CH 223 Practice Problem Set #1

This is a ***practice problem set*** *and not the actual graded problem set that you will turn in for credit. Answers to each problem can be found at the end of this assignment.*

Covering: **Chapter Twelve** *and* **Chapter Guide One**
Important Tables and/or Constants: **Table of Thermodynamic Values** *(found at the end of CH 223 Problem Set #1 or here:* **http://mhchem.org/thermo***)*

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1. Which substance has the higher entropy in each of the following pairs?
   a. dry ice (solid CO_2) at -78 °C or $CO_2(g)$ at 0 °C
   b. liquid water at 25 °C or liquid water at 50 °C
   c. pure alumina, $Al_2O_3(s)$, or ruby (ruby is $Al_2O_3(s)$ in which some of the Al^{3+} ions in the crystalline lattice are replaced with Cr^{3+} ions.)
   d. one mole of $N_2(g)$ at 1 bar pressure or one mole of $N_2(g)$ at 10 bar pressure (both at 298 K)
2. By comparing the formulas for each pair of compounds, decide which is expected to have the higher entropy. Assume all are at the same temperature.
   a. $O_2(g)$ or $CH_3OH(g)$ (two substances with the same molar mass)
   b. HF(g), HCl(g), or HBr(g)
   c. $NH_4Cl(s)$ or $NH_4Cl(aq)$
   d. $HNO_3(g)$, $HNO_3(l)$, or $HNO_3(aq)$
3. Use $S°$ values to calculate the entropy change, $\Delta S°$, for each of the following processes and comment on the sign of the change.
   a. $LiOH(s) \rightarrow LiOH(aq)$ (*Note:* $S°(LiOH(aq)) = 91.6$ J/molK)
   b. $Na(g) \rightarrow Na(s)$
   c. $Br_2(l) \rightarrow Br_2(g)$
   d. $HCl(g) \rightarrow HCl(aq)$ (*Note:* $S°(HCl(aq)) = 56.5$ J/molK)
4. Calculate the standard molar entropy change of formation ($\Delta S_f°$) for each of the following compounds from the elements at 25 °C.
   a. HCl(g) b. $Ca(OH)_2(s)$
5. Calculate the standard molar entropy change for each of the following reactions at 25 °C. Comment on the sign of $\Delta S°$.
   a. $2\ Al(s) + 3\ Cl_2(g) \rightarrow 2\ AlCl_3(s)$
   b. $2\ CH_3OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 4\ H_2O(g)$
6. Classify each of the reactions according to their spontaneity. Are these reactions enthalpy and/or entropy driven?
   a. $Fe_2O_3(s) + 2\ Al(s) \rightarrow 2\ Fe(s) + Al_2O_3(s)$ $\Delta H° = -851.5$ kJ $\Delta S° = -375.2$ J/K
   b. $N_2(g) + 2\ O_2(g) \rightarrow 2\ NO_2(g)$ $\Delta H° = 66.2$ kJ; $\Delta S° = -121.6$ J/K
7. Heating some metal carbonates, among them calcium carbonate, leads to their decomposition.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

   a. Calculate $\Delta H°$ and $\Delta S°$ for the reaction.
   b. Is the reaction spontaneous at 298 K?
   c. Is the reaction predicted to be spontaneous at higher temperatures?

8. Using values of ΔH°_f and S°, calculate $\Delta G^\circ_{\text{rxn}}$ for the following reaction. Is the reaction product-favored? Is the reaction enthalpy or entropy driven?

   $$2\ \text{Pb(s)} + \text{O}_2\text{(g)} \rightarrow 2\ \text{PbO(s, yellow)}$$

9. Using values of ΔG°_f, calculate $\Delta G^\circ_{\text{rxn}}$ for each of the following reactions. Which are product-favored?
   a. $2\ \text{K(s)} + \text{Cl}_2\text{(g)} \rightarrow 2\ \text{KCl(s)}$
   b. $2\ \text{CuO(s)} \rightarrow 2\ \text{Cu(s)} + \text{O}_2\text{(g)}$
   c. $4\ \text{NH}_3\text{(g)} + 7\ \text{O}_2\text{(g)} \rightarrow 4\ \text{NO}_2\text{(g)} + 6\ \text{H}_2\text{O(g)}$
10. For the reaction: $\text{BaCO}_3\text{(s)} \rightarrow \text{BaO(s)} + \text{CO}_2\text{(g)}$, $\Delta G^\circ_{\text{rxn}} = +219.7$ kJ. Using this value and a table of thermodynamic data, calculate the value of ΔG°_f for $\text{BaCO}_3\text{(s)}$.
11. Estimate the temperature required to decompose HgS(s) into Hg(l) and S(g).

Answers to the Practice Problem Set:

1. a. CO_2(g)   b. 50° H_2O(l)   c. ruby   d. N_2(g) at 1 bar
2. a. CH_3OH(g)   b. HBr(g)   c. NH_4Cl(aq)   d. HNO_3(g)
3. a. 48.8 J/K (entropy increase)   b. -102.4 J/K (entropy decrease)   c. 93.3 J/K (entropy increase)   d. -130.4 J/K (entropy decrease)   (*Instructor note:* your values of ΔS might be slightly different depending on the textbook used, etc., but they should be *close* to these values.)
4. a. 10.0 J/K   b. -294.1 J/K (see note in answer #17, above)
5. a. -504.6 J/K (entropy increase)   b. 313.6 J/K (entropy decrease)   (see note in answer #17, above)
6. a. enthalpy driven, spontaneous at low temperatures   b. non-spontaneous at all temperatures
7. a. $\Delta H^o = 191.59$ kJ, $\Delta S^o = 141.9$ J/K   b. no   c. yes
8. $\Delta H^o = -434.64$ kJ, $\Delta S^o = -197.4$ J/K, $\Delta G^o = -375.77$ kJ; product favored, enthalpy driven
9. a. $\Delta G^o = -817.0$ kJ; product favored   b. $\Delta G^o = 259.4$ kJ; reactant favored   c. $\Delta G^o = -1101.3$ kJ; product favored
10. $\Delta G_f^o[BaCO_3(s)] = -1134.4$ kJ/mol
11. 2089 K or greater