Buffers, Titrations and Solubility Worksheet

Buffer Problems
1. What is the pH of a buffer containing 0.25 M NH\textsubscript{3} and 0.45 M NH\textsubscript{4}Cl?

2. By how much will the pH change if 0.050 mol HCl is added to 1.00 L of the buffer in the previous problem?

3. What is the pH of a buffer that is prepared by mixing 35.0 mL of 0.250 M acetic acid and 25.0 mL of 0.180 M NaOH?
4. How many grams of sodium formate would have to be dissolved in 1.0 L of 0.12 M formic acid (pKa 3.74) to make the solution have a pH of 3.80?

5. Using table 1 in Appendix IIC (pg A-12), select a good buffer system for a buffer with a pH of 7.8.

6. Calculate the pH of a buffer that is made by dissolving 2.85 g of benzoic acid (see Appendix IIC in your text book) with 3.78 g of sodium benzoate in water to a final volume of 500 mL. How would this pH differ if the final volume was 250 mL?
Titration Problems
7. 15.0 mL of a solution of H₂SO₄ (aq) of unknown concentration is titrated with 0.30 M NaOH. 35.2 mL of NaOH are required to reach the equivalence point (with diprotic acids “the” equivalence point refers to the second equivalence point).
   a. Write the molecular equation and the net ionic equation for this reaction.

   b. Calculate the molarity of the H₂SO₄ solution.

8. If 25 mL of 0.050 M formic acid (HCO₂H, a weak, monoprotic acid) is titrated with 0.125 M NaOH.
   a. Write the net ionic equation for this reaction.

   b. How many mL of NaOH are required to reach the equivalence point of this reaction?

   c. Is the resulting solution at the equivalence point acidic or basic? Explain your answer.
9. When 50.0 mL of 0.10 M formic acid is titrated with 0.10 M sodium hydroxide, what is the pH at the equivalence point? Select a good indicator for this titration from figure 19.4.

10. For the titration of 25.00 mL of 0.1000 M acetic acid with 0.1000 M NaOH, calculate the pH.
   a. at the beginning, before any NaOH is added
   b. after 10.00 mL of NaOH is added
   c. after half of the acetic acid has been neutralized
   d. at the equivalence point
11. Consider the titration of 40.0 mL of 0.200 M HClO₄ by 0.100 M KOH. Calculate the pH after the following volumes of KOH have been added.
   a. 0.0 mL
   b. 10.0 mL
   c. 40.0 mL
   d. 80.0 mL
   e. 100.0 mL
12. Consider the titration of 25.0 mL of 0.100 M lactic acid (pKₐ = 3.86) by 0.100 M KOH. Calculate the pH after the following volumes of KOH have been added.

a. 0.0 mL

b. 4.0 mL

c. 12.5 mL

d. 20.0 mL

e. 25.0 mL

f. 28.0 mL

g. 30.0 mL
13. What is the molar solubility of Ag₂CrO₄ (Kᵣₚ = 1.2 x 10⁻¹²) in 0.150 M potassium chromate?

14. How does the molar solubility of Ag₂C₂O₄ change when each of the following compounds is added to a saturated solution of aqueous Ag₂C₂O₄? Check the correct box.

<table>
<thead>
<tr>
<th></th>
<th>Solubility will Increase</th>
<th>Solubility will Decrease</th>
<th>Solubility will Not Change</th>
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<tbody>
<tr>
<td>a. NaNO₃</td>
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<tr>
<td>b. HNO₃</td>
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<tr>
<td>c. NaCN (forms [Ag(CN)₂]⁻ ion)</td>
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<tr>
<td>d. Na₂C₂O₄</td>
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15. 2.55 g of CaCl₂ is added to 5.25L of a 4.75 x 10⁻⁶ M solution of Na₂CO₃. Will a precipitate of CaCO₃(s) form? The Kᵣₚ of CaCO₃ is 2.8 x 10⁻⁹.
16. An aqueous solution has a concentration of $2.00 \times 10^{-3}$ M each of Br$^-$ ions and Cl$^-$ ions. As aqueous silver nitrate is added to the solution (assuming negligible volume change), which will precipitate first, silver nitrate, silver bromide ($K_{sp} = 5.0 \times 10^{-13}$) or silver chloride ($K_{sp} = 1.8 \times 10^{-10}$)?

17. What concentration of NaIO$_3$ will be required to precipitate Ba(IO$_3$)$_2$ ($K_{sp} = 1.5 \times 10^{-9}$) in a solution that contains 0.50 M Ba$^{2+}$ ions?

18. Calculate the concentration of ammonia necessary to precipitate Ca(OH)$_2$ from a solution that has [Ca$^{2+}$] = 2.0 M. [K$_{sp}$ (Ca(OH)$_2$) = 6.5 x 10$^{-6}$]. Hint: ammonia is a weak base.
Complex Ion Equilibria (only do these if complex ion equilibria problems have been covered in class)

19. During the processing of black-and-white photographic film, excess silver(I) is removed by washing the film in a bath containing sodium thiosulfate. This treatment is based on the following complexation reaction:

\[ \text{Ag}^+ (aq) + 2 \text{S}_2\text{O}_3^{2-} (aq) \rightleftharpoons [\text{Ag(S}_2\text{O}_3]^{3-} (aq) \quad K_f = 5 \times 10^{13} \]

What is the resulting concentration of Ag$^+$ if 30.0 mL 0.57 M Na$_2$S$_2$O$_3$ is added to 50.0 mL of a solution containing 0.048 M Ag$^+$ ions?

20. The $K_{sp}$ for NiCO$_3$ is 1.3 x 10$^{-7}$ and the $K_f$ for [Ni(NH$_3$)$_6$]$^{2+}$ is 2.0 x 10$^8$. What is the $K_c$ for the reaction NiCO$_3$(s) + 6 NH$_3$ ⇄ [Ni(NH$_3$)$_6$]$^{2+}$ + CO$_3^{2-}$?
Answers...
1. 8.99
2. pH decreases by 0.14 units
3. 4.76
4. 9.4 g NaCHO₂
5. A buffer using HClO/ClO⁻ would be best for this buffer because the pKₐ of HClO is 7.5, which is close to 7.8.
6. 4.23; pH of a buffer is independent of volume of solution (as long as it is not too dilute)
7. a. molecular: H₂SO₄ + 2 NaOH → Na₂SO₄ + 2 H₂O  
   net ionic: H⁺ + HSO₄⁻ + 2 OH⁻ → SO₄²⁻ + 2 H₂O  
   (tricky one! H₂SO₄ is a strong acid, but HSO₄⁻ is a weak acid)
   b. 0.35 M H₂SO₄
8. a. HCO₂H + OH⁻ → HCO₂⁻ + H₂O
   b. = 10. mL NaOH
   c. The resulting solution would be basic. At the equivalence point, the moles of OH⁻ added equal the moles H₃O⁺ added. These react to make water. However, when a weak acid is titrated, once equivalence has been reached, all the H⁺ have been removed from the acid leaving its conjugate base (HCO₂⁻). This conjugate base makes the solution basic.
9. 8.22, indicator: phenolphthalein or thymol blue (second color change).
10. a. 2.87   b. 4.58   c. 4.74   d. 8.72
11. a. 0.699  b. 0.854  c. 1.301  d. 7.00   e. 12.15
12. a. 2.43   b. 3.14   c. 3.86   d. 4.46   e. 8.28   f. 11.75   g. 11.96
13. 1.4 x 10⁻⁶ mol/L
14. a. No Change
   b. Increase (C₂O₄²⁻ is the anion of a weak acid)
   c. Increase (formation of the complex ion reduces the concentration of Ag⁺, shifting the equilibrium to the right)
   d. Decrease (common ion effect)
15. Yes, a ppt will form (Qₛₚ = 2.1 x 10⁻⁸, so Qₛₚ > Kₛₚ)
16. Silver bromide will precipitate first, since it has the lowest Kₛₚ
17. 5.5 x 10⁻⁵ M NaIO₃
18. 0.19 M NH₃
19. 3 x 10⁻¹⁴ M Ag⁺