20. Ball A: $PE = mgz = 2.00\ kg \times \frac{9.8\ m}{s^2} \times 10.0\ m = \frac{196\ kg\ m^2}{s^2} = 196\ J$

At Point I: All of this energy is transferred to Ball B. All of B's energy is kinetic energy at this point. $E_{total} = KE = 196\ J$. At point II, the sum of the total energy will equal 196 J.

At Point II: $PE = mgz = 4.00\ kg \times \frac{9.8\ m}{s^2} \times 3.00\ m = 118\ J$

$KE = E_{total} - PE = 196\ J - 118\ J = 78\ J$

22. a. $\Delta E = q + w = -47\ kJ + 88\ kJ = 41\ kJ$

b. $\Delta E = 82 + 47 = 129\ kJ$ c. $\Delta E = 47 + 0 = 47\ kJ$

d. When the surroundings deliver work to the system, $w > 0$. This is the case for a and b.

28. $H_2O(g) \rightarrow H_2O(l)$; $\Delta E = q + w$; $q = -40.66\ kJ$; $w = -P\Delta V$

Volume of 1 mol $H_2O(l)$ = 1 mol $H_2O(l) \times \frac{18.02\ g}{mol} \times \frac{1cm^3}{0.996\ g} = 18.1\ cm^3 = 18.1\ mL$

$w = -P\Delta V = -\ 1.00\ atm \times (0.0181\ L - 30.6\ L) = 30.6\ L\ atm \times \frac{101.3\ J}{L\ atm} = 3.10 \times 10^3\ J = 3.1\ kJ$

$\Delta E = q + w = -40.66\ kJ + 3.10\ kJ = -37.56\ kJ$

34. $4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$ $\Delta H = -1652\ kJ$; Note that 1652 kJ of heat are released when 4 mol Fe reacts with 3 mol O_2 to produce 2 mol Fe_2O_3.

a. $4.00\ mol\ Fe \times \frac{-1652\ kJ}{4\ mol\ Fe} = -1650\ kJ$ heat released

b. $1.00\ ml\ Fe_2O_3 \times \frac{-1652\ kJ}{2\ mol\ Fe_2O_3} = -826\ kJ$ heat released

c. $1.00\ g\ Fe \times \frac{1\ mol\ Fe}{55.85\ g} \times \frac{-1652\ kJ}{4\ mol\ Fe} = -7.39\ kJ$ heat released

d. $10.0\ g\ Fe \times \frac{1\ mol\ Fe}{55.85\ g} = 0.179\ mol\ Fe$; $2.00\ g\ O_2 \times \frac{1\ mol\ O_2}{32.00\ g} = 0.0625\ mol\ O_2$

0.179 mol Fe/0.0625 mol O_2 = 2.86; The balanced equation requires a 4 mol Fe/3 mol O_2 = 1.33 mol ratio. O_2 is limiting since the actual mol Fe/mol O_2 ratio is less than the required mol ratio.

$0.0625\ mol\ O_2 \times \frac{-1652\ kJ}{3\ mol\ O_2} = -34.4\ kJ$ heat released

38. a. s = specific heat capacity = $\frac{0.24\text{ J}}{\text{g °C}} = \frac{0.24\text{ J}}{\text{g K}}$ since $\Delta T(\text{K}) = \Delta T(\text{°C})$.

$$\text{energy} = s \times m \times \Delta T = \frac{0.24\text{ J}}{\text{g °C}} \times 150.0\text{ g} \times (298\text{ K} - 273\text{ K}) = 9.0 \times 10^2\text{ J}$$

b. molar heat capacity = $\frac{0.24\text{ J}}{\text{g °C}} \times \frac{107.9\text{ g Ag}}{\text{mol Ag}} = \frac{26\text{ J}}{\text{mol °C}}$

c. $1250\text{ J} = \frac{0.24\text{ J}}{\text{g °C}} \times m \times (15.2\text{°C} - 12.0\text{°C})$, $m = \frac{1250}{0.24 \times 3.2} = 1.6 \times 10^3\text{ g Ag}$

42. Heat loss by Ni = Heat gain by water; Keeping ΔT values positive to avoid sign errors:

$$\frac{0.444\text{ J}}{\text{g °C}} \times 15.0\text{ g} \times (100.0\text{°C} - T_f) = \frac{4.18\text{ J}}{\text{g °C}} \times 55.0\text{ g} \times (T_f - 23.0\text{°C})$$

$$666 - 6.66\,T_f = 230.\,T_f - 5290,\ \ T_f = \frac{5960}{237} = 25.1\text{°C}$$

48. $0.100\text{ L} \times \frac{0.500\text{ mol HCl}}{\text{L}} = 5.00 \times 10^{-2}\text{ mol HCl}$

$0.300\text{ L} \times \frac{0.500\text{ mol Ba(OH)}_2}{\text{L}} = 0.150\text{ mol Ba(OH)}_2$

To react with all the HCl present, $5.00 \times 10^{-2}/2 = 2.50 \times 10^{-2}$ mol $Ba(OH)_2$ are required. Since 0.150 mol $Ba(OH)_2$ are present, then HCl is the limiting reactant.

$5.00 \times 10^{-2}\text{ mol HCl} \times \frac{118\text{ kJ}}{2\text{ mol HCl}} = 2.95$ kJ of heat is evolved by reaction.

Heat gained by solution = $2.95 \times 10^3\text{ J} = \frac{4.18\text{ J}}{\text{g °C}} \times 400.0\text{ g} \times \Delta T$

$\Delta T = 1.76\text{°C} = T_f - T_i = T_f - 25.0\text{°C},\ \ T_f = 26.8\text{°C}$

52. $C_4H_4(g) + 5\,O_2(g) \rightarrow 4\,CO_2(g) + 2\,H_2O(l)$ $\Delta H_{comb} = -2341$ kJ

$C_4H_8(g) + 6\,O_2(g) \rightarrow 4\,CO_2(g) + 4\,H_2O(l)$ $\Delta H_{comb} = -2755$ kJ

$H_2(g) + 1/2\,O_2(g) \rightarrow H_2O(l)$ $\Delta H_{comb} = -286$ kJ

By convention, $H_2O(l)$ is produced when enthalpies of combustion are given and since per mol quantities are given, the combustion reaction refers to 1 mol of that quantity reacting with $O_2(g)$.

Using Hess's Law to solve:

$$\begin{array}{ll}
C_4H_4(g) + 5\,O_2(g) \rightarrow 4\,CO_2(g) + 2\,H_2O(l) & \Delta H_1 = -2341\text{ kJ} \\
4\,CO_2(g) + 4\,H_2O(l) \rightarrow C_4H_8(g) + 6\,O_2(g) & \Delta H_2 = -(-2755\text{ kJ}) \\
2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l) & \Delta H_3 = 2(-286\text{ kJ}) \\
\hline
C_4H_4(g) + 2\,H_2(g) \rightarrow C_4H_8(g) & \Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 \\
 & \Delta H = -158\text{ kJ}
\end{array}$$

56.

$$\begin{array}{ll}
C_6H_4(OH)_2 \rightarrow C_6H_4O_2 + H_2 & \Delta H = 177.4\text{ kJ} \\
H_2O_2 \rightarrow H_2 + O_2 & \Delta H = -(-191.2\text{ kJ}) \\
2\,H_2 + O_2 \rightarrow 2\,H_2O(g) & \Delta H = 2(-241.8\text{ kJ}) \\
2\,H_2O(g) \rightarrow 2\,H_2O(l) & \Delta H = 2(-43.8\text{ kJ}) \\
\hline
C_6H_4(OH)_2(aq) + H_2O_2(aq) \rightarrow C_6H_4O_2(aq) + 2\,H_2O(l) & \Delta H = -202.6\text{ kJ}
\end{array}$$

60. a. aluminum oxide = Al_2O_3; $2\,Al(s) + 3/2\,O_2(g) \rightarrow Al_2O_3(s)$

b. $C_2H_5OH(l) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 3\,H_2O(l)$

c. $NaOH(aq) + HCl(aq) \rightarrow H_2O(l) + NaCl(aq)$

d. $2\,C(\text{graphite}, s) + 3/2\,H_2(g) + 1/2\,Cl_2(g) \rightarrow C_2H_3Cl(g)$

e. $C_6H_6(l) + 15/2\,O_2(g) \rightarrow 6\,CO_2(g) + 3\,H_2O(l)$

Note: ΔH_{comb} values assume one mol of compound combusted.

f. $NH_4Br(s) \rightarrow NH_4^+(aq) + Br^-(aq)$

66. $5\,N_2O_4(l) + 4\,N_2H_3CH_3(l) \rightarrow 12\,H_2O(g) + 9\,N_2(g) + 4\,CO_2(g)$

$$\Delta H° = \left[12\text{ mol}\left(\frac{-242\text{ kJ}}{\text{mol}}\right) + 4\text{ mol}\left(\frac{-393.5\text{ kJ}}{\text{mol}}\right)\right] - \left[5\text{ mol}\left(\frac{-20.\text{ kJ}}{\text{mol}}\right) + 4\text{ mol}\left(\frac{54\text{ kJ}}{\text{mol}}\right)\right] = -4594\text{ kJ}$$

70. $CO(g) + 2\,H_2(g) \rightarrow CH_3OH(l)$, $\Delta H° = -239\text{ kJ} - (-110.5\text{ kJ}) = -129\text{ kJ}$

74. Mass of H_2O = $1.00\text{ gal} \times \frac{3.785\text{ L}}{\text{gal}} \times \frac{1000\text{ mL}}{\text{L}} \times \frac{1.00\text{ g}}{\text{mL}} = 3790\text{ g } H_2O$

Energy required (theoretical) = $s \times m \times \Delta T = \frac{4.18\text{ J}}{\text{g °C}} \times 3790\text{ g} \times 10.0\text{ °C} = 1.58 \times 10^5\text{ J}$

For an actual (80.0% efficient) process, more than this quantity of energy is needed since heat is always lost in any transfer of energy. The energy required is:

$$1.58 \times 10^5\text{ J} \times \frac{100.\text{ J}}{80.0\text{ J}} = 1.98 \times 10^5\text{ J}$$

Mass of C_2H_2 = $1.98 \times 10^5\text{ J} \times \frac{1\text{ mol } C_2H_2}{1300. \times 10^3\text{ J}} \times \frac{26.04\text{ g } C_2H_2}{\text{mol } C_2H_2} = 3.97\text{ g } C_2H_2$