1. Calculate the pH and $[\text{OH}^-]$ of a $2.2 \times 10^{-3}$ M HNO$_3$ solution.

A. pH = 2.66, $[\text{OH}^-] = 2.2 \times 10^{-11}$  
B. pH = 2.66, $[\text{OH}^-] = 4.5 \times 10^{-12}$  
C. pH = 11.34, $[\text{OH}^-] = 2.2 \times 10^{-11}$  
D. pH = 11.34, $[\text{OH}^-] = 4.5 \times 10^{-12}$

2. The autoionization of water

$$\text{H}_2\text{O}(l) \rightleftharpoons \text{H}^+(aq) + \text{OH}^-(aq)$$

has $K_w = 2.93 \times 10^{-15}$ at 10 °C and $K_w = 5.48 \times 10^{-14}$ at 50 °C. The autoionization of water

A. proceeds far to the right.  
B. has $\Delta H_{\text{rxn}} = 0$.  
C. is an exothermic reaction.  
D. is an endothermic reaction.

3. What is the pH of a 0.42 M formic acid (HCHO$_2$) solution?

$K_a (\text{HCHO}_2) = 1.8 \times 10^{-4}$

A. 4.12  
B. 3.74  
C. 2.06  
D. 0.377

4. What is the H$_3$O$^+$ concentration of a pH 13.440 solution?

A. $3.631 \times 10^{-14}$ M  
B. $2.304 \times 10^{-10}$ M  
C. $6.026 \times 10^{-4}$ M  
D. $1.136 \times 10^{-1}$ M
5. Calculate the % ionization of a 0.25 M benzoic acid (HC₇H₅O₂) solution.

\[ K_a (HC₇H₅O₂) = 6.5 \times 10^{-5} \]

A. 0.65%  
B. 1.6%  
C. 2.3%  
D. 100%

6. Determine the pH of a solution that is 0.60 M HClO (hypochlorous acid) and 0.30 M HClO₄ (perchloric acid).

\[ K_a (HClO) = 2.9 \times 10^{-8} \]

A. 1.64  
B. 0.92  
C. 0.52  
D. 0.22

7. What is the best method for finding the pH of a 0.100 M chloroacetic acid (HC₂H₂O₂Cl) solution?

\[ K_a (HC₂H₂O₂Cl) = 1.4 \times 10^{-3} \]

A. Solve for \([H^+]\) using the “\(x\) is small” approximation.  
B. Solve for \([H^+]\) using the quadratic equation.  
C. Solve for \([H^+]\) by finding \(x\) directly since the quadratic equation is not needed.  
D. Solve for \([H^+]\) using the method of perfect squares (taking the square root of both sides of the \(K_a\) expression).

8. What is the p\(K_b\) of the acetate ion?

\[ K_a \text{ (acetic acid)} = 1.8 \times 10^{-5} \]

A. 9.26  
B. 4.74  
C. 5.6 \times 10^{-10}  
D. 1.0 \times 10^{-14}
9. Which is the **strongest** of these bases?

A. pyridine (C₅H₅N), \( K_b = 1.7 \times 10^{-9} \)  
B. ammonia (NH₃), \( K_b = 1.8 \times 10^{-5} \)  
C. carbonate ion (CO₃²⁻), \( K_b = 1.8 \times 10^{-4} \)  
D. methylamine (CH₃NH₂), \( K_b = 4.4 \times 10^{-4} \)

10. Determine \([H_3O^+]\) of an ethylamine (C₂H₅NH₂) solution with pOH = 9.68.  
\( K_b (C₂H₅NH₂) = 4.9 \times 10^{-10} \)

A. \( 2.1 \times 10^{-3} \)  
B. \( 4.8 \times 10^{-5} \)  
C. \( 9.6 \times 10^{-8} \)  
D. \( 5.8 \times 10^{-10} \)

11. What is the pH of a 0.61 M cyanide (CN⁻) solution?  
\( K_a (HCN) = 4.9 \times 10^{-10} \)

A. 4.76  
B. 9.52  
C. 11.55  
D. 14.00

12. Which salt solution will have the indicated pH?

A. NH₄Cl, pH = 7  
B. KNO₂, pH < 7  
C. CH₃NH₃Br, pH > 7  
D. NaC₂H₃O₂, pH > 7
13. Which statement is true about the $K_a$ values of a diprotic acid?

$$
\begin{align*}
H_2A(aq) + H_2O(l) & \rightleftharpoons HA^-(aq) + H_3O^+(aq) \\
HA^- (aq) + H_2O(l) & \rightleftharpoons A^{2-}(aq) + H_3O^+(aq)
\end{align*}
$$

$K_{a1}$

$K_{a2}$

A. For any diprotic acid, $K_{a1} < K_{a2}$.  
C. For any diprotic acid, $K_{a1} = K_{a2}$.

B. For any diprotic acid, $K_{a1} > K_{a2}$.  
D. The magnitudes of $K_{a1}$ and $K_{a2}$ for a diprotic acid have no necessary relationship to one another.

14. Which ranking of binary acids is in order of decreasing acid strength (strongest to weakest)?

A. $H_2S > H_2Te > H_2Se > H_2O$

B. $H_2O > H_2S > H_2Se > H_2Te$

C. $H_2Te > H_2Se > H_2S > H_2O$

D. $H_2Se > H_2Te > H_2O > H_2S$

15. Which is the strongest of these acids?

A. 

B. 

C. 

D. 

16. Select the false statement about the following reaction:

$$HF + BF_3 \rightarrow H^+ + BF_4^-$$

A. $BF_4^-$ is a Lewis acid-base adduct.  
C. $BF_3$ acts as a Lewis acid.

B. HF acts as a Lewis acid.  
D. HF acts as a Lewis base.
17. When the ionic compound, Fe(NO$_3$)$_3$, dissolves in water, the Fe$^{3+}$ ions are hydrated as shown. Select the **true** statement.

\[ \text{Fe}^{3+}(aq) + 6 \text{H}_2\text{O}(l) \rightarrow \text{Fe}[\text{H}_2\text{O}]_6^{3+} (aq) \]

A. Fe$^{3+}$ is a Lewis acid because it is an electron pair acceptor.
B. Fe$^{3+}$ is a Lewis acid because it is an electron pair donor.
C. Fe$^{3+}$ is a Lewis base because it is an electron pair acceptor.
D. Fe$^{3+}$ is a Lewis base because it is an electron pair donor.

18. Which of the following is **not** a buffer solution?

A. 0.11 M HC$_2$H$_3$O$_2$ (acetic acid) + 0.10 M KC$_2$H$_3$O$_2$ (potassium acetate)
B. 0.18 M HC$_7$H$_5$O$_2$ (benzoic acid) + 0.21 M LiC$_7$H$_5$O$_2$ (lithium benzoate)
C. 0.50 M HF (hydrofluoric acid) + 0.55 M NaF (sodium fluoride)
D. 0.91 M HCl (hydrochloric acid) + 0.87 M CsCl (cesium chloride)

19. What is the pH of a solution that is 0.51 M benzoic acid (HC$_7$H$_5$O$_2$) and 0.26 M in potassium benzoate (KC$_7$H$_5$O$_2$)?

\[ K_a (HC_7H_5O_2) = 6.5 \times 10^{-5} \]

A. 3.89  
B. 4.48  
C. 4.69  
D. 6.15
20. A 1.0-L buffer is 0.150 M formic acid (HCHO₂) and 0.150 M sodium formate (NaCHO₂). What is the best estimate of the pH after the addition of 10.0 mL 0.0100 M KOH?

\( pK_a (\text{HCHO}_2) = 3.74 \)

A. \( \text{pH} = 3.74 \)  
B. \( 2.74 < \text{pH} < 3.74 \)
C. \( 3.74 < \text{pH} < 4.74 \)
D. \( 4.74 < \text{pH} < 5.74 \)

21. Calculate at the pH after 10.0 mL of 0.12 M HCl is added to 100.0 mL of a solution that is 0.15 M HNO₂ (nitrous acid) and 0.10 M NaNO₂ (sodium nitrite).

\( K_a (\text{HNO}_2) = 4.6 \times 10^{-4} \)

A. \( 3.07 \)  
B. \( 3.39 \)
C. \( 3.71 \)
D. \( 4.70 \)

22. What base-to-acid ratio is needed to make a pyruvic acid (HC₃H₅O₃)/potassium pyruvate (KC₃H₅O₃) buffer with a pH of 2.75?

\( K_a (\text{HC}_3\text{H}_5\text{O}_3) = 4.1 \times 10^{-3} \)

A. \( [\text{C}_3\text{H}_5\text{O}_3^-]/[\text{HC}_3\text{H}_5\text{O}_3] = 3.4 \)  
B. \( [\text{C}_3\text{H}_5\text{O}_3^-]/[\text{HC}_3\text{H}_5\text{O}_3] = 2.3 \)
C. \( [\text{C}_3\text{H}_5\text{O}_3^-]/[\text{HC}_3\text{H}_5\text{O}_3] = 0.58 \)
D. \( [\text{C}_3\text{H}_5\text{O}_3^-]/[\text{HC}_3\text{H}_5\text{O}_3] = 0.21 \)
23. Which is the most effective buffer for keeping a solution at pH 7.44? All concentrations are 0.25 M.
   A. nitrous acid ($pK_a = 3.34$) and sodium nitrite
   B. formic acid ($pK_a = 4.19$) and sodium formate
   C. hypochlorous acid ($pK_a = 7.56$) and sodium hypochlorite
   D. phenol ($pK_a = 9.89$) and sodium phenolate

24. Which statement is true about buffer capacity?
   A. The buffer capacity decreases with increasing absolute concentrations of the buffer components.
   B. The buffer capacity increases with decreasing absolute concentrations of the buffer components.
   C. The buffer capacity is greatest when [acid] >> [base].
   D. The buffer capacity is greatest when [acid] and [base] are large and approximately equal.

25. Which statement describes the titration depicted in the graph?

   A. A strong acid is added to a flask containing a weak base.
   B. A weak acid is added to a flask containing a strong base.
   C. A strong acid is added to a flask containing a strong base.
   D. A strong base is added to a flask containing a strong acid.
26. What is the pH when 25.0 mL of 0.150 M propanoic acid (HC\textsubscript{3}H\textsubscript{5}O\textsubscript{2}) has been titrated with 8.75 mL of 0.200 M KOH?

\[ K_a (HC_3H_5O_2) = 4.1 \times 10^{-3} \]

A. 2.33 \hspace{1cm} C. 4.94
B. 3.23 \hspace{1cm} D. 5.09

27. What is the pH of a mixture of 35 mL of 0.25 M HCl and 25 mL of 0.25 M NaF?

\[ K_a (HF) = 3.5 \times 10^{-4} \]

A. 1.38 \hspace{1cm} C. 2.20
B. 2.06 \hspace{1cm} D. 2.60
28. The plot for a polyprotic acid is given at right. Which acid is the best match to this plot?

A. hypophosphorous acid, $\text{H}_3\text{PO}_2$

B. phosphoric acid, $\text{H}_3\text{PO}_4$

C. phosphorous acid, $\text{H}_3\text{PO}_3$

D. pyrophosphoric acid, $\text{H}_4\text{P}_2\text{O}_7$

29. The $pK_a$ = 3.6 for the acid-base indicator bromophenol blue. The acid form of the indicator is yellow and the base form of the indicator is blue. What color is the indicator at a pH of 5.0?

A. yellow

B. green

C. blue

D. colorless

30. The plot to the right shows the results of titrating a series of unidentified acids (HA, HB, HC, and HD) with 0.100 M NaOH. Each flask contains 50.0 mL of 0.100 M acid. Rank the acids by $pK_a$.

A. $pK_a$ (HD) < $pK_a$ (HC) < $pK_a$ (HB) < $pK_a$ (HA)

B. $pK_a$ (HA) < $pK_a$ (HB) < $pK_a$ (HC) < $pK_a$ (HD)

C. $pK_a$ (HA) = $pK_a$ (HB) = $pK_a$ (HC) = $pK_a$ (HD)

D. More information is needed to rank the acids by $pK_a$. 
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1. B
2. D
3. C
4. A
5. B
6. C
7. B
8. A
9. D
10. B
11. C
12. D
13. B
14. C
15. A
16. B
17. A
18. D
19. A
20. C
21. A
22. B
23. C
24. D
25. C
26. A
27. A
28. B
29. C
30. B