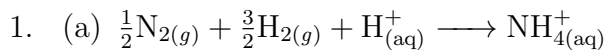


Chemistry 2740 Spring 2021 Test 1 Solutions



(b)

$$\begin{aligned}\Delta_f S^\circ(\text{NH}^+_{4(\text{aq})}) &= S^\circ(\text{NH}^+_{4(\text{aq})}) - \left[\frac{1}{2}S^\circ(\text{N}_2) + \frac{3}{2}S^\circ(\text{H}_2) + S^\circ(\text{H}^+_{(\text{aq})}) \right] \\ &= 111.2 - \left[\frac{1}{2}(191.609) + \frac{3}{2}(130.680) + 0 \right] \text{ J K}^{-1}\text{mol}^{-1} \\ &= -180.6 \text{ J K}^{-1}\text{mol}^{-1}\end{aligned}$$

2.

$$S^\circ(\text{Si}, 1473.15 \text{ K}) = S^\circ(\text{Si}, 298.15 \text{ K}) + \Delta S(298 \rightarrow 1473 \text{ K}).$$

$$\begin{aligned}\Delta S(298 \rightarrow 1473 \text{ K}) &= \int_{T_1}^{T_2} \frac{dq_{\text{rev}}}{T} = \int_{T_1}^{T_2} \frac{C_{p,m} dT}{T} \\ &= \int_{298.15 \text{ K}}^{1473.15} \frac{23.698 + 3.305 \times 10^{-3}T - \frac{4.354 \times 10^5}{T^2}}{T} dT \\ &= \int_{298.15 \text{ K}}^{1473.15} \left(\frac{23.698}{T} + 3.305 \times 10^{-3} - \frac{4.354 \times 10^5}{T^3} \right) dT \\ &= \left[23.698 \ln T + 3.305 \times 10^{-3}T + \frac{4.354 \times 10^5}{2T^2} \right]_{298.15 \text{ K}}^{1473.15} \\ &= 23.698 \ln \left(\frac{1473.15 \text{ K}}{298.15 \text{ K}} \right) + 3.305 \times 10^{-3} (1473.15 - 298.15 \text{ K}) \\ &\quad + 2.177 \times 10^5 \left(\frac{1}{1473.15^2} - \frac{1}{298.15^2} \right) \\ &= 39.394 \text{ J K}^{-1}\text{mol}^{-1}. \\ \therefore S^\circ(\text{Si}, 1473.15 \text{ K}) &= 18.82 + 39.394 \text{ J K}^{-1}\text{mol}^{-1} \\ &= 58.21 \text{ J K}^{-1}\text{mol}^{-1}.\end{aligned}$$

3. (a)

$$\begin{aligned}M_{\text{NH}_4\text{NO}_3} &= 2(14.01) + 4(1.01) + 3(16.00) \text{ g mol}^{-1} \\ &= 80.06 \text{ g mol}^{-1}. \\ n_{\text{NH}_4\text{NO}_3} &= \frac{59 \text{ g}}{80.06 \text{ g mol}^{-1}} = 0.74 \text{ mol}. \\ m_{\text{H}_2\text{O}} &= (250 \text{ cm}^3)(0.9982 \text{ g cm}^{-3}) \\ &= 250 \text{ g} \equiv 0.250 \text{ kg}.\end{aligned}$$

$$\begin{aligned}\therefore m_{\text{NH}_4\text{NO}_3} &= \frac{0.74 \text{ mol NH}_4\text{NO}_3}{0.250 \text{ kg H}_2\text{O}} \\ &= 3.0 \text{ mol kg}^{-1}.\end{aligned}$$

(b) $3.56 \text{ J K}^{-1}\text{g}^{-1}$

(c) We need the total mass of the solution: $m_{\text{soln}} = 59 + 250 \text{ g} = 309 \text{ g}$. We want to calculate the final temperature. The heat balance is as follows:

$$\begin{aligned}q = 0 &= \left\{ \begin{array}{c} \text{heat of} \\ \text{reaction} \end{array} \right\} + \left\{ \begin{array}{c} \text{cooling of} \\ \text{solution} \end{array} \right\} \\ &= n_{\text{NH}_4\text{NO}_3} \Delta_r H_m + m_{\text{soln}} c_p \Delta T. \\ \therefore \Delta T &= \frac{-n_{\text{NH}_4\text{NO}_3} \Delta_r H_m}{m_{\text{soln}} c_p} \\ &= \frac{-(0.74 \text{ mol})(25.69 \times 10^3 \text{ J mol}^{-1})}{(309 \text{ g})(3.56 \text{ J K}^{-1}\text{g}^{-1})} \\ &= -17 \text{ K}.\end{aligned}$$

This would give a final temperature of $20 - 17^\circ\text{C} = 3^\circ\text{C}$. Not bad!

(d) A little more ammonium nitrate will result in a little more cooling.