1. (3 pts) What is the molar solubility of barium sulfate given $K_{sp} = 1.5 \times 10^{-9}$? As always, include units!

2. (3 pts) What is the molar solubility of barium sulfate in a solution that contains 0.230 M sodium sulfate?

3. (4 pts) What is the $[Ag^+]$ in a saturated solution of $Ag_3PO_4$, given $K_{sp} = 1.8 \times 10^{-18}$?

4. (4 pts) What is the pH of a saturated solution of $Ca(OH)_2$, given $K_{sp} = 2.5 \times 10^{-16}$?

5. (5 pts) For which of these processes is $\Delta S > 0$?
   (a) solid sugar dissolving in hot water
   (b) iodine vapor condensing on a cold surface
   (c) a solution of salt mixing with a solution of sugar when poured together
   (d) crystals growing from a supersaturated solution
   (e) $2 H_2S(g) + SO_2(g) \rightarrow 3 S(s) + 2 H_2O(g)$

6. (5 pts) For which of these processes is $\Delta G^0 < 0$?
   (a) ice melting
   (b) water vapor condensing on a cold surface
   (c) a strong acid reacting with a strong base
   (d) $CH_4(g) + 2 O_2(g) \rightarrow CO_2(g) + 2 H_2O(l)$
   (e) $2 H(g) \rightarrow H_2(g)$

7. Consider the following reaction and data:
   $PbS(s) + 2 O_2(g) \rightarrow PbSO_4(s)$

<table>
<thead>
<tr>
<th></th>
<th>$\Delta H^0$ (kJ/mol)</th>
<th>$S^0$ (J/mol K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PbS(s)</td>
<td>-100</td>
<td>91</td>
</tr>
<tr>
<td>PbSO_4(s)</td>
<td>-920</td>
<td>149</td>
</tr>
<tr>
<td>O_2(g)</td>
<td>0</td>
<td>205</td>
</tr>
</tbody>
</table>

7a. (3 pts) Calculate $\Delta H^0_{rxn}$.

7b. (3 pts) Calculate $\Delta S^0_{rxn}$.

7c. (1 pt) Under what conditions will this reaction be spontaneous?
   (a) all temperatures (b) only at high temperatures (c) never (d) only at low temperatures

8. (3 pts) Consider the reactions:
   $S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta G^0 = -300. \text{ kJ}$
   $2 S(s) + 3 O_2(g) \rightarrow 2 SO_3(g)$ $\Delta G^0 = -742 \text{ kJ}$

Calculate $\Delta G^0$ for $2 SO_2(g) + O_2(g) \rightarrow 2 SO_3(g)$

As always, show your work.
9. A reaction that destroys ozone in the upper atmosphere is caused by high-flying jets:

\[
\text{NO(g) + O}_3(\text{g}) \rightarrow \text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \quad \Delta H^0 = -199 \text{ kJ}
\]

\[
\Delta S^0 = -5.0 \text{ J/K}
\]

9a. (3 pts) Calculate \(\Delta G^0\) for the reaction

9b. (4 pts) Calculate \(K_p\) for the reaction.

9c. (1 pt) How does \(K_p\) compare to \(K_c\)?

(a) \(K_p > K_c\)  
(b) \(K_p < K_c\)  
(c) \(K_p = K_c\)

9d. (4 pts) Calculate \(\Delta G\) at 298 K given \(P_{\text{NO}} = P_{\text{O}_3} = 0.00050\ \text{atm}\) and \(P_{\text{NO}_2} = P_{\text{O}_2} = 1.0\ \text{atm}\).

9e. (1 pt) Would increasing the temperature increase \(\Delta G\)? Circle: Yes  No  Need more info

10. (3 pts) The phase change \(\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})\) has

\[
\Delta H_{\text{vap}} = 30.9 \text{ kJ/mol} \quad \text{and} \quad \Delta S_{\text{vap}} = 102.6 \text{ J/mol K}
\]

What is the boiling point of bromine?

11a. (5 pts) Label the electrodes and metal ions in solutions in the diagram. Indicate electron flow.

11b. (3 pts) Determine \(E^0\). As always, show work.

11c. (1 pt) In which cell is the concentration of metal ions increasing? Circle: Anode or Cathode

11d. (1 pt) In which cell is the mass of the electrode increasing? Circle: Anode or Cathode

11e (3 pts) Write the reaction using cell notation assuming all concentrations are 1.0 M

11f. (4 pts) Determine \(\Delta G^0\).

11g. (4 pts) Determine \(K_c\).

11h. (4 pts) Determine \(E\) if \([\text{Ni}^{+2}] = 0.050 \text{ M}\) and \([\text{Cd}^{+2}] = 1.00 \text{ M}\).

12a. (3 pts) Write the balanced reaction for the Galvanic cell made from \Ag|Ag^+\ and \Al|Al^{3+}\.

12b. (2 pts) Determine \(E^0\) for the cell.

Subtotal from exam:  
Homework:  
Total:  

\[
\begin{align*}
\text{Cd(s)} + \text{Ni}^{+2(\text{aq})} & \rightarrow \text{Cd}^{+2(\text{aq})} + \text{Ni(s)} \\
\end{align*}
\]
Name: (only if you answer yes below):

Do you have work to be graded on the back side of this sheet?

YES: If you have done work to be graded on this sheet, you must submit it with your exam and include your name above. Do not clip it to the exam — simply hand them in together.

NO: If there is nothing to grade on this sheet, simply return it to the pile next to the exams.

Useful equations:

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

\[ \Delta G^0 = \Delta H^0 - T\Delta S^0 \]

\[ R = 8.314 \text{ J/mol K} \]

\[ \Delta G = \Delta G^0 + RT \ln Q \]

\[ \Delta G^0 = -RT \ln K \]

\[ E = E^0 - 0.0592/n \log Q \]

\[ E^0 = 0.0592/n \log K \]

\[ \Delta G = -nFE \quad \Delta G^0 = -nFE^0 \]

1 Faraday (F) = 96500 coul = 1 mol e\(^{-}\) = 96500 J/mol V

Charge = current x time

(coul) = (amps) x (sec)
**Answers**

1. $3.9 \times 10^{-5}$
2. $6.5 \times 10^{-9}$
3. $4.8 \times 10^{-5}$
4. 8.9
5. a, c
6. all (a, b, c, d, e)
7a. -820 kJ
7b. -352 J/K
7c. d
8. -142 kJ
9a. -197.5 kJ
9b. $4.2 \times 10^{34}$
9c. c
9d. -160 kJ
9e. $\Delta G$ would become less negative
10. 301 K
11a. Cd(s)/Cd$^{+2}$ in the anode; Ni(s)/Ni$^{+2}$ in the cathode
11b. $E^0 = 0.14$ v
11c. Anode
11d. Cathode
11e Cd(s)/Cd$^{+2}$ (1 M)||Ni$^{+2}$ (1 M)|Ni
11f. $\Delta G^0 = -27$ kJ
11g. $5.4 \times 10^4$
11h. 0.10 v
12a. $3 \text{Ag}^+ + \text{Al} \rightarrow \text{Al}^{+3} + 3 \text{Ag}$
12b. $E^0 = 2.46$ v