Chemistry 2740 Spring 2018 Test 1 solutions

1. (a) $q = (120\,\text{g})(2427\,\text{J}\,\text{g}^{-1}) = 291\,\text{kJ}$

   (b)

$$q = mc_p\Delta T$$
$$\therefore \Delta T = \frac{q}{mc_p} = \frac{291\,\text{kJ}}{(74\,\text{kg})(3.47\,\text{kJ}\,\text{K}^{-1}\text{kg}^{-1})} = 1.1\,\text{K}$$

2. (a)

$$S(\text{l},\text{mp}) = S(\text{ice},\text{mp}) + \Delta_{\text{fus}}S$$
$$\Delta_{\text{fus}}S = \frac{\Delta_{\text{fus}}H}{T_{\text{fus}}} = \frac{6.132\times10^3\,\text{J}\,\text{mol}^{-1}}{276.83\,\text{K}} = 22.15\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$$
$$\therefore S(\text{l},\text{mp}) = 43.37 + 22.15\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$$
$$= 65.52\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$$

   (b)

$$S(\text{l}, 298.15\,\text{K}) = S(\text{l},\text{mp}) + \Delta S(\text{mp}\to 298.15\,\text{K})$$
$$\Delta S(\text{mp}\to 298.15\,\text{K}) = \int \frac{dq_{\text{rev}}}{T} = \int_{T_{\text{mp}}}^{298.15\,\text{K}} \frac{C_{p,m}dT}{T}$$
$$= \int_{T_{\text{mp}}}^{298.15\,\text{K}} \frac{A + BT + C/T}{T}dT$$
$$= \int_{T_{\text{mp}}}^{298.15\,\text{K}} \left(\frac{A}{T} + B + \frac{C}{T^2}\right)dT$$
$$= \left[A\ln T + BT - \frac{C}{T}\right]_{T_{\text{mp}}}^{298.15\,\text{K}}$$
$$= (-91.35\,\text{J}\,\text{K}^{-1}\text{mol}^{-1})\ln\left(\frac{298.15\,\text{K}}{276.83\,\text{K}}\right)$$
$$+ (0.2628\,\text{J}\,\text{K}^{-2}\text{mol}^{-1})(298.15 - 276.83\,\text{K})$$
$$- (28\,777\,\text{J}\,\text{mol}^{-1})\left(\frac{1}{298.15} - \frac{1}{276.83\,\text{K}}\right)$$
$$= 6.26\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$$
$$\therefore S(\text{l}, 298.15\,\text{K}) = 65.52 + 6.26\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$$
$$= 71.78\,\text{J}\,\text{K}^{-1}\text{mol}^{-1}$$

3. Start by setting up the heat balance:

$$q = 0 = \left\{ \begin{array}{c} \text{combustion} \\ \text{of sample} \end{array} \right\} + \left\{ \begin{array}{c} \text{combustion} \\ \text{of wire} \end{array} \right\} + \left\{ \begin{array}{c} \text{calorimeter} \\ \text{warming} \end{array} \right\}$$
$$= n_{\text{acid}}\Delta_c U_m(\text{acid}) + \ell\Delta_c u_{\text{wire}} + C_V \Delta T$$

In this case, the unknown is $\Delta_c U_m(\text{acid})$.

$$\begin{aligned} n_{\text{acid}} &= \frac{1.1041\,\text{g}}{256.428\,\text{g mol}^{-1}} = 0.004\,3057\,\text{mol} \\ \Delta_c U_m &= -\frac{1}{n}\left(\ell\Delta_c u_{\text{wire}} + C_V\Delta T\right) \\ &= -\frac{1}{0.004\,3057\,\text{mol}}\left[(9.8\,\text{cm})(-9.6\times10^{-3}\,\text{kJ cm}^{-1}) + (11.08\,\text{kJ K}^{-1})(3.879\,\text{K})\right] \\ &= -9960\,\text{kJ mol}^{-1}. \end{aligned}$$

To go further, I need a balanced reaction:

$$C_{16}H_{32}O_{2(s)} + 23O_{2(g)} \rightarrow 16CO_{2(g)} + 16H_2O_{(l)}$$

From this reaction, we have

$$\begin{aligned} \Delta_c\nu_{\text{gas}} &= 16 - 23 = -7 \\ \Delta_c H_m &= \Delta_c U_m + RT\Delta_c\nu_{\text{gas}} \\ &= -9960\,\text{kJ mol}^{-1} + (8.314\,472\times10^{-3}\,\text{kJ K}^{-1}\text{mol}^{-1})(298.15\,\text{K})(-7) \\ &= -9977\,\text{kJ mol}^{-1} \end{aligned}$$

Also,

$$\begin{aligned} \Delta_c H_m &= 16\Delta_f H^\circ(CO_2) + 16\Delta_f H^\circ(H_2O,\text{l}) - [\Delta_f H^\circ(C_{16}H_{32}O_2) + 23\Delta_f H^\circ(O_2)] \\ \therefore \Delta_f H^\circ(C_{16}H_{32}O_2) &= 16\Delta_f H^\circ(CO_2) + 16\Delta_f H^\circ(H_2O,\text{l}) - \Delta_c H_m \\ &= 16(-393.51) + 16(-285.830) - (-9977)\,\text{kJ mol}^{-1} \\ &= -892\,\text{kJ mol}^{-1} \end{aligned}$$