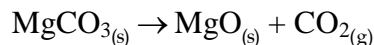


## Chemistry 102 Study Questions

1. The reaction



is not spontaneous at room temperature but becomes spontaneous at higher temperatures.

a. Calculate the temperature at which this reaction becomes spontaneous.

$$\Delta H = \left[ \left( \frac{1 \text{ mol MgO}}{\text{mol rxn}} \right) \left( \frac{-601.8 \text{ kJ}}{\text{mol MgO}} \right) + \left( \frac{1 \text{ mol CO}_2}{1 \text{ mol rxn}} \right) \left( \frac{-393.5 \text{ kJ}}{\text{mol CO}_2} \right) \right] - \left[ \left( \frac{1 \text{ mol MgCO}_3}{\text{mol rxn}} \right) \left( \frac{-1112.9 \text{ kJ}}{\text{mol MgCO}_3} \right) \right] = 117.6 \text{ kJ mol}^{-1}$$

$$\Delta S = \left[ \left( \frac{1 \text{ mol MgO}}{\text{mol rxn}} \right) \left( \frac{26.78 \text{ J}}{\text{mol MgO K}} \right) + \left( \frac{1 \text{ mol CO}_2}{1 \text{ mol rxn}} \right) \left( \frac{213.6 \text{ J}}{\text{mol CO}_2 \text{ K}} \right) \right] - \left[ \left( \frac{1 \text{ mol MgCO}_3}{\text{mol rxn}} \right) \left( \frac{65.69 \text{ J}}{\text{mol MgCO}_3 \text{ K}} \right) \right] = 174.7 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$T = \frac{\Delta H}{\Delta S} = \frac{117.6 \times 10^3 \text{ J mol}^{-1}}{174.7 \text{ J mol}^{-1} \text{ K}^{-1}} = 673.2 \text{ K}$$

b. Calculate the partial pressure of Carbon Dioxide at equilibrium in a container that is 25°C above the temperature you calculated in part a.

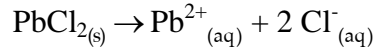
$$\Delta G = \Delta H - T\Delta S$$

$$= (117.6 \times 10^3 \text{ J mol}^{-1}) - (820. \text{ K})(174.7 \text{ J mol}^{-1} \text{ K}^{-1})$$

$$= -256.5 \times 10^3 \text{ J mol}^{-1}$$

$$K = e^{-\Delta G/RT} = e^{-(-2.565 \times 10^5) / (8.314)(820)} = 43.1 = K_P = P_{\text{CO}_2}$$

2. Is the reaction



spontaneous at 35.0°C when  $[\text{Pb}^{2+}] = 1.4 \times 10^{-5} \text{ M}$  and  $[\text{Cl}^{-}] = 2.6 \times 10^{-6} \text{ M}$ ?

$$\Delta H = \left[ \left( \frac{1 \text{ mol Pb}^{2+}}{\text{mol rxn}} \right) \left( \frac{1.6 \text{ kJ}}{\text{mol Pb}^{2+}} \right) + \left( \frac{2 \text{ mol Cl}^{-}}{\text{mol rxn}} \right) \left( \frac{-167.2 \text{ kJ}}{\text{mol Cl}^{-}} \right) \right] - \left[ \left( \frac{1 \text{ mol PbCl}_2}{\text{mol rxn}} \right) \left( \frac{-359.2 \text{ kJ}}{\text{mol PbCl}_2} \right) \right]$$

$$= 24.8 \text{ kJ mol}^{-1}$$

$$\Delta S = \left[ \left( \frac{1 \text{ mol Pb}^{2+}}{\text{mol rxn}} \right) \left( \frac{21.3 \text{ J}}{\text{mol Pb}^{2+} \text{ K}} \right) + \left( \frac{2 \text{ mol Cl}^{-}}{\text{mol rxn}} \right) \left( \frac{56.5 \text{ J}}{\text{mol Cl}^{-} \text{ K}} \right) \right] - \left[ \left( \frac{1 \text{ mol PbCl}_2}{\text{mol rxn}} \right) \left( \frac{136.4 \text{ J}}{\text{mol PbCl}_2 \text{ K}} \right) \right]$$

$$= -2.1 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$\Delta G = \Delta H - T\Delta S$$

$$= (24.8 \times 10^3 \text{ J mol}^{-1}) - (308.2 \text{ K})(-2.1 \text{ J mol}^{-1} \text{ K}^{-1})$$

$$= 25.4 \text{ kJ mol}^{-1}$$

The reaction is not spontaneous.

3. A cell is made from the  $\text{Fe}^{3+}|\text{Fe}$  and the  $\text{MnO}_4^-|\text{Mn}^{2+}$  half cells.

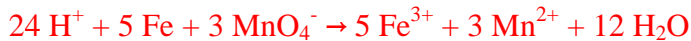
a. Calculate  $E_{\text{cell}}^\circ$ .

For  $\text{Fe}^{3+}|\text{Fe}$ :  $E^\circ = -0.04 \text{ V}$  Anode

For  $\text{MnO}_4^-|\text{Mn}^{2+}$ :  $E^\circ = +1.49 \text{ V}$  Cathode

$$E_{\text{cell}}^\circ = +1.49 \text{ V} - (-0.04 \text{ V}) = +1.53 \text{ V}$$

b. Write the overall cell equation.



c. Write the cell notation for the cell.



d. Calculate  $K_{\text{eq}}$

$$K = e^{-nFE_{\text{cell}}^\circ/RT} = e^{-(15)(96485)(1.53)/(8.314)(298.15)} = e^{893.30} = 10^{388}$$

e. Calculate  $E_{\text{cell}}$  when  $[\text{Fe}^{3+}] = 0.10 \text{ M}$ ,  $[\text{MnO}_4^-] = 0.25 \text{ M}$ ,  $[\text{Mn}^{2+}] = 1.50 \text{ M}$  and the pH is 1.67 at 298 K.

$$\begin{aligned} E &= E_{\text{cell}}^\circ - \frac{RT}{nF} \ln Q = E_{\text{cell}}^\circ - \frac{RT}{nF} \ln \frac{[\text{Fe}^{3+}]^5 [\text{Mn}^{2+}]^3}{[\text{H}^+]^{24} [\text{MnO}_4^-]^3} \\ &= 1.53 \text{ V} - \frac{(8.314 \text{ J mol}^{-1} \text{ K}^{-1})(298.15 \text{ K})}{(15 \text{ mol e}^- / \text{mol})(96485 \text{ C/mol e}^-)} \ln \frac{[0.10]^5 [1.50]^3}{[2.14 \times 10^{-2}]^{24} [0.25]^3} \\ &= 1.38 \text{ V} \end{aligned}$$