Acids & Bases

1. Identify the role of each species in the following reaction using Bronsted-Lowry definitions of acids and bases.

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

<table>
<thead>
<tr>
<th></th>
<th>H\textsubscript{2}PO\textsubscript{4} (aq)</th>
<th>HCO\textsubscript{3} (aq)</th>
<th>H\textsubscript{2}CO\textsubscript{3} (aq)</th>
<th>HPO\textsubscript{4}^{2-} (aq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>acid</td>
<td>acid</td>
<td>conj. base</td>
<td>conj. base</td>
</tr>
<tr>
<td>B</td>
<td>base</td>
<td>base</td>
<td>conj. acid</td>
<td>conj. acid</td>
</tr>
<tr>
<td>C</td>
<td>base</td>
<td>acid</td>
<td>conj. acid</td>
<td>conj. base</td>
</tr>
<tr>
<td>D</td>
<td>acid</td>
<td>base</td>
<td>conj. acid</td>
<td>conj. base</td>
</tr>
<tr>
<td>E</td>
<td>acid</td>
<td>base</td>
<td>conj. base</td>
<td>conj. acid</td>
</tr>
</tbody>
</table>

2. At 0°C, the ion-product constant of water, K\textsubscript{w}, is $1.2 \times 10^{-15}$. What is the pH of pure water at 0°C?

A. 7.00  
B. 6.88  
C. 7.56  
D. 7.46  
E. 7.12  

3. The conjugate acid and conjugate base of bicarbonate ion, HCO\textsubscript{3}^-, are, respectively:

A. H\textsubscript{3}O\textsuperscript{+} and OH\textsuperscript{-}  
B. H\textsubscript{3}O\textsuperscript{+} and CO\textsubscript{3}^{2-}  
C. H\textsubscript{2}CO\textsubscript{3} and OH\textsuperscript{-}  
D. H\textsubscript{2}CO\textsubscript{3} and CO\textsubscript{3}^{2-}  
E. CO\textsubscript{3}^{2-} and OH\textsuperscript{-}  

4. What is the pH of 1.3 x 10\textsuperscript{-3} M aqueous sodium hydroxide solution?

A. 11.1  
B. 8.3  
C. 7.9  
D. 2.9  
E. None of the above answers is correct.
5. Choose which of the following is correct. The pH’s of the solutions will change as indicated when 100 ml of H₂O is added to each of the following solutions:

   i. 100 mL of 0.02 M KCl
   ii. 100 mL of 0.02 M HCl

A. The pH’s of both (i) and (ii) will remain the same.
B. The pH of (i) will remain the same but that of (ii) will increase.
C. The pH of (ii) will remain the same but that of (i) will increase.
D. The pH of (i) will remain the same but that of (ii) will decrease.
E. The pH of (ii) will remain the same but that of (i) will decrease.

6. What is the H⁺ concentration in a solution with a pH of 3.75?

A. 5.6 x 10⁻³
B. 7.5 x 10⁻³
C. 5.6 x 10⁻¹¹
D. 1.8 x 10⁻⁴
E. 2.5 x 10⁻⁸

7. What is the pH of a 0.053 M solution of KOH?

A. 6.9
B. 12.7
C. 7.3
D. 1.3
E. 11.0

8. Milk of magnesia has a pH = 10.4. What is its [OH⁻]?

A. 1.0 x 10⁻⁴ M
B. 2.5 x 10⁻⁴ M
C. 4.0 x 10⁻¹¹ M
D. 3.6 M
E. 1.0 x 10⁻¹¹ M

9. A 0.1 M solution of an electrolyte has a pH of 4.0. The electrolyte is:

A. a strong acid.
B. a strong base.
C. a weak acid.
D. a weak base.
E. a salt of a strong acid and a strong base.
10. The pH of vinegar was measured to be 3.47 using a pH meter. What is the hydronium ion (H$_3$O$^+$) concentration in vinegar?

A. $3.4 \times 10^{-4}$ M  
B. $1.7 \times 10^{-2}$ M  
C. 0.5 M  
D. 1.9 M  
E. None of the above answers is correct.

11. Strong acids are characterized as:

1. weak electrolytes  
2. having spectator ions as conjugate bases  
3. having very large $K_a$ values

A. 1 and 2  
B. 2 and 3  
C. 1, 2 and 3  
D. 1 and 3  
E. 1 only

12. Calculate the hydronium ion (H$_3$O$^+$) concentration in 0.020 M hypochlorous acid ($K_a = 3.0 \times 10^{-8}$).

A. $6.1 \times 10^{-10}$ M  
B. $4.6 \times 10^{-8}$ M  
C. $2.4 \times 10^{-5}$ M  
D. $7.2 \times 10^{-11}$ M  
E. None of the above answers is correct.

13. What is the value of $K_a$ for the weak acid HA if a 0.35 M solution of HA has a pH of 5.95?

A. $3.2 \times 10^{-6}$  
B. 1.7  
C. $1.1 \times 10^{-6}$  
D. $3.6 \times 10^{-12}$  
E. $2.2 \times 10^{-16}$
14. Which of the following is true about a 0.10 M solution of a weak acid HX, whose $K_a = 1 \times 10^{-5}$?

A. $[X^-] = 0.10$ M  
B. $[H^+] = 0.10$ M  
C. pH = 1  
D. $[HX] > [H^+]$  
E. pH = 10

15. What percentage ionization would be expected for 0.400 M HN$_3$ ($K_a = 1.9 \times 10^{-5}$)?

A. 70%  
B. 35%  
C. 3.5%  
D. 0.7%  
E. None of the above answers is correct.

16. What is the % ionization of hypochlorous acid (HClO) in a 0.015 M solution of HClO? 
($K_a = 3.0 \times 10^{-8}$)

A. $4.5 \times 10^{-8}$ %  
B. 14 %  
C. $2.1 \times 10^{-5}$ %  
D. 0.14 %  
E. $4.5 \times 10^{-10}$ %

17. Which of the following statements is false?

A. Citric acid tastes sour.  
B. Hydrochloric acid corrodes many metals, usually releasing hydrogen gas.  
C. Acetic acid is a weak acid.  
D. The percentage dissociation is greater for 0.01 M acetic acid than for 0.001 M acetic acid.  
E. HBr dissociates completely in aqueous solution.
18. Which one of the following is true for any triprotic acid, H₃X?

A. \( K_{a1} > K_{a2} \)
B. \( K_{a2} = K_{a1} \)
C. \( K_{a1} < K_{a2} \)
D. \( K_{a2} < K_{a3} \)
E. \( K_{a1} = K_{a2} = K_{a3} \)

19. A diprotic acid, H₂A, has values of \( K_{a1} = 1.0 \times 10^{-5} \) and \( K_{a2} = 1.0 \times 10^{-10} \). In a 0.10 M solution of H₂A, the concentration of \( A^{2-} \), \([A^{2-}]\), is:

A. 0.10 M
B. 0.20 M
C. \( 3.2 \times 10^{-3} \) M
D. \( 1.0 \times 10^{-3} \) M
E. \( 1.0 \times 10^{-10} \) M

20. Which of the following statements is true concerning the equilibria shown below?

\[
\begin{align*}
&\text{H}_3\text{PO}_4 \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{H}^+ \quad K_{a1} \\
&\text{H}_2\text{PO}_4^- \rightleftharpoons \text{HPO}_4^{2-} + \text{H}^+ \quad K_{a2} \\
&\text{HPO}_4^{2-} \rightleftharpoons \text{PO}_4^{3-} + \text{H}^+ \quad K_{a3}
\end{align*}
\]

A. \( K_{a3} \) is larger than \( K_{a1} \).
B. \( \text{H}_3\text{PO}_4^- \) dissociates completely.
C. The pH of this aqueous solution is determined mainly by \( K_{a3} \).
D. The strongest conjugate base involved is the \( \text{PO}_4^{3-} \) species.
E. All of the above statements are false.

21. Considering the equilibria in the previous problem, what would change if 5 drops of concentrated HCl were added?

1. [H₃PO₄] would increase
2. [PO₄³⁻] would decrease
3. [OH⁻] will increase

A. 1, 2 and 3
B. 2 and 3 only
C. 1 and 3 only
D. 1 and 2 only
E. 3 only
22. What is the concentration of phosphate ions in a 2.5 M solution of phosphoric acid? (The pH of the solution is 0.87.)

The acid-dissociation constants of phosphoric acid (H₃PO₄) at 25°C are

\[
\begin{align*}
K_{a1} &= 7.5 \times 10^{-3} \\
K_{a2} &= 6.2 \times 10^{-8} \\
K_{a3} &= 4.2 \times 10^{-13}
\end{align*}
\]

A. \(1.9 \times 10^{-19}\) M
B. \(1.0 \times 10^{-6}\) M
C. 0.13 M
D. \(6.2 \times 10^{-8}\) M
E. \(4.2 \times 10^{-13}\) M

23. Which of the following bases is the strongest?

A. Ammonia \(K_b = 1.8 \times 10^{-5}\)
B. Methylamine \(K_b = 4.4 \times 10^{-4}\)
C. Nicotine \(K_b = 7.0 \times 10^{-7}\)
D. Hydroxylamine \(K_b = 1.1 \times 10^{-8}\)
E. More information is needed

24. Which of the following is the strongest base? (\(K_b\) for NH₃ is \(1.8 \times 10^{-5}\), \(K_{a2}\) for H₂SO₄ is \(1.2 \times 10^{-2}\), \(K_{a3}\) for H₃PO₄ is \(4.8 \times 10^{-13}\))

\[
\begin{align*}
\text{NH}_3 & \quad \text{SO}_4^{2-} & \quad \text{PO}_4^{3-} & \quad \text{NO}_3^{-}
\end{align*}
\]

A. \(\text{NH}_3\)
B. \(\text{SO}_4^{2-}\)
C. \(\text{PO}_4^{3-}\)
D. \(\text{NO}_3^{-}\)
E. Two of these are equally strong

25. What is the pH of a 0.05 M solution of CH₃COOK? (\(K_a\) for CH₃COOH = \(1.8 \times 10^{-5}\))

A. 4.8
B. 7.0
C. 5.3
D. 8.7
E. 9.2
26. Calculate the pH of a 0.50 M solution of NH₃. The Kᵢ of NH₃ is $1.8 \times 10^{-5}$.

A. 8.95  
B. 11.48  
C. 2.52  
D. 5.05  
E. 9.26

27. Which of the following salts will give the most basic solution when dissolved in water?

A. KBrO₄  
B. KBrO₃  
C. KBrO₂  
D. KBrO  
E. KClO₄

28. Of the following substances, an aqueous solution of __________ will form acidic solutions.

<table>
<thead>
<tr>
<th></th>
<th>NH₄Cl</th>
<th>Cu(NO₃)₂</th>
<th>K₂CO₃</th>
<th>NaF</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>NaF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>NaF</td>
<td>K₂CO₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>NH₄Cl</td>
<td>Cu(NO₃)₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D.</td>
<td>NH₄Cl</td>
<td>K₂CO₃</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.</td>
<td>NH₄Cl</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

29. Which salt (or salts) will form a basic solution?

1. KCl  
2. CsF  
3. KCN  
4. NH₄Cl

A. 1 only  
B. 2 only  
C. 3 only  
D. 4 only  
E. both 2 and 3
The following table may be useful for questions 30-32.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Equilibrium Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocyanic acid</td>
<td>HCN</td>
<td>$K_a = 4.9 \times 10^{-10}$</td>
</tr>
<tr>
<td>Nitrous acid</td>
<td>HNO₂</td>
<td>$K_a = 4.5 \times 10^{-4}$</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>CH₃COOH</td>
<td>$K_a = 1.8 \times 10^{-5}$</td>
</tr>
<tr>
<td>Hydrazine</td>
<td>N₂H₂</td>
<td>$K_b = 1.7 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

30. What is the [$\text{OH}^-$] in a 0.80 M solution of hydrazine, N₂H₂?

A. $1.2 \times 10^{-3}$ M  
B. $8.6 \times 10^{-12}$ M  
C. $2.2 \times 10^{-3}$ M  
D. 0.80 M  
E. $1.4 \times 10^{-6}$ M

31. What is the value of the equilibrium constant for the following reaction:

$$\text{NO}_2^- (aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HNO}_2(aq) + \text{OH}^- (aq)$$

A. $4.5 \times 10^{-4}$  
B. $5.0 \times 10^{-4}$  
C. $2.0 \times 10^{-4}$  
D. $5.0 \times 10^{-11}$  
E. $2.2 \times 10^{-11}$

32. What is the pH of solution labeled 0.075 M HCN?

A. 5.2  
B. 8.8  
C. 7.0  
D. 10.4  
E. 3.6
33. Which of the following is not likely to be a Lewis acid?
   A. Fe$^{3+}$
   B. BF$_3$
   C. CH$_4$
   D. Be$^{2+}$
   E. Ca$^{2+}$

34. Which of the following is not likely to be a Lewis acid?
   A. Cr$^{3+}$
   B. BF$_3$
   C. CF$_4$
   D. Na$^+$
   E. H$^+$

35. In the following reaction, the BF$_3$ is acting as a(n) ______ acid.
   \[ \text{BF}_3 + F^- \rightarrow \text{BF}_4^- \]
   A. Arrhenius
   B. Bronsted-Lowry
   C. Lewis
   D. All of the above.
   E. None of the above, BF$_3$ is serving as a base.

36. Of the following, __________ is the strongest acid.
   A. F$_3$C-COOH
   B. Cl$_3$C-COOH
   C. Br$_3$C-COOH
   D. Br$_2$Cl-COOH
   E. H$_3$C-COOH