Midterm Examination 3

Multiple Choice Questions

1. Sulfurous Acid, H₂SO₃, is diprotic, with the following Acid Dissociation Constants:
   \[ K_{a1} = 1.39 \times 10^{-2} \]
   \[ K_{a2} = 6.73 \times 10^{-8} \]
   Calculate the \( K_b \) for SO₃²⁻.
   a) 4.11 \( \times 10^{-9} \)
   b) 7.99 \( \times 10^{-8} \)
   c) \textbf{1.48} \( \times 10^{-7} \) ******
   \[ K_{b1} = K_w / K_{a2} = (10^{-14}) / (6.73 \times 10^{-8}) = 1.48 \times 10^{-8} \]
   d) 2.76 \( \times 10^{-6} \)

2. Which of the following is the strongest acid?
   a) H₂O
   b) H₂S
   c) H₂Se ******

3. Which of the following acids is the weakest acid?
   a) H₂SO₄
   b) H₂SO₃
   c) H₂SeO₄
   d) H₂SeO₃ ******

4. What is the pH of a 0.5 M Pyridine, C₅H₅N, solution? \( K_b = 1.7 \times 10^{-9} \) for Pyridine.
   a) \textbf{9.5} ******
   b) 8.4
   c) 7.6
   d) 6.5

   \[ 1.7 \times 10^{-9} = x^2 / (0.50-x) \]
   \[ x = [OH^-] = 2.91 \times 10^{-5} \]
   \[ pOH = 4.54 \quad pH = 9.46 \]
5. A buffer is prepared such that \([H_2PO_4^-] = 0.095M\) and \([HPO_4^{2-}] = 0.125M\)? What is the pH of this buffer solution? (pK\(_a\) = 7.21 for H\(_2PO_4\))

   a) 6.11 \( \text{pH} = \text{pK}_a + \log([HPO_4^{2-}] / [H_2PO_4^-]) \)
   b) 6.78
   c) 7.33 **** \( = 7.21 + \log(0.125 / 0.095) = 7.33 \)
   d) 7.49

6. Which of the following mixtures is a buffer:

   a) 25mL 0.1M HF.
   b) 25mL 0.1M HCl mixed with 25mL 0.1M NaOH.
   c) 25mL 0.1M NH\(_3\) mixed with 12.5mL 0.1M HCl. ****
   d) 25mL 0.1M NaF.

7. The pK\(_a\) of NH\(_4^+\) is 9.25. What is the highest pH that a buffer system composed of NH\(_4^+\) and NH\(_3\) will buffer at effectively?

   a) 13.25
   b) 12.25
   c) 11.25
   d) 10.25 ****

8. The Endpoint of an Acid-Base Titration is reached when:

   a) the Indicator changes color. ****
   b) an excess of the titrant has been added to the solution to be titrated.
   c) a buffer is formed in the solution.
   d) you get tired of filling the buret.

9. The pH at the Equivalence Point for a Titration of a Weak Base with a Strong Acid is:

   a) Acidic. **** Weak Base + Acid \( \rightarrow \) Conj. Acid + H\(_2\)O
   b) 7.
   c) Basic.
   d) not determinable apriori.
10. 15.0 mL of an H₃PO₄ solution is titrated with 21.74 mL of a 0.2114 M standardized NaOH solution. What is the concentration of the acid solution?

a) 0.0955 M  
\[ H_3PO_4 + 3 OH^- \rightarrow PO_4^{3-} + 3 H_2O \]

b) **0.1021 M**

c) 0.2007 M  
\[ \text{#mol } H_3PO_4 = (0.2114 \text{ M}) (0.002174 \text{ L}) (1 \text{ mol } H_3PO_4 / 3 \text{ mol } OH^-) \]
\[ [H_3PO_4] = 0.001532 \text{ mol} / 0.001500 \text{ L} = 0.1021 \text{ M} \]

d) 0.3554 M

11. The Kₐ₂ of a Polyprotic Acid is:

a) roughly equal to the Kₐ₁.

b) significantly larger than Kₐ₁.

c) significantly smaller than Kₐ₁.  

12. Potassium Perchlorate (KClO₄) is a water soluble salt that forms an aqueous solution that is:

a) Acidic.

b) **Neutral.**

c) Basic.

K⁺ is the conjugate of a strong base; KOH. Not acidic.
ClO₄⁻ is the conjugate of a strong acid; HClO₄. Not basic.

13. The solubility of PbCl₂ (Kₛₚ = 1.7 x 1₀⁻⁵) in Water is:

a) 0.0023 M  
PbCl₂(s) = Pb²⁺(aq) + 2 Cl⁻(aq)

b) 0.0087 M

c) **0.016 M**

d) 0.057 M

\[ 1.7 \times 10^{-5} = (S) (2S)^2 \]
\[ S = 0.016 \text{ M} \]

14. The solubility of PbCl₂ (Kₛₚ = 1.7 x 1₀⁻⁵) in an aqueous solution that it 0.10 M in Pb(NO₃)₂ is:

a) 0.0154 M  
Pb(NO₃)₂(aq) \rightarrow Pb²⁺(aq) + 2 NO₃⁻(aq)

b) **0.0065 M**

c) 0.0091 M

d) 0.1010 M

\[ 1.7 \times 10^{-5} = (0.10 + S) (2S)^2 \]
\[ S = 0.0065 \text{ M} \]
15. The $K_{sp} = 8.3 \times 10^{-17}$ for AgI and $K_f = 1 \times 10^{21}$ for $\text{Ag(CN)}_2^-$. What is the equilibrium constant for the following reaction:

$$\text{AgI(s)} + 2 \text{CN}^-(aq) \rightleftharpoons \text{Ag(CN)}_2^-(aq) + \text{I}^-(aq)$$

a) $3.2 \times 10^{-5}$

b) $9.2 \times 10^{-2}$

c) $1.1 \times 10^{+1}$

d) $8.3 \times 10^{+4}$

$$\text{AgI(s)} \rightleftharpoons \text{Ag}^+(aq) + \text{I}^-(aq) \quad K_{sp}$$

$$\text{Ag}^+(aq) + 2 \text{CN}^-(aq) \rightleftharpoons \text{Ag(CN)}_2^-(aq) \quad K_f$$

$$K = K_{sp} K_f = (8.3 \times 10^{-17}) (1 \times 10^{21}) = 8.3 \times 10^{4}$$
Short Answer

1/2/3/4. Consider the Titration of 25.00 mL 0.10M NH₃ with 0.10M HCl.

a) Sketch the Titration Curve.
b) Calculate the pH along the Titration Curve at the indicated titrant volumes.
c) Select an appropriate Indicator for this titration.

\[ K_b = 1.8 \times 10^{-5} \]
0 mL HCl Added

\[ \text{NH}_3 + \text{H}_2\text{O} = \text{NH}_4^+ + \text{OH}^- \]

\[
\begin{array}{cccc}
\text{I} & 0.10 \text{ M} & \text{lots} & 0 \text{ M} & 0 \text{ M} \\
\text{C} & -x \text{ M} & -x \text{ M} & +x \text{ M} & +x \text{ M} \\
\text{E} & 0.10 -x & \text{lots} & x & x \\
\end{array}
\]

~ 0.10

\[ K_b = [\text{NH}_4^+] [\text{OH}^-] / [\text{NH}_3] \Rightarrow 1.8 \times 10^{-5} = x^2 / 0.1 \]

\[ x = [\text{OH}^-] = 0.0013 \text{ M} \]

\[ \text{pOH} = -\log(0.0013) = 2.87 \]

\[ \text{pH} = 14 - 2.87 = 11.13 \]

12.5 mL HCl Added

\[ K_a = K_w / K_a = 10^{-14} / (1.8 \times 10^{-5}) = 5.6 \times 10^{-10} \]

\[ \text{pK}_a = -\log(5.6 \times 10^{-10}) = 9.26 \]

\[ \text{pH} = \text{pK}_a = 9.26 \]
25 mL HCl Added

\[
\begin{align*}
\text{NH}_3 & \quad + \quad \text{H}^+ & \quad \rightarrow & \quad \text{NH}_4^+ \\
\text{start} & \quad (0.1)(0.025) & \quad (0.1)(0.025) & \quad 0 \text{ mol} \\
& \quad = 0.0025 \text{ mol} & \quad = 0.0025 \text{ mol} & \quad \\
\text{end} & \quad 0 \text{ mol} & \quad 0 \text{ mol} & \quad 0.0025 \text{ mol} \\
\end{align*}
\]

\[\left[\text{NH}_4^+\right] = \frac{0.0025 \text{ mol}}{0.050 \text{ L}} = 0.05 \text{ M}\]

\[
\begin{align*}
\text{NH}_4^+ & \quad = \quad \text{NH}_3 & \quad + \quad \text{H}^+ \\
\text{I} & \quad 0.05 \text{ M} & \quad 0 \text{ M} & \quad 0 \text{ M} \\
\text{C} & \quad -x \text{ M} & \quad +x \text{ M} & \quad +x \text{ M} \\
\text{E} & \quad 0.05 -x & \quad x & \quad x \\
& \quad \sim 0.05
\end{align*}
\]

\[K_a = \frac{[\text{NH}_3][\text{H}^+]}{[\text{NH}_4^+]} \quad \Rightarrow \quad 5.6 \times 10^{-10} = \frac{x^2}{0.05}\]

\[x = [\text{H}^+] = 5.3 \times 10^{-6} \text{ M}\]

\[\text{pH} = -\log(5.3 \times 10^{-6}) = 5.28\]

Indicator Choice

Ethyl Red
5. Write chemical equations for the following reactions:

a) The Formation of Ag(NH$_3$)$_2^+$:

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

b) The titration of NH$_3$ with HCl:

\[ \text{NH}_3(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) \]

c) The addition of NaOH to a buffer composed of HAc / Ac$^-$, where Ac$^-$ represents the Acetate Ion:

\[ \text{HAc}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{Ac}^-(\text{aq}) + \text{H}_2\text{O} \]

d) An aqueous solution saturated with CaF$_2$ is acidified with HCl:

\[ \text{CaF}_2(\text{s}) \rightleftharpoons \text{Ca}^{2+}(\text{aq}) + 2 \text{F}^-(\text{aq}) \]
\[ \text{F}^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{HF}(\text{aq}) \]

e) The solid Coordination Compound [Mn(NH$_3$)$_4$Cl$_2$]Cl is dissolved in water.

\[ [\text{Mn(NH}_3)_4\text{Cl}_2]\text{Cl}(\text{aq}) \rightarrow \text{Mn(NH}_3)_4\text{Cl}_2^+(\text{aq}) + \text{Cl}^-(\text{aq}) \]
Useful Information

Constants

\[ N_A = 6.022045 \times 10^{23} \text{ entities/mole} \]
\[ k_B = 1.380662 \times 10^{-23} \text{ J/K} \]
\[ c = 2.99792458 \times 10^8 \text{ m/sec} \]
\[ h = 6.626176 \times 10^{-34} \text{ J sec} \]
\[ R = 8.314 \text{ J/K mol} \]
\[ = 0.08206 \text{ L atm/K mol} \]
\[ 1 \text{ amu} = 1.6605 \times 10^{-24} \text{ g} \]
\[ K_w = 10^{-14} \text{ at } 25^\circ C \]

Common Acid-Base Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>pK_a</th>
</tr>
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<tbody>
<tr>
<td>Methyl Green</td>
<td>~1</td>
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<tr>
<td>Thymol Blue</td>
<td>~2.2 and 8.9</td>
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<tr>
<td>Methyl Orange</td>
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<tr>
<td>Ethyl Red</td>
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<tr>
<td>Bromocresol Purple</td>
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<tr>
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<td>Clayton Yellow</td>
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# Periodic Table of the Elements

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*The labels on top (1A, 2A, etc.) are common American usage. The labels below (1, 2, etc.) are those recommended by the International Union of Pure and Applied Chemistry (IUPAC).

The names and symbols for elements 113 and above have not yet been decided.

Atomic weights in brackets are the names of the longest-lived or most important isotope of radioactive elements.

Further information is available at http://www.webelements.com

** Discovered in 2010, element 117 is currently under review by IUPAC.