COMBINATION PROBLEM 1

$C_4H_{10}(g) + \frac{13}{2}\,O_2(g) \longrightarrow 4\,CO_2(g) + 5\,H_2O(l) \qquad \Delta H^o = ?$

$$Q = mc\Delta T$$
$$Q = 30\,000 \text{ g x } 4.184\ \frac{J}{g^oC}\ (23.94\ -\ 20.00)^oC$$
$$Q = 494548.8 \text{ J}$$
$$Q = 494.55 \text{ kJ}$$

$$\frac{494.55 \text{ kJ}}{10 \text{ g } C_4H_{10}} \text{ x } \frac{58.14 \text{ g } C_4H_{10}}{1 \text{ mol } C_4H_{10}} = \frac{2875.31 \text{ kJ}}{1 \text{ mol } C_4H_{10}}$$

$$\Delta H = -Q$$
$$\Delta H = -2875.31 \text{ kJ/1 mol } C_4H_{10}$$

$C_4H_{10}(g) + \frac{13}{2}\,O_2(g) \longrightarrow 4\,CO_2(g) + 5\,H_2O(l) \qquad \Delta H^o = -2875.31 \text{ kJ}$

$$\Delta H^o = [4\Delta H^o_{CO_2(g)} + 5\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_4H_{10}(g)} + \tfrac{13}{2}\Delta H^o_{O_2(g)}]$$
$$-2875.31 \text{ kJ} = [4(-393.5 \text{ kJ}) + 5(-285.8 \text{ kJ})] - [\Delta H^o_{C_4H_{10}} + \tfrac{13}{2}(0)]$$
$$\Delta H^o_{C_4H_{10}(g)} = -3003.0 \text{ kJ} + 2875.31 \text{ kJ}$$
$$\Delta H^o_{C_4H_{10}(g)} = -127.69 \text{ kJ}$$

Please note that the textbook value (pg 799) for the heat of formation of C_4H_{10} is -125.6 kJ. This is definitely close enough!

COMBINATION PROBLEM 2

$C_4H_{10}(g) + \frac{13}{2}\,O_2(g) \longrightarrow 4\,CO_2(g) + 5\,H_2O(l) \qquad \Delta H^o = ?$

$$\Delta H^o = [4\Delta H^o_{CO_2(g)} \ + \ 5\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_4H_{10}(g)} \ + \ \tfrac{13}{2}\Delta H^o_{O_2(g)}]$$
$$\Delta H^o = [4(-393.5\text{ kJ}) \ + \ 5(-285.8\text{ kJ})] - [-125.6\text{ kJ} + \tfrac{13}{2}(0)]$$
$$\Delta H^o = -2877.4\text{ kJ}$$

$C_4H_{10}(g) + \frac{13}{2}\,O_2(g) \longrightarrow 4\,CO_2(g) + 5\,H_2O(l) \qquad \Delta H^o = -2877.4\text{ kJ}$

$$Q = -\Delta H$$
$$Q = 2877.4\text{ kJ/mol } C_4H_{10}$$

$$25.00\text{ g } C_4H_{10}\text{ x }\frac{1\text{ mol } C_4H_{10}}{58.14\text{ g } C_4H_{10}}\ \text{x}\ \frac{2877.4\text{ kJ}}{1\text{ mol } C_4H_{10}}\ \text{x}\ \frac{1000\text{ J}}{1\text{ kJ}}\ =\ 1237272\text{ J}$$

$$\Delta T = \frac{Q}{mc}$$
$$\Delta T = \frac{1237272\text{ J}}{50\,000\text{ g x }4.184\frac{\text{J}}{\text{g}^o\text{C}}}$$
$$\Delta T = 5.914\ ^o\text{C}$$

COMBINATION PROBLEM 3

$$C_6H_{14}(l) + \tfrac{19}{2}\,O_2(g) \longrightarrow 6\,CO_2(g) + 7\,H_2O(l) \qquad \Delta H^o = ?$$

$$Q = mc\Delta T$$
$$Q = 25\,000 \text{ g x } 4.184\ \frac{J}{g^oC}\ (31.925\ -\ 25.000)^oC$$
$$Q = 724355 \text{ J}$$
$$Q = 724.36 \text{ kJ}$$

$$\frac{724.36 \text{ kJ}}{15 \text{ g } C_6H_{14}} \text{ x } \frac{86.20 \text{ g } C_6H_{14}}{1 \text{ mol } C_6H_{14}} = \frac{4162.63 \text{ kJ}}{1 \text{ mol } C_6H_{14}}$$

$$\Delta H = -Q$$
$$\Delta H = -4162.63 \text{ kJ}/1 \text{ mol } C_6H_{14}$$

$$C_6H_{14}(l) + \tfrac{19}{2}\,O_2(g) \longrightarrow 6\,CO_2(g) + 7\,H_2O(l) \qquad \Delta H^o = -4162.63 \text{ kJ}$$

$$\Delta H^o = [6\Delta H^o_{CO_2(g)} + 7\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_6H_{14}(l)} + \tfrac{19}{2}\,\Delta H^o_{O_2(g)}]$$
$$-4162.63 \text{ kJ} = [6(-393.5 \text{ kJ}) + 7(-285.8 \text{ kJ})] - [\Delta H^o_{C_6H_{14}} + \tfrac{19}{2}\,(0)]$$
$$\Delta H^o_{C_6H_{14}(l)} = -4361.6 \text{ kJ} + 4162.63 \text{ kJ}$$
$$\Delta H^o_{C_6H_{14}(l)} = -198.97 \text{ kJ}$$

Please note that the textbook value (pg 799) for the heat of formation of C_6H_{14} is -198.7 kJ. This is definitely close enough!

COMBINATION PROBLEM 4

$$P_4O_{10}(s) + 6\,H_2O(l) \longrightarrow 4\,H_3PO_4(aq) \qquad \Delta H^o = ?$$

$$Q = mc\Delta T$$
$$Q = 1\,000\text{ g x } 4.184\ \frac{J}{g^oC}\ (19.93\ -\ 15.03)^oC$$
$$Q = 20501.6\text{ J}$$
$$Q = 20.502\text{ kJ}$$

$$\frac{20.502\text{ kJ}}{13.5\text{ g } P_4O_{10}}\ \text{x}\ \frac{283.88\text{ g } P_4O_{10}}{1\text{ mol } P_4O_{10}}\ =\ \frac{431.11\text{ kJ}}{1\text{ mol } P_4O_{10}}$$

$$\Delta H\ =\ -Q$$
$$\Delta H\ =\ -431.11\text{ kJ}/1\text{ mol } P_4O_{10}$$

$$P_4O_{10}(s) + 6\,H_2O(l) \longrightarrow 4\,H_3PO_4(aq) \qquad \Delta H^o = -431.11\text{ kJ}$$

$$\Delta H^o = [4\Delta H^o_{H_3PO_4(aq)}] - [\Delta H^o_{P_4O_{10}} + 6\Delta H^o_{H_2O(l)}]$$
$$-431.11\text{ kJ} = [4\Delta H^o_{H_3PO_4(aq)}\ ] - [(-3012.48\text{ kJ}) + 6(-285.77\text{ kJ})]$$
$$-4\Delta H^o_{H_3PO_4(aq)} = 4727.10\text{ kJ} + 431.11\text{ kJ}$$
$$\Delta H^o_{H_3PO_4(aq)} = -1289.55\text{ kJ}$$

For comparison to the answer given in the question, convert to kcal

$$-1289.55\text{ kJx}\ \frac{1\text{ kcal}}{4.184\text{ kJ}} = -308.21\text{ kcal}$$

COMBINATION PROBLEM 5

$$C_6H_6(l) + \tfrac{15}{2}\,O_2(g) \longrightarrow 6\,CO_2(g) + 3\,H_2O(l) \qquad \Delta H^o = ?$$

$$\Delta H^o = [6\Delta H^o_{CO_2(g)} \ + \ 3\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_6H_6(g)} \ + \ \tfrac{15}{2}\Delta H^o_{O_2(g)}]$$
$$\Delta H^o = [6(-393.5\text{ kJ}) \ + \ 3(-285.8\text{ kJ})] - [+49.0\text{ kJ} + \tfrac{15}{2}(0)]$$
$$\Delta H^o = -3267.4\text{ kJ}$$

$$C_6H_6(l) + \tfrac{15}{2}\,O_2(g) \longrightarrow 6\,CO_2(g) + 3\,H_2O(l) \qquad \Delta H^o = -3267.4\text{ kJ}$$

$$Q = -\Delta H$$
$$Q = 3267.4\text{ kJ/mol } C_6H_6$$

$$100\text{ kJ x } \frac{1\text{ mol } C_6H_6}{3267.4\text{ kJ}} \ \text{ x } \ \frac{78.12\text{ g } C_6H_6}{1\text{ mol } C_6H_6} \ = \ 2.391\text{ g } C_6H_6$$

COMBINATION PROBLEM 6

$C_3H_8(g) + 5\,O_2(g) \longrightarrow 3\,CO_2(g) + 4\,H_2O(l) \qquad \Delta H^o = ?$

$$\Delta H^o = [3\Delta H^o_{CO_2(g)} \ + \ 4\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_3H_8(g)} \ + \ 5\Delta H^o_{O_2(g)}]$$
$$\Delta H^o = [3(-393.5\text{ kJ}) + 4(-285.8\text{ kJ})] - [-104.7\text{ kJ} + 5(0)]$$
$$\Delta H^o = -2219.0\text{ kJ}$$

$C_3H_8(g) + 5\,O_2(g) \longrightarrow 3\,CO_2(g) + 4\,H_2O(l) \qquad \Delta H^o = -2219.0\text{ kJ}$

$$Q = -\Delta H$$
$$Q = 2219.0\text{ kJ/mol } C_3H_8$$

$$Q = mc\Delta T$$
$$Q = 160\,000\text{ g x } 4.184\ \frac{J}{g^oC}\text{ x } (52.00 - 15.00)^oC$$
$$Q = 24769280\text{ J}$$
$$Q = 24769.28\text{ kJ}$$

$$24769.28\text{ kJ x } \frac{1\text{ mol } C_3H_8}{2219.0\text{ kJ}} \text{ x } \frac{44.11\text{ g } C_3H_8}{1\text{ mol } C_3H_8} = 492.37\text{ g } C_3H_8$$

COMBINATION PROBLEM 7

$C_{10}H_{22}(l) + \frac{31}{2}\,O_2(g) \longrightarrow 10\,CO_2(g) + 11\,H_2O(l) \qquad \Delta H^o = ?$

$$Q = mc\Delta T$$
$$Q = 50\,000\text{ g x } 4.184\ \frac{J}{g^oC}\text{ x } 11.469\ ^oC$$
$$Q = 2399314.8\text{ J}$$
$$Q = 2399.31\text{ kJ}$$

$$\frac{2399.31\text{ kJ}}{50\text{ g } C_{10}H_{22}}\ \text{x}\ \frac{142.32\text{ g } C_{10}H_{22}}{1\text{ mol } C_{10}H_{22}}\ =\ \frac{6829.41\text{ kJ}}{1\text{ mol } C_{10}H_{22}}$$

$$\Delta H\ =\ -Q$$
$$\Delta H\ =\ -6829.41\text{ kJ}/1\text{ mol } C_{10}H_{22}$$

$C_{10}H_{22}(l) + \frac{31}{2}\,O_2(g) \longrightarrow 10\,CO_2(g) + 11\,H_2O(l) \qquad \Delta H^o = -6829.41\text{ kJ}$

$$\Delta H^o = [10\Delta H^o_{CO_2(g)}\ +\ 11\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_{10}H_{22}(g)}\ +\ \tfrac{31}{2}\Delta H^o_{O_2(g)}]$$
$$-6829.41\text{ kJ} = [10(-393.5\text{ kJ})\ +\ 11(-285.8\text{ kJ})] - [\Delta H^o_{C_{10}H_{22}} + \tfrac{31}{2}(0)]$$
$$\Delta H^o_{C_{10}H_{22}(g)} = -7078.8\text{ kJ} + 6829.41\text{ kJ}$$
$$\Delta H^o_{C_{10}H_{22}(g)} = -249.39\text{ kJ}$$

COMBINATION PROBLEM 8

$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l) \qquad \Delta H^o = ?$

$$Q = mc\Delta T$$
$$Q = 8\,000 \text{ g x } 4.184 \frac{J}{g^oC} (40 - 20)^oC$$
$$Q = 669440 \text{ J}$$
$$Q = 669.44 \text{ kJ}$$

$$\frac{669.44 \text{ kJ}}{21.9 \text{ g } C_2H_5OH} \text{ x } \frac{46.08 \text{ g } C_2H_5OH}{1 \text{ mol } C_2H_5OH} = \frac{1408.58 \text{ kJ}}{1 \text{ mol } C_2H_5OH}$$

$$\Delta H = -Q$$
$$\Delta H = -1408.58 \text{ kJ/1 mol } C_2H_5OH$$

$C_2H_5OH(l) + 3\,O_2(g) \longrightarrow 2\,CO_2(g) + 3\,H_2O(l) \qquad \Delta H^o = -1408.58 \text{ kJ}$

$$\Delta H^o = [2\Delta H^o_{CO_2(g)} + 3\Delta H^o_{H_2O(l)}] - [\Delta H^o_{C_2H_5OH(g)} + 3\Delta H^o_{O_2(g)}]$$
$$-1408.58 \text{ kJ} = [2(-393.5 \text{ kJ}) + 3(-285.8 \text{ kJ})] - [\Delta H^o_{C_2H_5OH} + 3(0)]$$
$$\Delta H^o_{C_2H_5OH(g)} = -1644.4 \text{ kJ} + 1408.58 \text{ kJ}$$
$$\Delta H^o_{C_2H_5OH(g)} = -235.82 \text{ kJ}$$

Please note that the textbook value (pg 799) for the heat of formation of $C_2H_5OH(l)$ is -235.2 kJ. This is definitely close enough!