Useful Physical Constants and Equations

\[ T_C = T_K - 273.15 \]

\[ R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \]

Faraday Constant (F) = 96,485 C / mole of electrons

\[ \Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} \]

\[ \Delta S_{\text{surr}} = -\frac{\Delta H}{T} \]

\[ \Delta G = \Delta H - T \Delta S \]

\[ \Delta G^o_{\text{reaction}} = \sum \Delta G^o_f(\text{products}) - \sum \Delta G^o_f(\text{reactants}) \]

\[ \Delta S^o_{\text{reaction}} = \sum S^o(\text{products}) - \sum S^o(\text{reactants}) \]

\[ \Delta G = \Delta G^o - RT \ln (Q) \]

\[ \Delta G^o = -RT \ln (K) \]

\[ \Delta G^o = -n F E^o \]

Nernst Equation:

\[ E = E^o - \frac{(RT/nF) \ln (Q)}{25 \degree C} \text{ or } \]

\[ E = E^o - (0.0592/n) \log_{10}(Q) \text{ at } 25 \degree C \]

You will require some of the data on the following pages: (Appendix 4 of Zumdahl given)
Multiple Choice and short answer questions:
(Each question is worth 5 points)

**Question 1)** Circle one choice ( (a) through (e) ) indicating which of the following statements is/are always true:

1. In order for a process to be spontaneous the entropy of the universe must increase
2. A system cannot have both energy disorder and positional disorder
3. $\Delta S_{\text{univ}} = \Delta G / T$
4. $S^0$ is zero for all elements in their standard states

(a) 1  
(b) 1, 4  
(c) 1,3,4  
(d) 2,4  
(e) 2

**Question 2)** What does the second law of thermodynamics predict about spontaneous reactions?

**Question 3)** Why are the standard entropies of diamond and graphite different?
Long Questions (Show all your working for full credit):

Question 4) The $K_{sp}$ for Pb(OH)$_2$ is $1.2 \times 10^{-15}$ and for PbCl$_2$ is $1.6 \times 10^{-5}$.

A 0.1 M Pb(NO$_3$)$_2$ solution is adjusted to pH =10 by adding solid NaOH. What is the final concentration of Pb$^{2+}$ (aq)?
Question 5) For the process

\[ \text{CHCl}_3(\text{s}) \rightarrow \text{CHCl}_3(\text{l}) \]

\[ \Delta H^0 = 9.2 \text{ kJ mol}^{-1} \text{ and } \Delta S^0 = 43.9 \text{ J K}^{-1} \text{ mol}^{-1}. \] What is the temperature at the melting point of chloroform? Show your reasoning.
Question 6) What is the equilibrium constant for the reaction given below at standard temperature (298 K) and pressure (1 atmosphere)? (Hint: Use the data given at front of exam). Show your calculations.

\[
2\text{H}_2\text{S (g)} + \text{SO}_2 \text{ (g)} \leftrightarrow 3 \text{ S (s)} + 2 \text{H}_2\text{O (g)}
\]

Will the reaction be spontaneous as written if all the gaseous materials are present at 0.1 atm and there is 5 grams of S? Why?

(25 points)
**Question 7)** Draw a galvanic cell made with Ag and Cd electrodes and 1 mol L\(^{-1}\) solutions of AgNO\(_3\) and Cd(NO\(_3\))\(_2\). Label the anode and cathode and show the direction of electron flow.

What is the overall cell voltage (E\(^{\circ}\)) and what is \(\Delta G^{\circ}\) for this cell at 25 °C?

What would be the EMF of the galvanic cell if the AgNO\(_3\) concentration were 0.1 mol L\(^{-1}\) rather than 1 mol L\(^{-1}\)

(25 points)