1. An equation representing the reaction of a weak acid with water is

   A. \( \text{HCl} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Cl}^- \)
   B. \( \text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^- \)
   C. \( \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^- \)
   D. \( \text{HCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HCOO}^- \)

2. The equilibrium expression for the ion product constant of water is

   A. \( \text{Kw} = \frac{[\text{H}_3\text{O}^+][\text{OH}^-]}{[\text{H}_2\text{O}]} \)
   B. \( \text{Kw} = [\text{H}_3\text{O}^+]^2[\text{O}_2^-] \)
   C. \( \text{Kw} = [\text{H}_3\text{O}^+][\text{OH}^-] \)
   D. \( \text{Kw} = [\text{H}_3\text{O}^+]^2[\text{O}_2^-] \)

3. Consider the following graph for the titration of 0.1 M \( \text{NH}_3 \) with 1.0 M \( \text{HCl} \).

   ![Graph]

   A buffer solution is present at point

   A. I
   B. II
   C. III
   D. IV

4. Consider the following equilibrium system for an indicator: \( \text{HInd} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Ind}^- \)
Which two species must be of two different colours in order to be used as an indicator?

   A. \( \text{HInd and } \text{H}_2\text{O} \)
   B. \( \text{HInd and } \text{Ind}^- \)
   C. \( \text{H}_3\text{O}^+ \text{ and } \text{Ind}^- \)
   D. \( \text{HInd and } \text{H}_3\text{O}^+ \)

5. Which of the following indicators is yellow at pH 10.0?

   A. methyl red
   B. phenol red
   C. thymol blue
   D. methyl violet
6. A sample containing $1.20 \times 10^{-2}$ mole HCl is completely neutralized by 100.0 mL of Sr(OH)$_2$. What is the [Sr(OH)$_2$]?

A. $6.00 \times 10^{-3}$ M
B. $6.00 \times 10^{-2}$ M
C. $1.20 \times 10^{-1}$ M
D. $2.4 \times 10^{-1}$ M

7. Which of the following titrations will have the highest pH at the equivalence point?

A. HBr with NH$_3$
B. HNO$_2$ with KOH
C. HCl with Na$_2$CO$_3$
D. HNO$_3$ with NaOH

8. An Arrhenius acid is defined as a chemical species that

A. is a proton donor.
B. is a proton acceptor.
C. produces hydrogen ions in solution.
D. produces hydroxide ions in solution.

9. Consider the following acid-base equilibrium system: HC$_2$O$_4$\(^{-}\) + H$_2$BO$_3$\(^{-}\) $\Rightarrow$ H$_3$BO$_3$ + C$_2$O$_4$\(^{2-}\). Identify the Bronsted-Lowry bases in this equilibrium.

A. H$_2$BO$_3$\(^{-}\) and H$_3$BO$_3$
B. HC$_2$O$_4$\(^{-}\) and H$_3$BO$_3$
C. HC$_2$O$_4$\(^{-}\) and C$_2$O$_4$\(^{2-}\)
D. H$_2$BO$_3$\(^{-}\) and C$_2$O$_4$\(^{2-}\)

10. The equation representing the predominant reaction between NaCH$_3$COO with water is

A. CHCOO\(^{-}\) + H$_2$O $\rightleftharpoons$ CH$_3$COOH + OH\(^{-}\)
B. CHCOO\(^{-}\) + H$_2$O $\rightleftharpoons$ H$_3$O + CH$_3$COO\(^{2-}\)
C. CHCOOH + H$_2$O $\rightleftharpoons$ H$_3$O$^+$ + CH$_3$COO\(^{-}\)
D. CHCOOH + H$_2$O $\rightleftharpoons$ CH$_3$COOH$^+$ + OH\(^{-}\)

11. Which of the following solutions will have the lowest electrical conductivity?

A. 0.10 M HF
B. 0.10 M NaF
C. 0.10 M H$_2$SO$_3$
D. 0.10 M NaHSO$_3$

12. Which of the following is the strongest Bronsted-Lowry base?

A. NH$_3$
B. CO$_3$\(^{2-}\)
C. HSO$_3$\(^{-}\)
D. H$_2$BO$_3$\(^{-}\)
13. A 1.0 \times 10^{-4} M solution has a pH of 10.00. The solute is a

A. weak acid
B. weak base
C. strong acid]
D. strong base

14. The ionization of water at room temperature is represented by

A. \( H_2O \rightleftharpoons 2H^+ + O^{2-} \)
B. \( 2H_2O \rightleftharpoons 2H_2 + O_2 \)
C. \( 2H_2O \rightleftharpoons H_2 + 2OH^+ \)
D. \( 2H_2O \rightleftharpoons 2H_3O^+ + OH^- \)

15. Addition of HCl to water causes

A. both \([H_3O^+]\) and \([OH^-]\) to increase
B. both \([H_3O^+]\) and \([OH^-]\) to decrease
C. \([H_3O^+]\) to increase and \([OH^-]\) to decrease
D. \([H_3O^+]\) to decrease and \([OH^-]\) to increase

16. Consider the following:

I. \( H_2SO_4 \)
II. \( HSO_4^- \)
III. \( SO_4^{2-} \)

Which of the above is/are present in a reagent bottle labeled 1.0 M \( H_2SO_4 \)?

A. I only
B. I and II only
C. II and III only
D. I, II, and III

17. The pH of 0.10 M KOH solution is

A. 0.10
B. 1.00
C. 13.00
D. 14.10

18. An indicator changes colour in the pH range 9.0 to 11.0. What is the value of the Ka for the indicator?

A. \( 1 \times 10^{-13} \)
B. \( 1 \times 10^{-10} \)
C. \( 1 \times 10^{-7} \)
D. \( 1 \times 10^{-1} \)
19. Which of the following are amphiprotic in aqueous solution?

I. HBr
II. H₂O
III. HCO₃⁻
IV. H₂C₆H₅O₇⁻

A. I and II only
B. II and IV only
C. II, III, and IV only
D. I, II, III, and IV

20. Which of the following always applies at the transition point for the indicator Hind?

A. [Ind⁻] = [OH⁻]
B. [HInd] = [Ind⁻]
C. [Ind⁻] = [H₂O⁺]
D. [HInd] = [H₂O⁺]

21. Calculate the [H₃O⁺] of a solution prepared by adding 10.0 mL of 2.0 M HCl to 10.0 mL of 1.0 M NaOH.

A. 0.20 M
B. 0.50 M
C. 1.0 M
D. 2.0 M

22. Both acidic and basic solutions

A. taste sour
B. feel slippery
C. conduct electricity
D. turn blue litmus red

23. The conjugate acid of HPO₄²⁻ is

A. PO₄³⁻
B. H₂PO₄⁻
C. H₂PO₄²⁻
D. H₂PO₄³⁻

24. What is the value of the Kw at 25 °C?

A. 1.0 x 10⁻¹⁴
B. 1.0 x 10⁻⁷
C. 7
D. 14

25. Consider the following equilibrium: 2H₂O(l) ⇌ H₃O⁺(aq) + OH⁻(aq)

A small amount of Fe(H₂O)₆³⁺ is added to water and equilibrium is re-established. Which of the following represents the changes in ion concentrations?

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26. Consider the following equilibrium for an indicator: \( \text{HInd} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Ind}^- \)
In a solution of pH of 6.8, the colour of bromthymol blue is

A. blue because \([\text{HInd}] = [\text{Ind}^-]\)
B. green because \([\text{HInd}] = [\text{Ind}^-]\)
C. green because \([\text{HInd}] < [\text{Ind}^-]\)
D. yellow because \([\text{HInd}] > [\text{Ind}^-]\)

27. The indicator with \(K_a = 4 \times 10^{-8}\) is

A. neutral red
B. methyl red
C. indigo carmine
D. phenolphthalein

28. In a titration a 25.00 mL sample of \(\text{Sr(OH)}_2\) is completely neutralized by 28.60 mL of 0.100 M HCl. The concentration of the \(\text{Sr(OH)}_2\) is

A. \(1.43 \times 10^{-3}\) M
B. \(2.86 \times 10^{-3}\) M
C. \(5.72 \times 10^{-5}\) M
D. \(1.14 \times 10^{-5}\) M

29. A student mixes 15.0 mL of 0.100 M NaOH with 10.0 mL of 0.200 M HCl. The resulting solution is

A. basic
B. acidic
C. neutral
D. amphiprotic

30. Which of the following salts will dissolve in water to produce a neutral solution?

A. LiF
B. CrCl₃
C. KNO₃
D. NH₄Cl

31. What is the value of the \(K_b\) for \(\text{HC}_6\text{H}_5\text{O}_7^2^-\)?

A. \(5.9 \times 10^{-10}\)
B. \(2.4 \times 10^{-8}\)
C. \(4.1 \times 10^{-7}\)
D. \(1.7 \times 10^{-5}\)

32. The \(pOH\) of 0.015 M HCl solution is

A. 0.97
B. 1.80
C. 12.18
D. 13.03
33. Which of the following will produce an acidic solution?

A. NaCl
B. NH₄NO₃
C. Ca(NO₃)₂
D. Ba(NO₃)₂

34. Which of the following salts will dissolve in water to produce an acid solution?

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36. A student mixes 400 mL of 0.100 M NaOH with 100 mL of 0.200 M H₂SO₄. The resulting solution has a pH of

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B. 0.000
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37. A student mixes 500 mL of 0.400 M NaOH with 500 mL of 0.100 M H₂SO₄. The resulting solution has a pH of

A. 14.000
B. 0.000
C. 13.000
D. 7.000

38. The strongest acid in water is

A. HClO₄
B. HI
C. HF
D. H₃O⁺

39. The formula that has the highest pH in water is

A. HF
B. H₂CO₃
C. H₂C₂O₄
D. HCN

39. The formula that has the highest pH in water is

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B. NaCl
C. H₂C₂O₄
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1. A chemist prepares a solution by dissolving the salt NaCN in water.
   a) Write the equation for the dissociation reaction that occurs.
   
   b) Write the equation for the hydrolysis reaction that occurs.
   
   c) Calculate the value of the equilibrium constant for the hydrolysis

2. A $3.50 \times 10^{-3}$ M sample of unknown acid, HA has a pH of 2.90. Calculate the value of the Ka and identify this acid.

3. Calculate the mass of NaOH needed to prepare 2.0 L of a solution with a pH of 12.00.
4. A 1.00 M $\text{OCl}^-$ solution has an [OH$^-$] of $5.75 \times 10^{-4}$ M. Calculate the $K_b$ for $\text{OCl}^-$. 

5. Calculate the pH of a solution prepared by adding 15.0 mL of 0.500 M $\text{H}_2\text{SO}_4$ to 35.0 mL of 0.750 M $\text{NaOH}$. 

6. Determine the pH of a 0.10 M solution of hydrogen cyanide.
7. Determine the pH of 0.100 M NH₃.

8. Determine the pH of a saturated solution of Mg(OH)₂.

Answers
1. An equation representing the reaction of a weak acid with water is

A. \( \text{HCl} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Cl}^- \)
B. \( \text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^- \)
C. \( \text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^- \)
D. \( \text{HCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HCOO}^- \)

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B. \text{phenol red}
C. \text{thymol blue}
D. \text{methyl violet}
6. A sample containing $1.20 \times 10^{-2}$ mole HCl is completely neutralized by 100.0 mL of Sr(OH)$_2$. What is the [Sr(OH)$_2$]? 

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C. $1.20 \times 10^{-1}$ M 
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10. The equation representing the predominant reaction between NaCH$_3$COO with water is 

A. CH$_3$COO$^-$ + H$_2$O ⇄ CH$_3$COOH + OH$^-$ 
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C. CH$_3$COOH + H$_2$O ⇄ H$_3$O$^+$ + CH$_3$COO$^-$ 
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A. 0.10 M HF 
B. 0.10 M NaF 
C. 0.10 M H$_2$SO$_3$ 
D. 0.10 M NaHSO$_3$ 

12. Which of the following is the strongest Bronsted-Lowry base? 

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B. CO$_3^{2-}$ 
C. HSO$_3^-$ 
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13. A 1.0 x 10^{-4} M solution has a pH of 10.00. The solute is a

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B. \( 2H_2O \rightleftharpoons 2H_2 + O_2 \)  
C. \( 2H_2O \rightleftharpoons H_2 + 2OH^+ \)  
D. \( 2H_2O \rightleftharpoons 2H_3O^+ + OH^- \)

15. Addition of HCl to water causes

A. both \([H_3O^+]\) and \([OH^-]\) to increase  
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Which of the above is/are present in a reagent bottle labeled 1.0 M \( H_2SO_4 \)?

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21. Calculate the [H₃O⁺] of a solution prepared by adding 10.0 mL of 2.0 M HCl to 10.0 mL of 1.0 M NaOH.

A. 0.20 M
B. **0.50 M**
C. 1.0 M
D. 2.0 M

22. Both acidic and basic solutions

A. taste sour
B. feel slippery
C. **conduct electricity**
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23. The conjugate acid of HPO₄²⁻ is

A. PO₄³⁻
B. **H₂PO₄⁻**
C. H₂PO₄²⁻
D. H₂PO₄³⁻

24. What is the value of the Kw at 25 °C?

A. **1.0 x 10⁻¹⁴**
B. 1.0 x 10⁻⁷
C. 7
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25. Consider the following equilibrium: 2H₂O(l) ⇌ H₃O⁺(aq) + OH⁻(aq)
A small amount of Fe(H₂O)⁶³⁺ is added to water and equilibrium is re-established. Which of the following represents the changes in ion concentrations?

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B. acidic
C. neutral
D. amphiprotic

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37. A student mixes 500 mL of 0.400 M NaOH with 500 mL of 0.100 M H₂SO₄. The resulting solution has a pH of

A. 14.000  
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D. 7.000

38. The strongest acid in water is

A. HClO₄  
B. HI  
C. HF  
D. H₃O⁺

39. The formula that has the highest pH in water is

A. HF  
B. H₂CO₃  
C. H₂C₂O₄  
D. HCN

40. The formula that has the highest pH in water is

A. NaF  
B. NaCl  
C. H₂C₂O₄  
D. NaCN
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   a) Write the equation for the dissociation reaction that occurs.

   \[
   \text{NaCN} \rightarrow \text{Na}^+ + \text{CN}^- \\
   \]

   b) Write the equation for the hydrolysis reaction that occurs.

   \[
   \text{CN}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCN} + \text{OH}^- \\
   \]

   c) Calculate the value of the equilibrium constant for the hydrolysis

   \[
   K_b(\text{CN}^-) = \frac{K_w}{K_a(\text{HCN})} = \frac{1.0 \times 10^{-14}}{4.9 \times 10^{-10}} = 2.0 \times 10^{-5} \\
   \]

2. A 3.50 \times 10^{-3} M sample of unknown acid, HA has a pH of 2.90. Calculate the value of the Ka and identify this acid.

   \[
   [\text{H}^+] = 10^{-\text{pH}} = 10^{-2.90} = 0.00126 \text{ M} \\
   \]

   \[
   \text{HA} \rightleftharpoons \text{H}^+ + \text{A}^- \\
   \]

   \[
   \begin{array}{c|c|c|c}
   & \text{I} & \text{C} & \text{E} \\
   \hline
   [\text{HA}] & 0.00350 \text{ M} & 0.00126 \text{ M} & 0.00224 \text{ M} \\
   [\text{H}^+] & 0 & 0.00126 \text{ M} & 0.00126 \text{ M} \\
   [\text{A}^-] & 0 & 0 & 0.00126 \text{ M} \\
   \end{array} \\
   \]

   \[
   K_a = \frac{(0.00126)^2}{0.00224} = 7.1 \times 10^{-4} \quad \text{Citric acid} \\
   \]

3. Calculate the mass of NaOH needed to prepare 2.0 L of a solution with a pH of 12.00.

   \[
   \text{pOH} = 14.00 - 12.00 = 2.00 \\
   [\text{OH}^-] = 10^{-2.00} = 0.010 \text{ M} \\
   2.0 \text{ L} \times \frac{0.010 \text{ mol}}{\text{L}} \times \frac{40.0 \text{ g}}{\text{mol}} = 0.80 \text{ g NaOH} \\
   \]

4. A 1.00 M OCl\(^-\) solution has an [OH\(^-\)] of 5.75 \times 10^{-4} M. Calculate the Kb for OCl\(^-\).
\[
\text{OCl}^- + \text{H}_2\text{O} \rightleftharpoons \text{HOCl} + \text{OH}^-
\]

<table>
<thead>
<tr>
<th></th>
<th>(1.00) M</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>(0.000575) M</td>
<td>(0.000575) M</td>
<td>(0.000575) M</td>
</tr>
<tr>
<td>E</td>
<td>(0.9994) M</td>
<td>(0.000575) M</td>
<td>(0.000575) M</td>
</tr>
</tbody>
</table>

\[
\text{Kb} = \frac{(0.000575)^2}{0.9994} = 3.31 \times 10^{-7}
\]

5. Calculate the pH of a solution prepared by adding \(15.0\) mL of \(0.500\) M \(\text{H}_2\text{SO}_4\) to \(35.0\) mL of \(0.750\) M \(\text{NaOH}\).

\[
\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}
\]

0.0150 L x \(0.500\) moles = 0.00750 moles
0.0350 L x \(0.750\) moles = 0.02625 moles

<table>
<thead>
<tr>
<th></th>
<th>(0.0075) moles</th>
<th>0.02625 moles</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>(0.0075) mole</td>
<td>(0.0150) moles</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0.01125 mole</td>
</tr>
</tbody>
</table>

\[
[\text{NaOH}] = \frac{0.01125 \text{ moles}}{0.0500\text{ L}} = 0.225\text{ M}
\]

\[
\text{pH} = 13.354
\]

6. Determine the pH of a \(0.10\) M solution of hydrogen cyanide.

\[
\text{HCN} \rightleftharpoons \text{H}^+ + \text{CN}^-
\]

<table>
<thead>
<tr>
<th></th>
<th>(0.10) M</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>(x)</td>
<td>(x)</td>
<td>(x)</td>
</tr>
<tr>
<td>E</td>
<td>(0.10 - x)</td>
<td>(x)</td>
<td>(x)</td>
</tr>
</tbody>
</table>
small Ka approximation \( x = 0 \)

\[
Ka = \frac{x^2}{0.10} = 4.9 \times 10^{-10}
\]

\( x = 7.0 \times 10^{-4} \quad \text{pH} = 5.15 \)

7. Determine the pH of 0.100 M \( \text{NH}_3 \).

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

<table>
<thead>
<tr>
<th>( I )</th>
<th>1.00 M</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C )</td>
<td>( x )</td>
<td>( x )</td>
<td>( x )</td>
</tr>
<tr>
<td>( E )</td>
<td>1.00 - ( x )</td>
<td>( x )</td>
<td>( x )</td>
</tr>
</tbody>
</table>

small Kb approximation \( x = 0 \)

\[
K_b(\text{NH}_3) = \frac{K_w}{K_a(\text{NH}_4^+)} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-10}} = 1.786 \times 10^{-5}
\]

\[
K_b = \frac{x^2}{0.100} = 1.786 \times 10^{-5}
\]

\( x = 4.22 \times 10^{-4} \quad \text{pH} = 11.13 \)

8. Determine the pH of a saturated solution of \( \text{Mg(OH)}_2 \).

\[
\text{Mg(OH)}_2 \rightleftharpoons \text{Mg}^{2+} + 2\text{OH}^-
\]

\[
4x^3 = 5.6 \times 10^{-12}
\]

\[
[\text{OH}^-] = 2x = 2.24 \times 10^{-4}
\]

pOH = 3.65 \quad \text{pH} = 10.35