(\text{atm}) = \frac{P'(\text{psig}) + 14.696}{14.696} \quad , \quad \text{V(L)} = V'\left(\text{ft}^3\right) \times \frac{28.317\ \text{ft}^3}{\text{L}}$$

$$n(\text{mol}) = n'(\text{lb-moles}) \times \frac{453.59\ \text{mol}}{\text{lb} - \text{moles}} \quad , \quad \text{T}(°\text{K}) = \frac{T'(°\text{F}) - 32}{1.8} + 273.15$$

$$\Rightarrow \frac{(P' + 14.696)}{14.696} \times V' \times 28.317 = 0.08206 \times n' \times \frac{453.59}{1} \times \left[\frac{(T' - 32)}{1.8} + 273.15\right]$$

$$\Rightarrow (P' + 14.696) \times V' = \frac{0.08206 \times 14.696 \times 453.59}{28.317 \times 1.8} \times n' \times (T' + 459.7)$$

$$\Rightarrow \underline{\underline{(P' + 14.696)V' = 10.73n'(T' + 459.7)}}$$

3.52 (cont'd)

(b) $n'_{tot} = \dfrac{(500+14.696)\times 3.5}{10.73\times(85+459.7)} = \underline{\underline{0.308 \text{ lb-mole}}}$

$$m_{CO} = \frac{0.308 \text{ lb-mole}}{} \left| \frac{0.30 \text{ lb-mole CO}}{\text{lb-mole}} \right| \frac{28 \text{ lb}_\text{m} \text{ CO}}{\text{lb-mole CO}} = \underline{\underline{2.6 \text{ lb}_\text{m} \text{ CO}}}$$

(c) $T' = \dfrac{(3000+14.696)\times 3.5}{10.73\times 0.308} - 459.7 = \underline{\underline{2733^\circ \text{F}}}$

3.53 (a) $T(^\circ\text{C}) = a\times r(\text{ohms}) + b$

$$\left.\begin{aligned} 0 &= 23.624a + b \\ 100 &= 33.028a + b \end{aligned}\right\} \Rightarrow \begin{aligned} a &= 10.634 \\ b &= -251.22 \end{aligned} \Rightarrow \underline{\underline{T(^\circ\text{C}) = 10.634r(\text{ohms}) - 251.22}}$$

(b) $\dot{n}\left(\dfrac{\text{kmol}}{\text{s}}\right) = \dfrac{\dot{n}' \text{ (kmol)}}{\text{min}} \left| \dfrac{1 \text{ min}}{60 \text{ s}} \right. = \dfrac{\dot{n}'}{60}$

$$P(\text{atm}) = \frac{P'(\text{mm Hg})}{} \left| \frac{1 \text{ atm}}{760 \text{ mm Hg}} \right. = \frac{P'}{760} \quad , \quad T(\text{K}) = T'(^\circ\text{C}) + 273.16$$

$$\dot{V}\left(\frac{\text{m}^3}{\text{s}}\right) = \dot{V}' \frac{\text{m}^3}{\text{min}} \left| \frac{1 \text{ min}}{60 \text{ s}} \right. = \frac{\dot{V}'}{60}$$

$$\frac{\dot{n}'}{60} = \frac{12.186}{} \left| \frac{P'}{760} \right| \frac{}{T'+273.16} \left| \frac{\dot{V}'}{60} \right. \Rightarrow \underline{\underline{\dot{n}' = \frac{0.016034 P'(\text{mm Hg})\dot{V}'(\text{m}^3/\text{min})}{T'(^\circ\text{C}) + 273.16}}}$$

(c) $T = 10.634r - 251.22$

$$\Rightarrow \begin{aligned} r_1 &= 26.159 \Rightarrow \underline{\underline{T_1 = 26.95^\circ \text{C}}} \\ r_2 &= 26.157 \Rightarrow \underline{\underline{T_2 = 26.93^\circ \text{C}}} \\ r_3 &= 44.789 \Rightarrow \underline{\underline{T_3 = 225.1^\circ \text{C}}} \end{aligned}$$

$$P \text{ (mm Hg)} = h + P_{\text{atm}} = h + (29.76 \text{ in Hg})\left(\frac{760 \text{ mm Hg}}{29.92 \text{ in Hg}}\right) = h + 755.9$$

$$\Rightarrow \begin{aligned} h_1 &= 232 \text{ mm} \Rightarrow \underline{\underline{P_1 = 987.9 \text{ mm Hg}}} \\ h_2 &= 156 \text{ mm} \Rightarrow \underline{\underline{P_2 = 911.9 \text{ mm Hg}}} \\ h_3 &= 74 \text{ mm} \Rightarrow \underline{\underline{P_3 = 829.9 \text{ mm Hg}}} \end{aligned}$$

3.53 (cont'd)

(d) $\dot{n}_1 = \dfrac{(0.016034)(987.9)(947/60)}{26.95+273.16} = 0.8331 \text{ kmol } CH_4/\text{min}$

$\dot{n}_2 = \dfrac{(0.016034)(911.9)(195)}{26.93+273.16} = 9.501 \text{ kmol air/min}$

$\dot{n}_3 = \dot{n}_1 + \dot{n}_2 = \underline{\underline{10.33 \text{ kmol/min}}}$

(e) $V_3 = \dfrac{\dot{n}_3(T_2+273.16)}{0.016034\,P_3} = \dfrac{(10.33)(225.1+273.16)}{(0.016034)(829.9)} = \underline{\underline{387 \text{ m}^3/\text{min}}}$

(f) $\dfrac{0.8331 \text{ kmol } CH_4}{\text{min}}\Bigg|\dfrac{16.04 \text{ kg } CH_4}{\text{kmol}} = 13.36\dfrac{\text{kg } CH_4}{\text{min}}$

$\dfrac{0.21\times 9.501 \text{ kmol } O_2}{\text{min}}\Bigg|\dfrac{32.0 \text{ kg } O_2}{\text{kmol } O_2} + \dfrac{0.79\times 9.501 \text{ kmol } N_2}{\text{min}}\Bigg|\dfrac{28.0 \text{ kg } N_2}{\text{kmol } N_2} = 274\ \dfrac{\text{kg air}}{\text{min}}$

$x_{CH_4} = \dfrac{13.36 \text{ kg } CH_4/\text{min}}{(13.36+274) \text{ kg / min}} = \underline{\underline{0.0465 \text{ kg } CH_4/\text{kg}}}$

3.54

```
      REAL, MW, T, SLOPE, INTCPT, KO, E
      REAL TIME (100), CA (100), TK (100), X (100), Y(100)
      INTEGER IT, N, NT, J
      READ (5,*) MW, NT
      DO 10 IT=1, NT
         READ (5,*) TC, N
         TK(IT) = TC + 273.15
         READ (5,*) (TIME (J), CA (J), J = 1, N)
         DO 1 J=1, N
            CA(J) = CA(J) / MW
            X(J) = TIME(J)
            Y(J) = 1./CA(J)
1        CONTINUE
         CALL LS (X, Y, N, SLOPE, INTCPT)
         K(IT) = SLOPE
         WRITE (E, 2) TK (IT), (TIME (J), CA (J), J = 1, N)
         WRITE (6, 3) K (IT)
10    CONTINUE
      DO 4 J=1, NT
         X(J) = 1./TK(J)
         Y(J) = LOG(K(J))
```

3.54 (cont'd)

```
4   CONTINUE
    CALL LS (X, Y, NT, SLOPE, INTCPT)
    KO = EXP(INTCPT)
    E = –8.314 = SLOPE
    WRITE (6, 5) KO, E
2   FORMAT (' TEMPERATURE (K):  ', F6.2, /
       *  '  TIME  CA', /,
       *  ' (MIN)  (MOLES)', /
       *  100 (IX, F5.2, 3X, F7.4, /))
3   FORMAT (' K (L/MOL – MIN):  ', F5.3, //)
5   FORMAT (/, ' KO (L/MOL – MIN) :  ', E 12.4, /, ' E (J/MOL):  ', E 12.4)
    END
    SUBROUTINE LS (X, Y, N, SLOPE, INTCPT)
    REAL X(100), Y(100), SLOPE, INTCPT, SX, SY, SXX, SXY, AN
    INTEGER N, J
    SX=0
    SY=0
    SXX=0
    SXY=0
    DO 10 J=1,N
       SX = SX + X(J)
       SY = SY + Y(J)
       SXX = SXX + X(J)**2
       SXY = SXY + X(J)*Y(J)
10  CONTINUE
    AN = N
    SX = SX/AN
    SY = SY/AN
    SXX = SXX/AN
    SXY = SXY/AN
    SLOPE = (SXY – SX*SY)/(SXX – SX**2)
    INTCPT = SY – SLOPE*SX
    RETURN
    END
```

```
$ DATA                     [OUTPUT]
65.0      4                TEMPERATURE (K):  367.15
94.0      6                TIME  CA
10.0      8.1              (MIN)  (MOLS/L)
20.0      4.3              10.00   0.1246
30.0      3.0              20.00   0.0662
40.0      2.2              30.00   0.0462
50.0      1.8              40.00   0.0338
```

3.54 (cont'd)

60.0	1.5	50.00 0.0277
		60.00 0.0231
		$\underline{\underline{\mathrm{K(L/MOL \cdot MIN)}:\ 0.707}}$ (at 94°C)
110.	6	
10.0	3.5	
20.0	1.8	TEMPERATURE (K): 383.15
30.0	1.2	⋮
40.0	0.92	K(L/MOL·MIN): 1.758
50.0	0.73	
60.0	0.61	⋮
127.	6	
⋮		K0(L/MOL – MIN): 0.2329E+10
⋮ ETC		$\underline{\underline{E\ \mathrm{(J/MOL)}:\ 0.6690\mathrm{E}+05}}$