CHAPTER TWO

2.1 (a)
$$\frac{3\text{ wk}}{}\left|\frac{7\text{ d}}{1\text{ wk}}\right|\frac{24\text{ h}}{1\text{ d}}\left|\frac{3600\text{ s}}{1\text{ h}}\right|\frac{1000\text{ ms}}{1\text{ s}}=\underline{\underline{1.8144\times10^{9}\text{ ms}}}$$

(b)
$$\frac{38.1\text{ ft/s}}{}\left|\frac{0.0006214\text{ mi}}{3.2808\text{ ft}}\right|\frac{3600\text{ s}}{1\text{ h}}=25.98\text{ mi/h}\Rightarrow\underline{\underline{26.0\text{ mi/h}}}$$

(c)
$$\frac{554\text{ m}^4}{\text{d}\cdot\text{kg}}\left|\frac{1\text{ d}}{24\text{ h}}\right|\frac{1\text{ h}}{60\text{ min}}\left|\frac{1\text{ kg}}{1000\text{ g}}\right|\frac{10^8\text{ cm}^4}{1\text{ m}^4}=\underline{\underline{3.85\times10^{4}\text{ cm}^4/\text{min}\cdot\text{g}}}$$

2.2 (a)
$$\frac{760\text{ mi}}{\text{h}}\left|\frac{1\text{ m}}{0.0006214\text{ mi}}\right|\frac{1\text{ h}}{3600\text{ s}}=\underline{\underline{340\text{ m/s}}}$$

(b)
$$\frac{921\text{ kg}}{\text{m}^3}\left|\frac{2.20462\text{ lb}_m}{1\text{ kg}}\right|\frac{1\text{ m}^3}{35.3145\text{ ft}^3}=\underline{\underline{57.5\text{ lb}_m/\text{ft}^3}}$$

(c)
$$\frac{5.37\times10^{3}\text{ kJ}}{\text{min}}\left|\frac{1\text{ min}}{60\text{ s}}\right|\frac{1000\text{ J}}{1\text{ kJ}}\left|\frac{1.34\times10^{-3}\text{ hp}}{1\text{ J/s}}\right.=119.93\text{ hp}\Rightarrow\underline{\underline{120\text{ hp}}}$$

2.3 Assume that a golf ball occupies the space equivalent to a $2\text{ in}\times2\text{ in}\times2\text{ in}$ cube. For a classroom with dimensions $40\text{ ft}\times40\text{ ft}\times15\text{ ft}$:

$$n_{\text{balls}}=\frac{40\times40\times15\text{ ft}^3}{}\left|\frac{(12)^3\text{ in}^3}{\text{ft}^3}\right|\frac{1\text{ ball}}{2^3\text{ in}^3}=5.18\times10^{6}\approx\underline{\underline{5\text{ million balls}}}$$

The estimate could vary by an order of magnitude or more, depending on the assumptions made.

2.4
$$\frac{4.3\text{ light yr}}{}\left|\frac{365\text{ d}}{1\text{ yr}}\right|\frac{24\text{ h}}{1\text{ d}}\left|\frac{3600\text{ s}}{1\text{ h}}\right|\frac{1.86\times10^{5}\text{ mi}}{1\text{ s}}\left|\frac{3.2808\text{ ft}}{0.0006214\text{ mi}}\right|\frac{1\text{ step}}{2\text{ ft}}=\underline{\underline{7\times10^{16}\text{ steps}}}$$

2.5 Distance from the earth to the moon = 238857 miles

$$\frac{238857\text{ mi}}{}\left|\frac{1\text{ m}}{0.0006214\text{ mi}}\right|\frac{1\text{ report}}{0.001\text{ m}}=\underline{\underline{4\times10^{11}\text{ reports}}}$$

2.6

$$\frac{19\text{ km}}{1\text{ L}}\left|\frac{1000\text{ m}}{1\text{ km}}\right|\frac{0.0006214\text{ mi}}{1\text{ m}}\left|\frac{1000\text{ L}}{264.17\text{ gal}}\right.=44.7\text{ mi/gal}$$

Calculate the total cost to travel x miles.

$$\text{Total Cost}_{\text{American}}=\$14{,}500+\frac{\$1.25}{\text{gal}}\left|\frac{1\text{ gal}}{28\text{ mi}}\right|\frac{x\text{ (mi)}}{}=14{,}500+0.04464x$$

$$\text{Total Cost}_{\text{European}}=\$21{,}700+\frac{\$1.25}{\text{gal}}\left|\frac{1\text{ gal}}{44.7\text{ mi}}\right|\frac{x\text{ (mi)}}{}=21{,}700+0.02796x$$

Equate the two costs $\Rightarrow x=\underline{\underline{4.3\times10^{5}\text{ miles}}}$

2.15 (a) $F = ma \Rightarrow 1 \text{ fern} = (1 \text{ bung})(32.174 \text{ ft / s}^2)\left(\frac{1}{6}\right) = \underline{\underline{5.3623 \text{ bung} \cdot \text{ft / s}^2}}$

$$\Rightarrow \underline{\underline{\frac{1 \text{ fern}}{5.3623 \text{ bung} \cdot \text{ft / s}^2}}}$$

(b) On the moon: $W = \frac{3 \text{ bung}}{} \left| \frac{32.174 \text{ ft}}{6 \quad \text{s}^2} \right| \frac{1 \text{ fern}}{5.3623 \text{ bung} \cdot \text{ft / s}^2} = \underline{\underline{3 \text{ fern}}}$

On the earth: $W = (3)(32.174) / 5.3623 = \underline{\underline{18 \text{ fern}}}$

2.16 (a) $\approx (3)(9) = \underline{\underline{27}}$

$(2.7)(8.632) = \underline{\underline{23}}$

(b) $\approx \frac{4.0 \times 10^{-4}}{40} \approx \underline{\underline{1 \times 10^{-5}}}$

$(3.600 \times 10^{-4}) / 45 = \underline{\underline{8.0 \times 10^{-6}}}$

(c) $\approx 2 + 125 = \underline{\underline{127}}$

$2.365 + 125.2 = \underline{\underline{127.5}}$

(d) $\approx 50 \times 10^3 - 1 \times 10^3 \approx 49 \times 10^3 \approx \underline{\underline{5 \times 10^4}}$

$4.753 \times 10^4 - 9 \times 10^2 = \underline{\underline{5 \times 10^4}}$

2.17 $R \approx \frac{(7 \times 10^{-1})(3 \times 10^5)(6)(5 \times 10^4)}{(3)(5 \times 10^6)} \approx 42 \times 10^2 \approx \underline{\underline{4 \times 10^3}}$ (Any digit in range 2-6 is acceptable)

$R_{exact} = 3812.5 \Rightarrow \underline{\underline{3810}} \Rightarrow \underline{\underline{3.81 \times 10^3}}$

2.18 (a)

A: $R = 73.1 - 72.4 = \underline{\underline{0.7^\circ \text{C}}}$

$$\overline{X} = \frac{72.4 + 73.1 + 72.6 + 72.8 + 73.0}{5} = \underline{\underline{72.8^\circ \text{C}}}$$

$$s = \sqrt{\frac{(72.4 - 72.8)^2 + (73.1 - 72.8)^2 + (72.6 - 72.8)^2 + (72.8 - 72.8)^2 + (73.0 - 72.8)^2}{5 - 1}}$$

$$= \underline{\underline{0.3^\circ \text{C}}}$$

B: $R = 103.1 - 97.3 = \underline{\underline{5.8^\circ \text{C}}}$

$$\overline{X} = \frac{97.3 + 101.4 + 98.7 + 103.1 + 100.4}{5} = \underline{\underline{100.2^\circ \text{C}}}$$

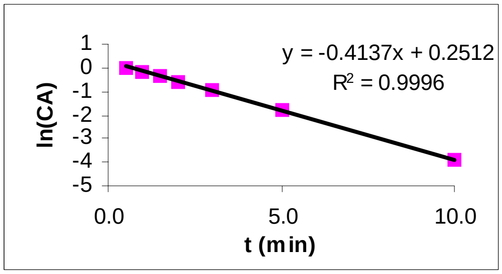
$$s = \sqrt{\frac{(97.3 - 100.2)^2 + (101.4 - 100.2)^2 + (98.7 - 100.2)^2 + (103.1 - 100.2)^2 + (100.4 - 100.2)^2}{5 - 1}}$$

$$= \underline{\underline{2.3^\circ \text{C}}}$$

(b) Thermocouple B exhibits a higher degree of scatter and is also more accurate.

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

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



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

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

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

$$t(\text{min}) = \frac{t'(s)}{} \cdot \frac{1\ \text{min}}{60\ \text{s}} = t'/60$$

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

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

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

3.32 **(a)** $$\frac{2600\ \text{mm Hg}}{} \cdot \frac{14.696\ \text{psi}}{760\ \text{mm Hg}} = \underline{\underline{50.3\ \text{psi}}}$$

(b) $$\frac{275\ \text{ft H}_2\text{O}}{} \cdot \frac{101.325\ \text{kPa}}{33.9\ \text{ft H}_2\text{O}} = \underline{\underline{822.0\ \text{kPa}}}$$

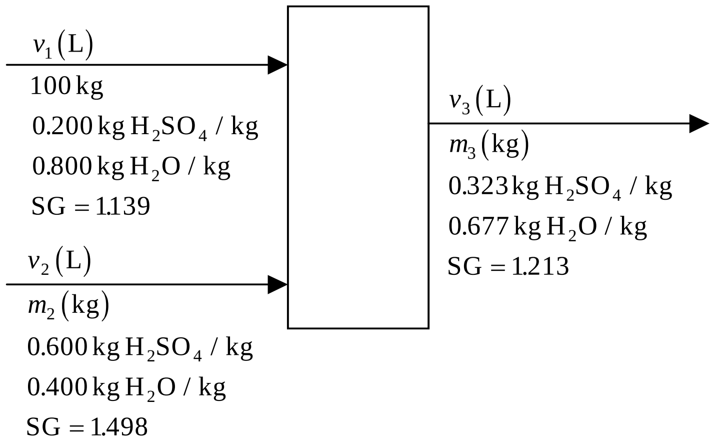
(c) $$\frac{3.00\ \text{atm}}{} \cdot \frac{1.01325\times10^5\ \text{N/m}^2}{1\ \text{atm}} \cdot \frac{1^2\ \text{m}^2}{100^2\ \text{cm}^2} = \underline{\underline{30.4\ \text{N/cm}^2}}$$

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

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

4.16 **a.** $\frac{4.00\text{ mol H}_2\text{SO}_4}{\text{L of solution}} \bigg| \frac{0.098\text{ kg H}_2\text{SO}_4}{\text{mol H}_2\text{SO}_4} \bigg| \frac{\text{L of solution}}{1.213\text{ kg solution}} = \underline{\underline{0.323(\text{kg H}_2\text{SO}_4/\text{kg solution})}}$

b.



5 unknowns (v_1, v_2, v_3, m_2, m_3)
– 2 balances
<u>– 3 specific gravities</u>
0 DF

<u>Overall mass balance</u>: $100 + m_2 = m_3$
<u>Water balance</u>: $0.800(100) + 0.400m_2 = 0.677m_3$
$\Rightarrow m_2 = 44.4\text{ kg}, \; m_3 = 144\text{ kg}$

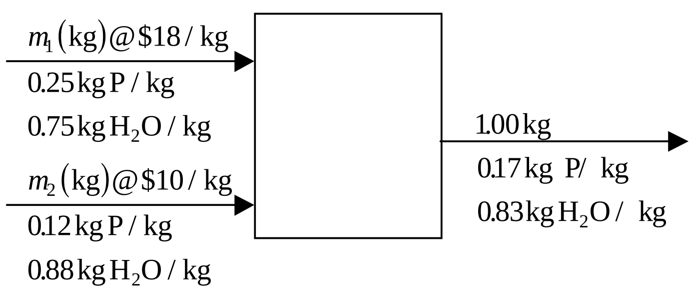
$v_1 = \frac{100\text{ kg}}{} \bigg| \frac{\text{L}}{1.139\text{ kg}} = 87.80\text{ L } 20\%\text{ solution}$

$v_2 = \frac{44.4\text{ kg}}{} \bigg| \frac{\text{L}}{1.498\text{ kg}} = 29.64\text{ L } 60\%\text{ solution}$

$\frac{v_1}{v_2} = \frac{87.80}{29.64} = \underline{\underline{2.96 \frac{\text{L } 20\%\text{ solution}}{\text{L } 60\%\text{ solution}}}}$

c. $\frac{1250\text{ kg P}}{\text{h}} \bigg| \frac{44.4\text{ kg } 60\%\text{ solution}}{144\text{ kg P}} \bigg| \frac{\text{L}}{1.498\text{ kg solution}} = \underline{\underline{257\text{ L/h}}}$

4.17



<u>Overall balance</u>: $m_1 + m_2 = 1.00$ (1)

<u>Pigment balance</u>: $0.25m_1 + 0.12m_2 = 0.17(1.00)$ (2)

Solve (1) and (2) simultaneously $\Rightarrow m_1 = 0.385\text{ kg } 25\%\text{ paint}, m_2 = 0.615\text{ kg } 12\%\text{ paint}$

<u>Cost of blend</u>: $0.385(\$18.00) + 0.615(\$10.00) = \$13.08\text{ per kg}$

<u>Selling price</u>: $1.10(\$13.08) = \underline{\underline{\$14.39\text{ per kg}}}$

4.67 (cont'd)

Air feed rate: $n_f = \dfrac{207.0 \text{ kmol } O_2}{\text{h}} \left| \dfrac{1 \text{ kmol air}}{0.21 \text{ kmol } O_2} \right| \dfrac{1.17 \text{ kmol air fed}}{\text{kmol air req.}} = \underline{\underline{1153 \text{ kmol air/h}}}$

b. $\underline{\underline{n_a = n_f \left(2x_1 + 3.5x_2 + 5x_3 + 6.5x_4\right)\left(1 + P_{xs}/100\right)\left(1/0.21\right)}}$

c. $\dot{n}_f = aR_f$, $(\dot{n}_f = 75.0 \text{ kmol / h}, R_f = 60) \Rightarrow \dot{n}_f = 1.25R_f$

$\dot{n}_a = bR_a$, $(\dot{n}_a = 550 \text{ kmol / h}, R_a = 25) \Rightarrow \dot{n}_a = 22.0R_a$

$$x_i = kA_i \Rightarrow \sum_i x_i = k\sum_i A_i = 1 \Rightarrow k = \frac{1}{\sum_i A_i}$$

$$\Rightarrow x_i = \frac{A_i}{\sum_i A_i}, \; i = CH_4, C_2H_4, C_3H_8, C_4H_{10}$$

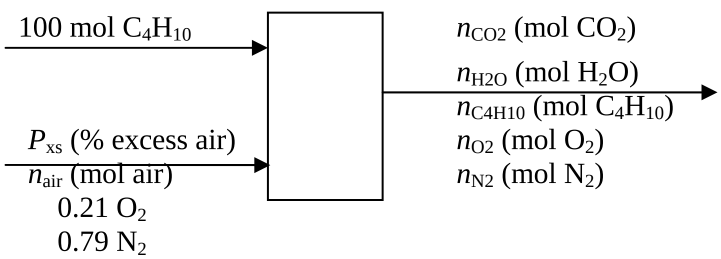
Run	P_{xs}	R_f	A_1	A_2	A_3	A_4
1	15%	62	248.7	19.74	6.35	1.48
2	15%	83	305.3	14.57	2.56	0.70
3	15%	108	294.2	16.61	4.78	2.11

Run	n_f	x_1	x_2	x_3	x_4	n_a	R_a
1	77.5	0.900	0.0715	0.0230	0.0054	934	42.4
2	103.8	0.945	0.0451	0.0079	0.0022	1194	54.3
3	135.0	0.926	0.0523	0.0150	0.0066	1592	72.4

d. Either of the flowmeters could be in error, the fuel gas analyzer could be in error, the flowmeter calibration formulas might not be linear, or the stack gas analysis could be incorrect.

4.68 a. $C_4H_{10} + 13/2\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$

Basis:



D.F. analysis

6 unknowns (n, n_1, n_2, n_3, n_4, n_5)

-3 atomic balances (C, H, O)

-1 N_2 balance

-1 % excess air

-1 % conversion

0 D.F.

6.47 N_2 - Henry's law: Perry's Chemical Engineers' Handbook, Page. 2-127, Table 2-138

$$\Rightarrow H_{N_2}(80°C) = 12.6\times10^4 \text{ atm/mole fraction}$$

$$\Rightarrow p_{N_2} = x_{N_2} H_{N_2} = (0.003)(12.6\times10^4) = 378 \text{ atm}$$

H_2O - Raoult's law: $p^*_{H_2O}(80°C) = \dfrac{355.1 \text{ mm Hg} \mid 1 \text{ atm}}{\mid 760 \text{ mm Hg}} = 0.467 \text{ atm}$

$$\Rightarrow p_{H_2O} = (x_{H_2O})(p^*_{H_2O}) = (0.997)(0.467) = 0.466 \text{ atm}$$

Total pressure: $P = p_{N_2} + p_{H_2O} = 378 + 0.466 = \underline{378.5 \text{ atm}}$

Mole fractions: $y_{H_2O} = p_{H_2O}/P = 0.466/378.5 = \underline{\underline{1.23\times10^{-3} \text{ mol } H_2O/\text{mol gas}}}$

$$y_{N_2} = 1 - y_{H_2O} = \underline{\underline{0.999 \text{ mol } N_2/\text{mol gas}}}$$

6.48 H_2O - Raoult's law: $p^*_{H_2O}(70°C) = \dfrac{233.7 \text{ mm Hg} \mid 1 \text{ atm}}{\mid 760 \text{ mm Hg}} = 0.3075 \text{ atm}$

$$\Rightarrow p_{H_2O} = x_{H_2O} p^*_{H_2O} = (1 - x_m)(0.3075)$$

Methane – Henry's law: $p_m = x_m \cdot H_m$

Total pressure: $P = p_m + p_{H_2O} = x_m \cdot 6.66\times10^4 + (1 - x_m)(0.3075) = 10$

$$\Rightarrow x_m = \underline{\underline{1.46\times10^{-4} \text{ mol } CH_4 \text{ / mol}}}$$

6.49 **a.**

Moles of water: $n_{H_2O} = \dfrac{1000 \text{ cm}^3 \mid 1 \text{ g} \mid \text{mol}}{\mid \text{cm}^3 \mid 18.02 \text{ g}} = 55.49 \text{ mol}$

Moles of nitrogen:

$$n_{N_2} = \frac{(1 - 0.334)\times 14.1 \text{ cm}^3(\text{STP}) \mid 1 \text{ mol} \mid 1 \text{ L}}{\mid 22.4 \text{ L (STP)} \mid 1000 \text{ cm}^3} = 4.192\times10^{-4} \text{ mol}$$

Moles of oxygen:

$$n_{O_2} = \frac{(0.334)\cdot 14.1 \text{ cm}^3(\text{STP}) \mid \text{mol} \mid \text{L}}{\mid 22.4 \text{ L (STP)} \mid 1000 \text{ cm}^3} = 2.102\times10^{-4} \text{ mol}$$

Mole fractions of dissolved gases:

$$x_{N_2} = \frac{n_{N_2}}{n_{H_2O} + n_{N_2} + n_{O_2}} = \frac{4.192\times10^{-4}}{55.49 + 4.192\times10^{-4} + 2.102\times10^{-4}} = 7.554\times10^{-6} \ \frac{\text{mol } N_2}{\text{mol}}$$

$$x_{O_2} = \frac{n_{O_2}}{n_{H_2O} + n_{N_2} + n_{O_2}} = \frac{2.102\times10^{-4}}{55.49 + 4.192\times10^{-4} + 2.102\times10^{-4}} = 3.788\times10^{-6} \text{ mol } O_2\text{/mol}$$

7.11 $A = \frac{\pi(3)^2 \text{ cm}^2}{} \left| \frac{1 \text{ m}^2}{10^4 \text{ cm}^2} \right. = 2.83 \times 10^{-3} \text{ m}^2$

(a) Downward force on piston:

$F_d = P_{atm} A + m_{piston+weight} g$

$= \frac{1 \text{ atm}}{} \left| \frac{1.01325 \times 10^5 \text{ N/m}^2}{\text{atm}} \right| \frac{2.83 \times 10^{-3} \text{ m}^2}{} + \frac{24.50 \text{ kg}}{} \left| \frac{9.81 \text{ m}}{\text{s}^2} \right| \frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} = 527 \text{ N}$

Upward force on piston: $F_u = AP_{gas} = \left(2.83 \times 10^{-3} \text{ m}^2\right)\left[P_g \left(\text{N/m}^2\right)\right]$

Equilibrium condition:

$F_u = F_d \Rightarrow 2.83 \times 10^{-3} \text{m}^2 \cdot P_0 = 527 \Rightarrow \underline{\underline{P_0 = 1.86 \times 10^5 \text{ N/m}^2 = 1.86 \times 10^5 \text{ Pa}}}$

$V_0 = \frac{nRT}{P_0} = \frac{1.40 \text{ g N}_2}{} \left| \frac{1 \text{ mol N}_2}{28.02 \text{ g}} \right| \frac{303 \text{ K}}{1.86 \times 10^5 \text{ Pa}} \left| \frac{1.01325 \times 10^5 \text{ Pa}}{1 \text{ atm}} \right| \frac{0.08206 \text{ L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = \underline{\underline{0.677 \text{ L}}}$

(b) For any step, $\Delta U + \Delta E_k + \Delta E_p = Q - W \underset{\Delta E_k = 0, \Delta E_p = 0}{\Rightarrow} \Delta U = Q - W$

Step 1: $Q \approx 0 \Rightarrow \underline{\underline{\Delta U = -W}}$

Step 2: $\underline{\underline{\Delta U = Q - W}}$ As the gas temperature changes, the pressure remains constant, so that $V = nRT/P_g$ must vary. This implies that the piston moves, so that W is not zero.

Overall: $T_{initial} = T_{final} \Rightarrow \Delta U = 0 \Rightarrow \underline{\underline{Q - W = 0}}$

In step 1, the gas expands $\Rightarrow W > 0 \Rightarrow \Delta U < 0 \Rightarrow \underline{\underline{T \text{ decreases}}}$

(c) Downward force $F_d = (1.00)(1.01325 \times 10^5)(2.83 \times 10^{-3}) + (4.50)(9.81)(1) = 331 \text{ N}$ (units as in Part (a))

Final gas pressure $P_f = \frac{F}{A} = \frac{331 \text{ N}}{2.83 \times 10^{-3} \text{ m}^2} = 1.16 \times 10^5 \text{ N/m}^2$

Since $T_0 = T_f = 30°\text{C}$, $P_f V_f = P_0 V_0 \Rightarrow V_f = V_0 \frac{P_0}{P_f} = (0.677 \text{ L}) \frac{1.86 \times 10^5 \text{ Pa}}{1.16 \times 10^5 \text{ Pa}} = 1.08 \text{ L}$

Distance traversed by piston $= \frac{\Delta V}{A} = \frac{(1.08 - 0.677) \text{ L}}{} \left| \frac{1 \text{ m}^3}{10^3 \text{ L}} \right| \frac{}{2.83 \times 10^{-3} \text{ m}^2} = 0.142 \text{ m}$

$\Rightarrow W = Fd = (331 \text{ N})(0.142 \text{ m}) = 47 \text{ N} \cdot \text{m} = 47 \text{ J}$

Since work is done by the gas on its surroundings, $W = +47 \text{ J} \underset{Q-W=0}{\Rightarrow} \underline{\underline{Q = +47 \text{ J}}}$

(heat transferred to gas)

7.12 $\hat{V} = \frac{32.00 \text{ g}}{\text{mol}} \left| \frac{4.684 \text{ cm}^3}{\text{g}} \right| \frac{10^3 \text{ L}}{10^6 \text{ cm}^3} = 0.1499 \text{ L/mol}$

$\hat{H} = \hat{U} + P\hat{V} = 1706 \text{ J/mol} + \frac{41.64 \text{ atm}}{} \left| \frac{0.1499 \text{ L}}{\text{mol}} \right| \frac{8.314 \quad \text{J/(mol} \cdot \text{K)}}{0.08206 \text{ L} \cdot \text{atm/(mol} \cdot \text{K)}} = \underline{\underline{2338 \text{ J/mol}}}$

8.46 (cont'd)

c. $Q = \Delta H = \sum_{out} n_i \hat{H}_i - \sum_{in} n_i \hat{H}_i \qquad V_{air} = \frac{100 \text{ mol}}{} \left| \frac{8.314 \text{ Pa}\cdot\text{m}^3}{\text{mol}\cdot\text{K}} \right| \frac{323 \text{ K}}{1.01325\times10^5 \text{ Pa}}$

$$\Rightarrow \frac{Q}{V_{air}} = \frac{\sum_{out} n_i \hat{H}_i - \sum_{in} n_i \hat{H}_i}{\frac{100 \text{ mol}}{} \left| \frac{8.314 \text{ Pa}\cdot\text{m}^3}{\text{mol}\cdot\text{K}} \right| \frac{323 \text{ K}}{1.01325\times10^5 \text{ Pa}}}$$

d. $\underline{2°\text{C superheat}} \Rightarrow y_1 = \frac{p*(48°\text{C})}{p} = \frac{83.71 \text{ mm Hg}}{760 \text{ mm Hg}} = 0.110 \text{ mol } H_2O/\text{mol}$

$\underline{\text{saturation at outlet}} \Rightarrow y_2 = \frac{p*(20°\text{C})}{p} = \frac{17.535 \text{ mm Hg}}{760 \text{ mm Hg}} = 0.023 \text{ mol } H_2O/\text{mol}$

$\underline{\text{dry air balance:}} \quad (100)(1-0.110) = n_2(1-0.023) \Rightarrow n_2 = 91.10 \text{ mol}$

$\underline{H_2O \text{ balance:}} \quad (100)(0.110) = (91.10)(0.023) + n_3 \Rightarrow n_3 = \frac{8.90 \text{ mol } H_2O}{} \left| \frac{0.018 \text{ kg}}{1 \text{ mol}} \right.$

$= 0.160 \text{ kg } H_2O \text{ condensed}$

$Q = \Delta H = \sum_{out} n_i \hat{H}_i - \sum_{in} n_i \hat{H}_i = -480.5 \text{ kJ}$

$V_{air} = \frac{100 \text{ mol}}{} \left| \frac{8.314 \text{ Pa}\cdot\text{m}^3}{\text{mol}\cdot\text{K}} \right| \frac{323 \text{ K}}{1.01325\times10^5 \text{ Pa}} = 2.65 \text{ m}^3$

$$\Rightarrow \frac{0.160 \text{ kg } H_2O \text{ condensed}}{2.65 \text{ m}^3 \text{ air fed}} = \underline{\underline{0.0604 \text{ kg } H_2O \text{ condensed / m}^3 \text{ air fed}}}$$

$$\Rightarrow \frac{-480.5 \text{ kJ}}{2.65 \text{ m}^3 \text{ air fed}} = \underline{\underline{-181 \text{ kJ / m}^3 \text{ air fed}}}$$

e. Solve equations with E-Z Solve.

f. $Q = \frac{-181 \text{ kJ}}{\text{m}^3 \text{ air fed}} \left| \frac{250 \text{ m}^3 \text{ air fed}}{\text{h}} \right| \frac{1 \text{ h}}{3600 \text{ s}} \left| \frac{1 \text{ kW}}{1 \text{ kJ / s}} \right. = \underline{\underline{-12.6 \text{ kW}}}$

9.35 (cont'd)

```
C   **DECREMENT BY 50 DEG. AND LOOK FOR A SIGN IN PSI
      DO 10I =1, 20
      CALL PSICAL (T, PHI, PSI)
      IF ((PSIL*PSI).LT.0.0) GO TO 40
      TLAST = T
      PSIL = PSI
      T = T – 50.
 10   CONTINUE
 40   IF (T.GE.0.0) GO TO 45
      WRITE (3, 2)
  2   FORMAT (1X, 'T LESS THAN ZERO -- ERROR')
      STOP
C   **APPLY REGULA-FALSI
 45   DO 50 I = 1, 20
      IF (I.NE.1) T2L = T2
      T2 = (T*PSIL-TLAST*PSI)/(PSIL-PSI)
      IF (ABS(T2-T2L).LT.0.01) GO TO 99
      CALL PSICAL (T2, PHIT, PSIT)
      IF (PSIT.EQ.0) GO TO 99
      IF ((PBIT*PBIL).GT.0.0) PSIL = PSIT
      IF ((PSIT*PSIL).GT.0.0) TLAST = T2
      IF ((PSIT*PSI).GT.0.0) PSI = PSIT
      IF ((PSIT*PSI).GT.0.0) T = T2
 50   CONTINUE
      IF (I.EQ.20) WRITE (3, 3)
  3   FORMAT ('0', 'REGULA-FALSI DID NOT CONVERGE IN 20 ITERATIONS')
 93   STOP
      END
      SUBROUTINE PSICAL (T, PHI, PSI)
      REAL KF
      PHI = (3052 + 36.2*T + 36.2*T + 0.05943*T**2)/(127240. – 11.35*T
     * – 0.0636*T**2)
      KP = 7.28E6*EXP(-17000./T)
      FBI = SQRT((KP/(1. + KP)) – 1./12. + PHI)
      WRITE (3, 1) T, PSI
  1   FORMAT (6X, 'T =', F6.2, 4X, 'PSI =', E11,4)
      RETURN
      END
```

<u>OUTPUT:</u> SOLUTION TO PROBLEM 9-35

$T = 1200.00 \quad PSI = 0.8226E+00$

$T = 1150.00 \quad PSI = 0.7048E+00$

$T = 1100.00 \quad PSI = 0.5551E+00$

$T = 1050.00 \quad PSI = 0.3696E+00$

$T = 1000.00 \quad PSI = 0.1619E+00$

$T = 950.00 \quad PSI = -0.3950E-01$

$T = 959.80 \quad PSI = -0.1824E-02$

$T = 960.25 \quad PSI = -0.7671E-04$

$T = 960.27 \quad PSI = -0.3278E-05$

<u>Solution:</u> $T = 960.3$ K, $f = 0.360$ mol C_2H_6 reacted/mol fed