Aqueous Equilibria and Thermodynamics

\[ R = 8.314 \text{ J/mol} \cdot \text{K} \]
\[ \Delta G = \Delta H^\circ - T \Delta S^\circ \]
\[ \Delta G = \Delta G^\circ + RT \ln Q \]

1. Determine the pH of a solution prepared by adding 0.40 mol of solid KOAc to 1.00 L of 0.50 M HOAc. \( K_a = 1.8 \times 10^{-5} \) for HOAc. (8 pt.)

2. What is the pH of the solution above after the addition of 0.020 mol of NaOH solution? (10 pt.) Writing the reaction out will help.
3. For the titration curve below, assuming all reagents are 0.10 M, describe
   (a) what is in the flask; strong acid weak acid strong base weak base
   (b) what is being titrated with; strong acid weak acid strong base weak base
   (c) what is the pH at the equivalence point: <7 7 >7

4. Circle the combinations that could produce buffers. (8 pt.)
   NaOH/NaCl  HF/NaF  HI/NaI  NH₃/NH₄Cl

5. A saturated solution of cobalt hydroxide, Co(OH)₂, has a pH of 8.90. What is K_sp for Co(OH)₂? (12 pt.)
6. Which of the following salts will be more soluble in acidic solution than in pure water? (10 pt.)

   AgI    ZnS    PbCl₂    Cr(OH)₃    CaF₂

7. For BaSO₄, Ksp = 1.1x10⁻¹⁰. If you mix 200 mL of 1.0x10⁻⁴ M Ba(NO₃)₂ and 500 mL of 8.0x10⁻² M H₂SO₄, will a precipitate form. Show calculations to support your answer. (12 pt)

8. In the following, indicate whether the entropy of the system is increasing or decreasing. (4 pt.)

   a. 3 C₂H₂(g) → C₆H₆(l)       Increasing       Decreasing
   b. HOAc(aq) → H⁺(aq) + OAc⁻(aq)       Increasing       Decreasing
9. Assuming that the dissolved reactants and products are present at 1 M concentrations, indicate whether the following reactions are spontaneous or not spontaneous in the forward direction. (4 pt.)
   a. $\text{HCN(aq) + H}_2\text{O(l) }\rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{CN}^- (aq); \text{K}=4.9\times10^{-10}$  Spontaneous  Not Spontaneous
   b. $\text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \rightleftharpoons 2 \text{H}_2\text{O(l)}; \text{K} = 1.0\times10^{14}$  Spontaneous  Not Spontaneous

10. Consider the reaction:

   $\text{Ag}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{AgCl(s)}$

   Given the following table of thermodynamic data

<table>
<thead>
<tr>
<th>substance</th>
<th>$\Delta H_f^\circ$(kJ/mol)</th>
<th>$S^\circ$(J/mol·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Ag}^+(aq)$</td>
<td>105.90</td>
<td>73.93</td>
</tr>
<tr>
<td>$\text{Cl}^-(aq)$</td>
<td>-167.2</td>
<td>56.5</td>
</tr>
<tr>
<td>$\text{AgCl(s)}$</td>
<td>-127.0</td>
<td>96.11</td>
</tr>
</tbody>
</table>

   a. Determine the value of $\Delta G^\circ$ and the equilibrium constant, $\text{K}$, at 25°C.(10 pt.)
   b. Determine the temperature (in °C) where the reaction becomes non-spontaneous. (6 pt.)
11. At 2600 K, $\Delta G^\circ = 775$ kJ for the vaporization of boron carbide:

$$B_4C(s) \rightleftharpoons 4 \text{B}(g) + \text{C}(s)$$

Find $\Delta G$ and determine if the process is spontaneous if the reaction vessel contains 4.00 mol of $B_4C(s)$, 0.400 mol of $C(s)$, and $B(g)$ at a partial pressure of $1.0 \times 10^{-5}$ atm. (10 pt.)