Acids and Bases

1. (4 points) In the following reaction from organic chemistry designate the Brønsted acid, the Brønsted base, and their conjugates.

\[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{O} \\
\text{H}
\end{array} + \begin{array}{c}
\text{H} \\
\text{O} \\
\text{H}
\end{array} \xrightarrow{} \begin{array}{c}
\text{H} \\
\text{C} \\
\text{O} \\
\text{H}
\end{array} + \begin{array}{c}
\text{H} \\
\text{O} \\
\text{H}
\end{array}
\]

(a) Brønsted base = _________________ and its conjugate acid is _________________
(b) Brønsted acid = _________________ and its conjugate base is _________________

2. (6 points) Equal amounts of the hydrogen phosphate ion (as Na$_2$HPO$_4$) ammonium ion (as NH$_4$Cl) are mixed in water. The net ionic equation for a possible reaction is

\[
\text{HPO}_4^{2-}(aq) + \text{NH}_4^+(aq) \rightleftharpoons \text{H}_2\text{PO}_4^-(aq) + \text{NH}_3(aq)
\]

(a) Circle the formulas of the two acids in the reaction.

\[
\begin{array}{c}
\text{HPO}_4^{2-}(aq) \\
\text{NH}_4^+(aq) \\
\text{H}_2\text{PO}_4^-(aq) \\
\text{NH}_3(aq)
\end{array}
\]

(b) Which of the acids is the stronger of the two? __________
(c) Does the equilibrium lie predominantly to the left or to the right? _______________

3. (8 points) You have three different acids in separate beakers. All have a concentration of 0.05 M.

Beaker A: Boric acid  Beaker B: Acetic acid  Beaker C: H$_3$PO$_4$

Which beaker has the largest [H$_3$O$^+$] concentration? ________________

Which beaker has the highest pH? ________________

Which beaker has the highest concentration of OH$^-$? ________________

Which acid has the strongest conjugate base? ________________
4. (4 points) When the \([\text{H}_3\text{O}^+]\) in a solution increases by a factor of 10, the pH
(a) increases by 10  (b) does not change
(c) increases by 0.10  (d) increases by 1
(e) decreases by 10  (f) decreases by 1
(g) decreases by 0.1  (h) doubles

When the pH increases by 1.00, the \([\text{OH}^-]\) changes in the following manner:
(a) \([\text{OH}^-]\) decreases by a factor of 2
(b) \([\text{OH}^-]\) increases by a factor of 10
(c) \([\text{OH}^-]\) decreases by a factor of 10
(d) \([\text{OH}^-]\) increases by a factor of 1

5. (3 points) A solution has \([\text{H}_3\text{O}^+]\) = 6.8 \times 10^{-4} M. Which answer below is correct?

<table>
<thead>
<tr>
<th>pH</th>
<th>pOH</th>
<th>([\text{OH}^-])</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>3.17</td>
<td>10.83 1.47 \times 10^{-11}</td>
</tr>
<tr>
<td>(b)</td>
<td>6.80</td>
<td>7.20 1.00 \times 10^{-14}</td>
</tr>
<tr>
<td>(c)</td>
<td>10.83</td>
<td>3.17 1.47 \times 10^{-11}</td>
</tr>
<tr>
<td>(d)</td>
<td>3.17</td>
<td>10.83 6.8 \times 10^{-4}</td>
</tr>
</tbody>
</table>

6. (3 points) What is the pH of a 0.0423 M solution of HNO\(_3\)?
(a) 0.042
(b) 1.37
(c) 4.23
(d) 12.63

7. (3 points) What is the pH of a 0.015 M solution of acetic acid?
(a) 1.82
(b) 3.28
(c) 4.74
(d) 6.57
8. (3 points) What is the pH of a 0.015 M solution of the carbonate ion, CO$_3^{2-}$ (with a cation that does not affect the pH)?
   (a) 2.75
   (b) 3.68
   (c) 10.32
   (d) 11.25

9. (7 points) Enough of each substance below is added to water to make a 0.10 M solution. Decide if each solution below is *acidic, basic, or neutral*.

<table>
<thead>
<tr>
<th>Salt</th>
<th>Acidity in Aqueous Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) NaBr</td>
<td></td>
</tr>
<tr>
<td>(b) K$_2$HPO$_4$</td>
<td></td>
</tr>
<tr>
<td>(c) NH$_4$NO$_3$</td>
<td></td>
</tr>
<tr>
<td>(d) AlCl$_3$</td>
<td></td>
</tr>
<tr>
<td>(e) (NH$_4$)$_3$PO$_4$</td>
<td></td>
</tr>
<tr>
<td>(f) Na$_2$SO$_3$</td>
<td></td>
</tr>
<tr>
<td>(g) NaH$_2$PO$_4$ + Na$_2$HPO$_4$</td>
<td></td>
</tr>
</tbody>
</table>

10. (2 points) Chloroacetic acid (ClCH$_2$CO$_2$H) has pK$_a$ = 2.867. Chloroacetic acid is *(stronger)(weaker)* than acetic acid. _______________________

11. (3 points) The pH of 0.015 M benzilic acid (a weak acid) is 2.50. What is the value of K$_a$ for the acid?
   (a) 0.015
   (b) 3.6 x 10$^{-3}$
   (c) 8.4 x 10$^{-4}$
   (d) 1.3 x 10$^{-5}$
12. (5 points) You have a buffer solution based on NH₃ and NH₄Cl. If the pH of the buffer is 9.00, which is present in larger amount in the solution, NH₃ or NH₄Cl?
   (a) NH₃
   (b) NH₄Cl

   Explain your answer in words and using appropriate calculations

12. (5 points) What mass of sodium acetate, NaCH₃CO₂ (molar mass = 82 g/mol) do you have to add to 1.00 L of 0.15 M acetic acid to prepare a buffer solution with a pH of 4.89?
   (a) 12.3 g NaCH₃CO₂
   (b) 17.2 g NaCH₃CO₂
   (c) 22.1 g NaCH₃CO₂
   (d) 82.0 g NaCH₃CO₂

   After you make the NaCH₃CO₂/acetic acid buffer solution, you add 500 mL of water. What happens to the pH of the buffer?
   (a) The pH increases
   (b) The pH decreases
   (c) The pH stays the same
13. (6 points) Acid-base reactions

(a) A solution of formic acid (15 mL, 0.050 M) is mixed with 15 mL of 0.050 M NaOH. Is the resulting solution acidic, basic, or neutral? ____________________________

(b) 50.0 mL of 0.40 M NH₃ is mixed with 50.0 mL of 0.40 M HCl. Is the resulting solution acidic, basic, or neutral? ____________________________

(c) 30 mL of 0.050 M acetic acid is mixed with 15 mL of 0.050 M NaOH. Is the resulting solution acidic, basic, or neutral? ____________________________

14. (6 points) When placed in water, copper ions give the solution a beautiful blue color. The color comes from the interaction of Cu²⁺ with water.

In this reaction, Cu²⁺ is a (Lewis acid)(Lewis base) __________________ and water is a (Lewis acid)(Lewis base). __________________

Nickel ion also interacts with ammonia to give a purple, octahedral complex ion.

The hybridization of the N in NH₃ is ________________ and the hybridization of Ni²⁺ in the square planar Ni(NH₃)₆²⁺ ion is ________________ (2 bonus points for the 2nd answer!)
15. (4 points) Identify each of the two titration curves below as one of the following:
(a) a strong acid titrated with a strong base
(b) a strong acid titrated with a weak base
(c) a weak acid titrated with a strong base
(d) a strong base titrated with a strong acid
(e) a weak base titrated with a strong acid

16. 11 points) Suppose you titrate 50.0 mL of 0.050 M phenylacetic acid ($C_6H_5CH_2CO_2H$) with 0.050 M NaOH.

$$C_6H_5CH_2CO_2H(aq) + OH^-(aq) \rightarrow \text{products}$$

Use the titration curve on the next page to answer the following questions:

(a) What is the pH at the beginning of the titration? ________________

(b) The $pK_a$ of phenylacetic acid is about ________________ and the $K_a$ is about ________________

(c) The pH at the equivalence point is ________________

(d) Explain why the pH at the equivalence point is (acidic)(basic)(neutral).
Volume (mL) of 0.050 M NaOH added to 50 mL of 0.050 M acid
VALENCE BOND THEORY AND HYBRIDIZATION

1. (7 points) Draw a Lewis electron dot structure for \( \text{SO}_3^{2-} \); the sulfite ion.

Provide the following information:

- The number of valence electrons in the ion ________________________________
- The electron pair geometry of the ion ________________________________
- The molecular geometry of the ion ________________________________
- The O—S—O bond angle ________________________________
- The S atom hybridization ________________________________

2. (8 points) The structure of aspirin is shown here.

Bond angles:
- Angle A = __________
- Angle B = __________
- Angle C = __________
- Angle D = __________

Atom hybridizations:
- C atom 1 = _____________________
- C atom 3 = _____________________
- O atom 2 = _____________________
- C atom 4 = _____________________

3. (2 points) Give the hybridization used by each underlined atom.
   (a) C in CO\(_2\) ________________
   (b) B in BH\(_4^-\) ________________