Calorimetry Problems

55) $6.50\,g\ NaOH$ a) $q = mC\Delta T$

$100.0\,g\ H_2O$ $q = (106.5\,g)(4.18\ J/g°C)(16.2°C)$

$21.6 \rightarrow 37.8\,°C$ $q = 7211.754$

$7210\ J = 7.21\ kJ$ heat released

b) $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

$$\frac{7.21\ kJ}{6.50\,g\ NaOH} \times \frac{40.00\,g\ NaOH}{1\,mol\ NaOH} = 44.4\ kJ/mole$$

$$\boxed{\Delta H_{soln} = -44.4\ kJ/mol}$$

56) $4.25\,g\ NH_4NO_3$

$60.0\,g\ H_2O$ $q = mC\Delta T$

$22.0 \rightarrow 16.9\,°C$ $= (64.25\,g)(4.18\ J/g°C)(5.1)$

endo $= 1369.7\ J$

$= 1400\ J = 1.4\ kJ$ absorbed

$NH_4NO_{3(s)} \rightarrow NH^+_{4(aq)} + NO^-_{3(aq)}$

$$\frac{1.4\ kJ}{4.25\,g\ NH_4NO_3} \times \frac{80.06\,g\ NH_4NO_3}{1\,mol\ NH_4NO_3} = 26.4$$

$$\boxed{\Delta H_{soln} = +26.4\ kJ/mol}$$

57) $2.200\,g\ C_6H_4O_2$

$C_{cal} = 7.854\ kJ/°C$ $C_6H_4O_2 + 5O_2 \rightarrow 6CO_2 + 2H_2O$

$23.44 \rightarrow 30.57\,°C$ $\Delta H_{comb} = \_\_\_\ kJ/g = \_\_\_\ kJ/mol$

$q = C_{cal} \times \Delta T$

$= 7.854\ kJ/°C \times 7.13\,°C$

$= 55.999\ kJ$

$= 56.0\ kJ$

$$\frac{56.0\ kJ}{2.200\,g\ C_6H_4O_2} = 25.5\ kJ/g\ C_6H_4O_2$$

$$\boxed{\Delta H_{comb} = -25.5\ kJ/g}$$

$$\frac{25.5\ kJ}{1\,g\ C_6H_4O_2} \times \frac{108.10\,g}{1\,mol\ C_6H_4O_2} = 2756$$

$2760\ kJ/mole$

$$\boxed{\Delta H_{comb} = -2760\ kJ/mol}$$

59.) $\Delta H_{comb} = -15.57$ kJ/g
3.500 g $C_6H_{12}O_6$
$20.94 \rightarrow 24.72°C$

a) $q = C_{cal}\Delta T$

$q = 15.57$ kJ/g $\times$ 3.500 g
$= 54.50$ kJ

$C_{cal} = \dfrac{q}{\Delta T}$

$C_{cal} = \dfrac{54.50 \text{ kJ}}{3.78°C} = \boxed{14.4 \text{ kJ/°C}}$

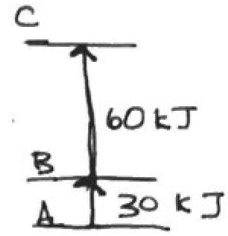
b) Twice as much glucose, produces twice as much heat, which raises the calorimeter temperature by twice as many degrees Celsius.

$\dfrac{7.000 \cancel{\text{g glucose}}}{1} \times \dfrac{15.57 \text{ kJ}}{1 \cancel{\text{g}} \text{ glucose}} \times \dfrac{1°C}{14.4 \text{ kJ}} = \boxed{7.57°C}$

Compare to 3.78°C

62.)

$$A \rightarrow \cancel{B} \qquad \Delta H = +30\text{ kJ}$$
$$\cancel{B} \rightarrow C \qquad \Delta H = +60\text{ kJ}$$
$$A \rightarrow C \qquad \Delta H = +90\text{ kJ}$$



63.)

$$\cancel{P_4 + 3O_2 \rightarrow P_4O_6 \qquad \Delta H = -1640.1\text{ kJ}}$$

flip

$$\cancel{P_4} + \cancel{5}\,{}^{2}O_2 \rightarrow P_4O_{10} \qquad \Delta H = -2940.1\text{ kJ}$$
$$P_4O_6 \rightarrow \cancel{P_4} + \cancel{3O_2} \qquad \Delta H = +1640.1\text{ kJ}$$
$$* \; P_4O_6 + 2O_2 \rightarrow P_4O_{10} \qquad \Delta H = -1300.0\text{ kJ}$$

64.) $* \; CO + 2H_2 \rightarrow CH_3OH \qquad \Delta H = ?$

$$\cancel{2C + O_2 \rightarrow 2CO \qquad \Delta H = -221.0\text{ kJ}}$$

flip + ÷2

$$\cancel{2C} + \cancel{\tfrac{1}{2}O_2} + \boxed{\cancel{4}\,{}^{2}H_2} \rightarrow \cancel{2}\boxed{CH_3OH} \qquad \Delta H = -\frac{402.4}{2}\text{ kJ}$$
$$\boxed{CO} \rightarrow \cancel{C} + \cancel{\tfrac{1}{2}O_2} \qquad \Delta H = +110.5\text{ kJ}$$
$$* \; CO + 2H_2 \rightarrow CH_3OH \qquad \Delta H = -90.7\text{ kJ}$$

65.) $* \; C_2H_4 + 6F_2 \rightarrow 2CF_4 + 4HF$

$$\times 2 \rightarrow \cancel{2H_2} + \boxed{2F_2} \rightarrow \boxed{\cancel{8}\,{}^{4}HF} \qquad \Delta H = (-537\text{ kJ})2$$
$$\times 2 \rightarrow \cancel{2C} + \boxed{\cancel{8}\,{}^{4}F_2} \rightarrow \boxed{2CF_4} \qquad \Delta H = (-680\text{ kJ})2$$

flip

$$\cancel{2C + 2H_2 \rightarrow C_2H_4 \qquad \Delta H = +52.3\text{ kJ}}$$
$$\boxed{C_2H_4} \rightarrow \cancel{2C} + \cancel{2H_2} \qquad \Delta H = -52.3\text{ kJ}$$
$$* \; C_2H_4 + 6F_2 \rightarrow 4HF + 2CF_4 \qquad \Delta H = -2486.3\text{ kJ}$$

66.) * $N_2O + NO_2 \rightarrow 3NO \quad \Delta H = ?$

$\cancel{N_2} + \cancel{O_2} \rightarrow \boxed{2NO} \qquad \Delta H = +180.7\ kJ$

$\cancel{2NO + O_2 \rightarrow 2NO_2 \qquad \Delta H = -113.1\ kJ}$

flip ÷2 $\div 2 \rightarrow \cancel{2}\boxed{N_2O} \rightarrow \cancel{2N_2} + \cancel{O_2} \qquad \Delta H = \frac{-163.2\ kJ}{2}$

$\boxed{NO_2} \rightarrow \boxed{NO} + \cancel{\tfrac{1}{2}O_2} \qquad \Delta H = +56.55\ kJ$

$N_2O + NO_2 \rightarrow 3NO \qquad \Delta H = +155.65\ kJ$

110.) * $2CH_4 \rightarrow C_2H_4 + 2H_2$

$\times 2 \rightarrow \boxed{2CH_4} + \cancel{\overset{4}{2}O_2} \rightarrow \cancel{2CO_2} + \cancel{\overset{4}{2}H_2O} \qquad (-890.3)2 = -1780.6$

$\cancel{C_2H_4 + H_2 \rightarrow C_2H_6 \qquad -136.3}$

flip $\cancel{2H_2 + O_2 \rightarrow 2H_2O \qquad -571.6}$

$\cancel{2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O \qquad -3120.8}$

flip ÷2

$\cancel{C_2H_6} \rightarrow \boxed{C_2H_4} + \boxed{H_2} \qquad +136.3$

$\cancel{2CO_2} + \cancel{3H_2O} \rightarrow \cancel{C_2H_6} + \cancel{3\tfrac{1}{2}O_2} \qquad +1560.4$

flip ÷2 $\cancel{H_2O} \rightarrow \boxed{H_2} + \cancel{\tfrac{1}{2}O_2} \qquad +285.8$

$2CH_4 \rightarrow C_2H_4 + 2H_2 \qquad \Delta H = +201.9\ kJ$

72.) $C_3H_{8\,(g)} + 5O_{2\,(g)} \longrightarrow 3CO_{2\,(g)} + 4H_2O_{(g)}$

$$\Delta H_{comb} = \Delta H_r = \left[3(-393.5) + 4(-241.8)\right] - \left[-103.85 + 5(0)\right]$$

$$= \left[-1180.5 + (-967.2)\right] - \left[-103.85\right]$$

$$= -2043.9 \text{ kJ } \underline{\text{per}} \ \underline{\text{mole}} \ C_3H_8$$

$$\frac{10.0\,g\,C_3H_8}{1} \times \frac{1\text{ mol } C_3H_8}{44.11\,g\,C_3H_8} \times \frac{-2043.9\text{ kJ}}{1\text{ mol } C_3H_8} = -463.36\text{ kJ}$$

$$\boxed{-463\text{ kJ}}$$

95.) $C_3H_4 + 4O_2 \rightarrow 3CO_2 + 2H_2O$

$$\Delta H_{comb} = \left[3(-393.5) + 2(-241.8)\right] - \left[+185.4 + 4(0)\right]$$

$$\Delta H_{comb} = \boxed{-1849.5\text{ kJ/mol } C_3H_4}$$

$$2C_3H_6 + 9O_2 \rightarrow \overset{6}{\cancel{3}}CO_2 + \overset{6}{\cancel{3}}H_2O$$

$$\Delta H_{comb} = \left[6(-393.5) + 6(-241.8)\right] - \left[2(+20.4) + 9(0)\right]$$

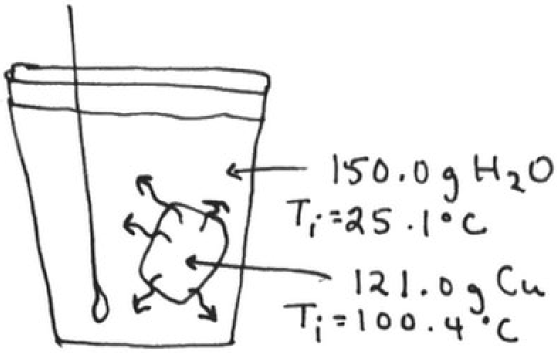
$$\Delta H_{comb} = -3852.6\text{ kJ}/2 = \boxed{-1926.3\text{ kJ/mol } C_3H_6}$$

see #72

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

$$\boxed{\Delta H_{comb} = -2044.0\text{ kJ/mole } C_3H_8} \rightarrow$$ see #72 above for calculation

106.)



$T_f = 30.1°C$

a) Heat lost by Cu

$$q = mc\Delta T$$
$$= (121.0\cancel{g})(.385\ J/\cancel{g}\cancel{°C})(100.4 - 30.1\cancel{°C})$$
$$= 3270\ J \qquad \boxed{q = -3270\ J}$$

b)
$$q = mc\Delta T$$
$$= (150.0\cancel{g})(4.184\ J/\cancel{g}\cancel{°C})(30.1 - 25.1\cancel{°C})$$
$$= 3140\ J \qquad \boxed{q = 3140\ J}$$

c) Heat lost = Heat gained

$$3270 - 3140 = 130\ J$$
$$\frac{130\ J}{5.0°C} = 26\ J/°C = \boxed{26\ J/K}$$

d)
$$q = mc\Delta T$$
$$\Delta T = \frac{q}{mc} = \frac{3270\cancel{J}}{(150.0\cancel{g})(4.184\cancel{J}/g°C)} = 5.21°C$$
$$T_f = 25.1 + 5.21 = \boxed{30.3°C}$$

107.) a) First find heat capacity of calorimeter:

$$\frac{.235\,g\ \cancel{\text{benz acid}}}{1.642\,°C} \times \frac{26.38\ kJ}{1\ g\ \cancel{\text{benz. acid}}} = \boxed{3.77\ \frac{kJ}{°C}}$$

$$\frac{1\ \cancel{\text{mole}\ C_8H_{10}N_4O_2}}{1}\ \frac{194.2\,\cancel{g\ C_8H_{10}N_4O_2}}{\cancel{1\ \text{mole}}\ C_8H_{10}N_4O_2}\ \frac{1.525\,\cancel{°C}}{.265\,\cancel{g\ C_8H_{10}N_4O_2}}\ \frac{3.77\ kJ}{1\,\cancel{°C}}$$

$$= \boxed{4210\ kJ}$$

$$\frac{4210\ kJ}{\text{mole}}$$

b) The overall uncertainty is approximately equal to the sum of the uncertainties due to each effect.

mass uncertainty

$$\frac{.001}{.265} \approx \frac{1}{265} \qquad \frac{1}{265} = \frac{x}{4210} \qquad x = 16\ kJ$$

$$\frac{.001}{.235} \approx \frac{1}{235} \qquad \frac{1}{235} = \frac{x}{4210} \qquad x = 18\ kJ$$

Temperature uncertainty

$$\frac{.002}{1.525} \approx \frac{1}{760} \qquad \frac{1}{760} = \frac{x}{4210} \qquad x = 6\ kJ$$

$$\frac{.002}{1.642} \approx \frac{1}{820} \qquad \frac{1}{820} = \frac{x}{4210} \qquad x = 5\ kJ$$

overall uncertainty → 45 kJ

109.) a) + b)

$CH_{4(g)} + O_{2(g)} \rightarrow C_{(s)} + 2H_2O_{(l)}$

$\Delta H^\circ_r = [0 + 2(-285.8\,kJ)] - [(-74.8\,kJ) + 0] = -496.8\,kJ$

$CH_{4(g)} + \frac{3}{2}O_2 \rightarrow CO_{(g)} + 2H_2O_{(l)}$

$\Delta H^\circ_r = [(-110.5\,kJ) + 2(-285.8\,kJ)] - [(-74.8\,kJ) + 0] = -607.3\,kJ$

$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

$\Delta H^\circ_r = [(-393.5\,kJ) + 2(-285.8\,kJ)] - [(-74.8\,kJ + 0] = -890.3\,kJ$

c) The reaction that produces CO_2 is the most exothermic reaction. Since it releases the most heat, the products are the most stable and will predominate.