The first questions are a variety of multiple choice, multiple select, and other assorted types. Point totals are indicated to the right of each problem number.

1. (5 points) Which of the following statements is true of a Brønsted-Lowry base? Check all that apply.
   - [ ] A base contains a OH⁻.
   - [ ] A base is a H⁺ donor.
   - [x] A base is a H⁺ acceptor.
   - [ ] A base is a OH⁻ acceptor.
   - [ ] A base can only be defined in aqueous solutions.

2. (4 points) Mark all of the species below that are acids in the following equilibrium:
   \[ \text{H}_2\text{PO}_4^- (aq) + \text{H}_2\text{O} (\ell) \leftrightarrow \text{HPO}_4^{2-} (aq) + \text{H}_3\text{O}^+ (aq) \]
   - [x] H₂PO₄⁻
   - [ ] H₂O
   - [ ] HPO₄²⁻
   - [x] H₃O⁺

3. (4 points) Mark all of the species below that are acids in the following equilibrium:
   \[ \text{H}_2\text{PO}_4^- (aq) + \text{H}_2\text{O} (\ell) \leftrightarrow \text{H}_3\text{PO}_4 (aq) + \text{OH}^- (aq) \]
   - [ ] H₂PO₄⁻
   - [x] H₂O
   - [x] H₃PO₄
   - [ ] OH⁻

4. (2 points) A solution has a pH of 4.50. The [OH⁻] in the solution is:
   a. 9.50  b. 3.2 \times 10^{-10} \text{ M}  c. 3.2 \times 10^{-5} \text{ M}  d. 3.2 \times 10^{-4} \text{ M}  e. 3.2 \times 10^{-9} \text{ M}

   \[ pH = pK_a + \log \left( \frac{[\text{base}]}{[\text{acid}]} \right) \]
5. (2 points) You have a 0.15 M solution of a salt that could be NH₄Cl, KBr, NaClO₃, or NaF. If the pH of the solution is 8.3, which one of the salts is in the solution?
   a. NH₄Cl  b. KBr  c. NaClO₃  d. NaF

6. (3 points) What is the pH of a 0.150 M solution of HClO. The $K_a$ of HClO is $3.5 \times 10^{-8}$.
   a. 3.73  b. 4.14  c. 7.00  d. 7.46

7. (3 points) What is the percent ionization of 0.150 M solution of HClO. The $K_a$ of HClO is $3.5 \times 10^{-8}$.
   a. $4.8 \times 10^{-4}$%  b. $4.8 \times 10^{-2}$%  c. 4.8%  d. 100%

8. (3 points) The pH of a solution of 0.150 M Ba(OH)₂ is:
   a. 0.52  b. 0.82  c. 13.18  d. 13.48

9. (3 points) The pH of a 0.100 M solution of the base aniline is 8.81. What is the value of $K_b$ for aniline?
   a. $2.40 \times 10^{-17}$  b. $4.17 \times 10^{-10}$  c. $1.55 \times 10^{-9}$  d. $1.55 \times 10^{-8}$

10. (2 points) In which one of the following solutions would PbCl₂ be the least soluble?
    a. 0.10 M NaCl  b. 0.080 M BaCl₂  c. 0.06 M AlCl₃  d. pure water

11. (2 points) Which of the following would be the strongest acid?
    a. HBrO  b. HBrO₂  c. HBrO₃  d. HBrO₄

12. (2 points) In a series of binary acids where the non-oxygen atom is from the same period, the acidity of the binary acid increases as the electronegativity of the non-oxygen _______.
    a. increases  b. decreases

$$pH = pK_a + \log \frac{[base]}{[acid]}$$
13. (4 points) Consider the solubility of AgCl. Silver can form a complex with ammonia according to the equation:

$$\text{Ag}^+ (aq) + 2 \text{NH}_3 (aq) \rightleftharpoons \text{Ag(NH}_3)_2^+ (aq)$$

If one started initially with a test tube of AgCl in water with solid sitting on the bottom, what would be observed as ammonia was added to the solution? Mark all responses that are correct.

☐ More solid AgCl would form in the test tube.
☒ The solid AgCl would dissolve.
☐ The solution would turn pink.
☐ Gas bubbles would evolve.

14. (2 points) The $K_{sp}$ for Cd$_3$(AsO$_4$)$_2$ is $2.2 \times 10^{-32}$. What is the molar solubility of Cd$_3$(AsO$_4$)$_2$ in pure water?

(a) $1.83 \times 10^{-7}$ M  
(b) $3.26 \times 10^{-7}$ M  
(c) $4.66 \times 10^{-7}$ M  
(d) $2.43 \times 10^{-6}$ M

15. (2 points) How many mL of 0.100 M Ba(OH)$_2$ are required to reach the equivalence point in titrating 25.00 mL of 0.150 M HNO$_3$?

(a) 18.75 mL  
(b) 25.00 mL  
(c) 37.5 mL  
(d) 75.00 mL

16. (5 points) A titration is performed and 25.00 mL of 0.100 NaOH is required to consume all of the H$^+$ in the acid being titrated. Which of the following solutions could be the acid? Check ALL that are correct.

☐ 25.00 mL of 0.200 M H$_2$SO$_4$
☒ 25.00 mL of 0.100 M HF
☒ 12.50 mL of 0.100 M H$_2$SO$_3$
☐ 50.00 mL of 0.100 M H$_2$SO$_3$
☒ 8.33 mL of 0.100 M H$_3$PO$_4$

\[ pH = pK_a + \log \frac{[\text{base}]}{[\text{acid}]} \]
Problem area. Show your work on these last problems to be able to receive partial credit. Point totals are indicated to the right of each problem number.

17. (9 points) Find the pH of each of the following solutions.

a. 0.075 M NH₄Cl if the $K_a$ for NH₃ is $1.8 \times 10^{-5}$

\[
\begin{align*}
\text{NH}_4^+ (aq) &\rightleftharpoons \text{NH}_3 (aq) + \text{H}^+ (aq) \\
\text{[NH}_4^+] &\approx \sqrt{K_a \times [\text{NH}_3]} = 6.45 \times 10^{-6} \\
pH &\approx 5.719
\end{align*}
\]

b. A solution that is 0.150 M in HNO₂ and 0.250 M in NaN₂O₂. $K_a$ for HNO₂ is $4.5 \times 10^{-4}$.

\[
pH = pK_a + \log \frac{[\text{HNO}_2]}{[\text{NaN}_2O_2]}
\]

\[
pH = 3.35 + \log \frac{0.50}{1.25} = 3.57
\]

c. A solution that is 0.100 M in pyridine (C₅H₅N) and 0.210 M in C₅H₅NHCl. The $K_b$ for pyridine is $1.5 \times 10^{-9}$.

\[
pH = pK_a + \log \frac{[\text{base}]}{[\text{acid}]} = 5.18 + \log \frac{[\text{C}_5\text{H}_5\text{N}]}{[\text{C}_5\text{H}_5\text{NHCl}]} = 5.18 + \log \frac{1.00}{2.10} = 4.86
\]

\[
pH = pK_a + \log \frac{[\text{base}]}{[\text{acid}]}
\]
18. (12 points) 0.100 M NaOH is used to titrate 25.00 mL of 0.150 M HC_2H_3O_2. The K_a for HC_2H_3O_2 is 1.8 \times 10^{-5}. Find the pH of the contents of the flask at the points in the titration indicated below.

a. Before any NaOH is added

\[ [\text{H}^+] = \sqrt{(0.150 \text{ M})(0.8 \times 10^{-5})} = 1.64 \times 10^{-3} \]

\[ \text{pH} = 2.78 \]

b. After the addition of 10.0 mL of the NaOH.

\[ \text{HC}_2\text{H}_3\text{O}_2 (aq) + \text{OH}^- (aq) \rightarrow \text{C}_2\text{H}_5\text{O}_2^- (aq) + \text{H}_2\text{O} (l) \]

\[ \begin{array}{c|c}
\text{C}_2\text{H}_3\text{O}_2^- & \text{OH}^- \\
\hline
\text{Initial} & 0.150 \text{ M} \\
\text{Added} & 0.04 \text{ M} \\
\text{Final} & 0 \text{ M} \\
\end{array} \]

\[ \text{Final concentration:} \quad \text{pH} = 0.47 \log \frac{0.47}{2.77 \text{ M}} = 4.71 \]

c. At the equivalence point

To reach equivalence point, need \( 25.00 \times 0.150 \text{ M} = 3.75 \text{ mmol} \) of O^- to react with HC_2H_3O_2.

To get 3.75 mmol O^-, you will need \( \frac{3.75 \text{ mmol}}{0.100 \text{ M}} = 37.5 \text{ mL} \).

Total volume at equivalence point = 37.5 mL of O^- + 25.00 mL of NaOH = 62.5 mL.

All of the 3.75 mmol NaOH have been converted to C_2H_5O_2^- which is a weak base with a concentration of \( \frac{3.75 \text{ mmol}}{62.5 \text{ mL}} = 0.0600 \text{ M} \).

\[ \text{pH} = 8.76 \]

d. 10.00 mL after the equivalence point.

Total volume = 62.5 mL + 10.0 mL = 72.5 mL

Excess O^- = \( 62.5 \text{ mL} \times 0.04 = 2.50 \text{ mmol} \) \( \sim \) 3.75 mmol = 1.00 mmol OH^-.

\[ [\text{OH}^-] = \frac{1.00 \text{ mmol OH}^-}{72.5 \text{ mL}} = 0.0138 \]

\[ \text{pH} = 12.14 \]

\[ pH = pK_a + \log \frac{[\text{base}]}{[\text{acid}]} \]