1. Which of these substances is an Arrhenius acid?
   A. \( \text{Cl}_2\text{H}_6(g) \)  
   B. \( \text{CH}_4(g) \)  
   C. \( \text{HBr(g)} \)  
   D. \( \text{KOH(s)} \)

2. Which statement is true?
   A. \( \text{BF}_3(g) + \text{NH}_3(g) \rightarrow \text{BF}_2\text{NH}_4(s) \) is an example of a Brønsted-Lowry reaction.  
   B. \( \text{H}_2\text{O}(aq) + \text{OH}^-(aq) \rightarrow 2\text{H}_2\text{O}(l) \) is an example of a Brønsted-Lowry reaction.  
   C. The Brønsted-Lowry Theory states that an acid and a base react through electron transfer.  
   D. The hydroxide ion is normally a Brønsted-Lowry acid.

3. If equal volumes of 0.10 mol/L \( \text{HCl(aq)} \) solution and 0.10 mol/L \( \text{CH}_3\text{COOH(aq)} \) solution are compared, which would be true of the \( \text{CH}_3\text{COOH(aq)} \)?
   A. It would have a higher hydronium ion concentration.  
   B. It would have a higher pH.  
   C. It would produce a larger volume of hydrogen gas when reacted with zinc.  
   D. It would require a greater volume of 0.10 mol/L \( \text{NaOH(aq)} \) solution for neutralization.

4. Water can act as either an acid or a base. Which equation represents water reacting as an acid?
   A. \( \text{H}_2\text{O}(l) + \text{NH}_3(g) \rightarrow \text{OH}^-(aq) + \text{NH}_4^+(aq) \)  
   B. \( \text{H}_2\text{O}(l) \rightarrow \text{H}(g) + \frac{1}{2}\text{O}_2(g) \)  
   C. \( \text{H}_2\text{O}(l) + \text{HCl(aq)} \rightarrow \text{H}_3\text{O}^+(aq) + \text{Cl}^-(aq) \)  
   D. \( \text{H}_2\text{O}(l) + \text{C(s)} \rightarrow \text{CO}(g) + \text{H}_2(g) \)

5. 11.2 g of potassium hydroxide (\( \text{KOH} \)) is dissolved in sufficient water to make 1 L of solution. What is the concentration of \( \text{KOH} \) in the solution?
   A. 0.01 mol/L  
   B. 0.02 mol/L  
   C. 0.1 mol/L  
   D. 0.2 mol/L

6. If 0.012 mol of solid sodium hydroxide is added to 1 L of 0.010 mol/L hydrochloric acid solution, what is the pH of the solution?
   A. 2.7  
   B. 3.3  
   C. 11.3  
   D. 13.1

7. What is the pH of a 0.015 mol/L aqueous solution of \( \text{HCl} \) (hydrochloric acid)?
   A. 0.015  
   B. 0.085  
   C. 1.82  
   D. 2.18

8. A student recorded observations regarding colours of various indicators in an unknown acid solution:
   I. The solution turns red with the addition of methyl red.  
   II. The solution turns blue with the addition of indigo carmine.  
   III. The solution turns blue with the addition of bromothymol blue.  
   IV. The solution turns blue litmus paper red.
   Which observation is inconsistent with the other observations.
   A. Observation I  
   B. Observation II  
   C. Observation III  
   D. Observation IV

9. If 46.25 mL of 0.861 M \( \text{CH}_3\text{COOH(aq)} \) is required to titrate a 0.933 M \( \text{LiOH(aq)} \) solution, what is the volume of the \( \text{LiOH(aq)} \)?
   A. 0.0234 mL  
   B. 37.15 mL  
   C. 42.68 mL  
   D. 50.12 mL

10. What is one property of acids?
    A. Acidic solutions feel slippery.  
    B. Acids react with certain metals to generate hydrogen.  
    C. Acids taste bitter.  
    D. Acids turn red litmus paper blue.

11. According to Arrhenius, what does the reaction \( \text{Ba(OH)}_2(s) \rightarrow \text{Ba}^{2+}(aq) + 2\text{OH}^-(aq) \) represent?
    A. dissociation of an acid.  
    B. formation of an acidic solution.  
    C. dissociation of a base.  
    D. formation of a neutral solution.

12. According to the Brønsted-Lowry theory, what is a base?
    A. a hydrogen ion (proton) acceptor  
    B. an electrolyte  
    C. a nonelectrolyte  
    D. a substance that increases the hydrogen (hydronium) ion concentration.

13. Which equation shows an acid-base neutralization reaction?
    A. \( \text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{H}_2(g) + \text{ZnCl}_2(aq) \)  
    B. \( 2\text{NaOH(aq)} + \text{CaCl}_2(aq) \rightarrow 2\text{NaCl(aq)} + \text{Ca(OH)}_2(s) \)  
    C. \( \text{H}_2\text{CO}_3(aq) \rightarrow \text{CO}_2(aq) + \text{H}_2\text{O}(l) \)  
    D. \( \text{NaOH(aq)} + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O}(l) \)

14. What are the Brønsted-Lowry acids in this reaction?
    \( \text{H}_2\text{O}(l) + \text{HPO}_4^{2-}(aq) \rightarrow \text{H}_3\text{PO}_4(aq) + \text{OH}^-(aq) \)
    A. \( \text{HPO}_4^{2-}(aq) \) and \( \text{OH}^-(aq) \)  
    B. \( \text{H}_2\text{O}(l) \) and \( \text{HPO}_4^{2-}(aq) \)  
    C. \( \text{H}_2\text{O}(l) \) and \( \text{H}_3\text{PO}_4(aq) \)  
    D. \( \text{H}_2\text{O}(l) \) and \( \text{OH}^-(aq) \)
15. What does the strength of an acid depend upon?
   A. concentration of the acid  C. time it takes the acid to neutralize a base
   B. extent to which the acid ionizes  D. volume of the acid

16. What is the hydrogen ion concentration in lemon juice that has a pH of 3.0?
   A. $1 \times 10^{-3}$ mol/L  B. $1 \times 10^{-11}$ mol/L  C. $1 \times 10^{-14}$ mol/L  D. $3 \times 10^{-1}$ mol/L

17. Which describes tap water that has a pH of 8?
   A. acidic with $[H^+] = 10^{-8}$ mol/L  B. basic with $[H^+] = 10^{-8}$ mol/L
   C. basic with $[OH^-] = 10^{-8}$ mol/L  D. basic with $[OH^-] = 10^{-8}$ mol/L

18. What is the pH of a 0.001 mol/L aqueous solution of NaOH?
   A. 3  B. 4  C. 11  D. 14

19. What does a $K_a$ of $2.8 \times 10^{-11}$ imply about an acid?
   A. It is a strong acid.  B. It is extremely soluble.
   C. It is highly ionized.  D. It is very slightly ionized.

20. In a titration experiment, 18.62 mL of 0.0975 mol/L HNO$_3$ acid was needed to completely neutralize 20.0 mL of KOH(aq). What was the concentration of the KOH(aq)?
   A. 0.001 91 mol/L  B. 0.00382 mol/L  C. 0.0908 mol/L  D. 0.105 mol/L

21. Which is not and operational (i.e., empirical) definition of a base?
   A. decreases the hydrogen ion concentration  B. feels slippery
   C. has a bitter taste  D. turns red litmus paper blue.

22. According to the Arrhenius theory, what causes the characteristic properties of bases?
   A. aqueous hydrogen ions  B. aqueous hydroxide ions
   C. lone pairs of electrons in the base molecule  D. proton donors in the base molecule

23. According to the Brønsted-Lowry theory, what is a base?
   A. electron acceptor  B. electron donor
   C. hydrogen ion acceptor  D. hydrogen ion donor

24. What are the Brønsted-Lowry bases in the following equation?
   \[ \text{HSO}_3^-(aq) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{SO}_3(aq) + \text{OH}^-(aq) \]
   A. H$_2$O(l) and H$_2$SO$_3$(aq)  B. HSO$_3^-(aq)$ and H$_2$O(l)
   C. HSO$_3^-(aq)$ and OH$^-(aq)$  D. H$_2$SO$_3$(aq) and OH$^-(aq)$

25. How would a 0.001 mol/L solution of an acid that ionizes completely in solution be classified?
   A. concentrated and strong  B. concentrated and weak
   C. dilute and strong  D. dilute and weak

26. According to the Brønsted-Lowry concept, how would a substance that can act as an acid in some reactions and as a base in other reactions be classified?
   A. acid-base pair  B. amphoteric
   C. conjugate  D. neutral

27. A drop in pH level of 2 in an aquarium would mean that the acidity, as measured by $[H^+]$, had changed by what factor?
   A. 2  B. 10  C. 100  D. 1000

28. A pH meter used to test a freshly opened carbonated soft drink gives a reading of 3.14. What is the $[H^+]$?
   A. $7.2 \times 10^{-2}$ mol/L  B. $3.1 \times 10^{-3}$ mol/L
   C. $7.2 \times 10^{-4}$ mol/L  D. $3.1 \times 10^{-5}$ mol/L

29. Which numerical value of $K_a$ indicates the strongest acid?
   A. $1 \times 10^{-7}$  B. $1.7 \times 10^{-4}$  C. $6.7 \times 10^{-4}$  D. $7.1 \times 10^{-3}$

30. For complete neutralization, 15.0 mL of 0.35 mol/L NaOH(aq) solution was required to react with 0.425 g of an acid. What is the possible identity of the acid?
   A. HBr(aq)  B. HCl(aq)  C. HNO$_3$(aq)  D. H$_2$SO$_4$(aq)

31. When a weak base such as NH$_3$(aq) is titrated with HCl(aq), what is the pH at the equivalence point?
   A. equal to 0  B. equal to 7  C. greater than 7  D. less than 7

32. A student found that orange IV indicator turned yellow and methyl orange turned red in samples of an unknown solution. What is the pH for the unknown solution likely to be?
   A. 1.2  B. 3.0  C. 5.3  D. 9.0

33. Which substance can be called an Arrhenius base?
   A. CH$_3$OH  B. HBr  C. KOH  D. NaCl

34. What is the pH of a solution if the OH$^-(aq)$ ion concentration is $2.5 \times 10^{-3}$ mol/L?
   A. 2.6  B. 8.6  C. 9.8  D. 11.4
35. According to the Arrhenius definition of acids and bases, what does an acid do when it is dissolved in water?
   A. increases the hydrogen ion concentration  C. turns blue litmus paper red
   B. increases the hydroxide ion concentration  D. turns red litmus paper blue

36. Why is acetic acid classified as a weak acid?
   A. It does not ionize in water.  C. It gives vinegar a sour taste.
   B. It does not neutralize bases.  D. It ionizes slightly in water.

37. In the Brønsted-Lowry theory, what must a base do?
   A. accept a proton during a collision with an acid
   B. dissociate in aqueous solution
   C. raise the hydrogen ion concentration of an aqueous solution above 1.0 x 10^-7 mol/L
   D. taste bitter and feel slippery

38. What are the two Brønsted-Lowry acids in the reaction:
   \[ \text{HNO}_2(aq) + \text{H}_2\text{O}(aq) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{NO}_2^-(aq) \]
   A. HNO_2 and H_2O  B. H_2O and HNO_2  C. H_2O and H_3O^+  D. H_2O and NO_2^-

39. If aluminum hydroxide is an amphoteric compound, what can be said about it?
   A. It can act as a base in the presence of strong bases.  C. It can act as either an acid or a base.
   B. It can act as a base in the presence of weak bases.  D. It is a strong base.

40. What happens to the concentration of hydroxide ion if the pH decreases from 11.5 to 8.5 during a reaction?
   A. It decreases by a factor of 3.  C. It increases by a factor of 3.
   B. It decreases by a factor of 1000.  D. It increases by a factor of 1000.

41. What is the hydroxide ion concentration in an aqueous solution in which the hydronium ion concentration is 1 x 10^-14 mol/L?
   A. 1 x 10^-4 mol/L  B. 1 x 10^-9 mol/L  C. 1 x 10^-7 mol/L  D. 1 x 10^-6 mol/L

42. In a titration experiment, 20.0 mL of HBr was needed to completely neutralize 40.0 mL of 0.10 mol/L KOH. What was the concentration of the acid?
   A. 0.0080 mol/L  B. 0.080 mol/L  C. 0.20 mol/L  D. 2.0 mol/L

43. An unidentified aqueous solution is a strong electrolyte that causes blue litmus to turn red. Which of the following could be the solution?
   A. CH_3OH(aq)  B. HBr(aq)  C. KOH(aq)  D. NaCl(aq)

44. Which of the four statements are true?
   1. Acids increase the concentration of hydrogen ions in solution.
   2. Acids increase the concentration of hydroxide ions in solution.
   3. Acids increase the pH of a solution.
   4. Acids react with magnesium to produce hydrogen gas.
   A. 1 and 4  B. 2 and 4  C. 1, 2, and 4  D. 2, 3, and 4

45. Which equation represents the reaction of HSO_3^-(aq) as an acid?
   A. HSO_3^-(aq) + H^+(aq) \rightleftharpoons H_2SO_3(aq)  C. HSO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2SO_3(aq) + H_2O(l)
   B. HSO_3^-(aq) + H_2O(l) \rightleftharpoons H_2SO_3(aq) + OH^-(aq)  D. HSO_3^-(aq) + NH_3(aq) \rightleftharpoons SO_3^{2-}(aq) + NH_4^+(aq)

46. Which equation shows an acid-base neutralization reaction?
   A. Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)  C. H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l)
   B. 2NaOH(aq) + CaCl_2(aq) \rightarrow 2NaCl(aq) + Ca(OH)_2(s)  D. NaOH(aq) + HCl(aq) + NaCl(aq) + H_2O(l)

47. Which phrase describes a weak aqueous acid?
   A. highly dissociated  B. partially ionized  C. unreactive with zinc  D. very dilute

48. Which property is characteristic of solutions of both strong acids and strong bases?
   A. are good conductors of electricity  B. react with zinc to produce hydrogen gas
   C. have a pH of 7  D. turn red litmus blue

49. If egg whites have a hydroxide ion concentration of 3.3 x 10^-7 mol/L, what is the hydrogen ion concentration?
   A. 3.3 x 10^7 mol/L  B. 1.0 x 10^-7 mol/L  C. 6.7 x 10^-8 mol/L  D. 3.0 x 10^-8 mol/L

50. A weak acid, HA, ionizes according to the equation: \[ \text{HA}(aq) \rightleftharpoons \text{H}^+(aq) + \text{A}^-(aq) \]
    If a 0.10 mol/L HA(aq) solution has [H^+] = 0.0010 mol/L, what is the numerical value of Ka?
    A. 1.0 x 10^-1 mol/L  B. 1.0 x 10^-3 mol/L  C. 1.0 x 10^-5 mol/L  D. 1.0 x 10^-6 mol/L

51. What is the concentration of NaOH(aq) solution, if 30.0 mL of 1.0 mol/L HCN(aq) neutralizes 25.0 mL of the NaOH(aq) solution?
   A. 0.25 mol/L  B. 0.83 mol/L  C. 1.0 mol/L  D. 1.2 mol/L
A. 1.0     B. 2.1      C. 3.6     D. 5.2

68. The juice of the lime has a hydronium ion concentration which is about 100,000 times greater than that of pure water.
A. blue to green to yellow  B. blue to yellow to green  C. green to blue to yellow  D. yellow to green to blue

67. A solution of sodium hydroxide, NaOH(aq), contains the indicator bromothymol blue. If hydrochloric acid, HCl(aq), is added drop by drop to the NaOH(aq), what will be the order of the color changes?
A. 0.33     B. 0.48      C. 0.60     D. 3.5

66. What is the pH of a solution that contains 0.25 mol of HBr in 750 mL of solution?
A. Cl

65. Which of the following is amphiprotic (amphoteric)?
A. HCOO\(^{-}\) and HCOOH  B. HCOO\(^{-}\) and OH\(^{-}\)  C. H2O and HCOOH  D. H2O and OH\(^{-}\)

64. Why does the addition of a small volume of dilute HCl(aq) to a mixture of aqueous solutions of CH\(_3\)COOH and NaCH\(_3\)COO have little effect on the pH?
A. HCl(aq) + OH\(^{-}\) \(\rightleftharpoons\) H\(_2\)O(l) + Cl\(^{-}\)
B. The CH\(_3\)COO\(^{-}\) ions in the buffer solution react with the H\(_3\)O\(^{+}\) ions from the HCl(aq)
C. The quantity of H\(_3\)O\(^{+}\) ions produced by the CH\(_3\)COOH(aq) approximately equals the H\(_3\)O\(^{+}\) ions produced by the HCl(aq)
D. The volume of the solution is not increased to a significant extent.

63. What is the main reaction that occurs when hydrochloric acid is added to the Na\(_2\)H\(_2\)COO-CH\(_3\)COOH buffer?
A. CH\(_3\)COOH(aq) + Cl\(^{-}\) \(\rightleftharpoons\) HCl(aq) + CH\(_3\)COO\(^{-}\)
B. HCl(aq) + OH\(^{-}\) \(\rightleftharpoons\) H\(_2\)O(l) + Cl\(^{-}\)
C. H\(_2\)O\(^{+}\) + Cl\(^{-}\) \(\rightleftharpoons\) HCl(aq) + CH\(_3\)COO\(^{-}\)

62. Which of the following solutions has the greatest hydroxide ion concentration?
A. a buffer solution with pH = 5  B. a strong base  C. a weak acid  D. a weak base

61. A solution of milk of magnesia, Mg(OH)\(_2\)(aq), has a pH of 10.40. What is its [OH\(^{-}\)]?
A. 4.0 \times 10^{-11} mol/L  B. 1.0 \times 10^{-7} mol/L  C. 1.0 \times 10^{-4} mol/L  D. 2.5 \times 10^{-4} mol/L

60. What is the [H\(_3\)O\(^{+}\)] of seawater that has a pH of 8.10?
A. 7.9 \times 10^{-9} mol/L  B. 1.0 \times 10^{-8} mol/L  C. 1.3 \times 10^{-6} mol/L  D. 8.0 \times 10^{-5} mol/L

59. Which solution would have the lowest pH?
A. 0.1 mol/L CH\(_3\)COOH(aq)  B. 0.1 mol/L HCl(aq)  C. 0.1 mol/L NaOH(aq)  D. 0.1 mol/L NH\(_3\)(aq)

58. If a 0.1 mol/L solution has a pH of 4, what is the solution likely to be?
A. a strong acid  B. a strong base  C. a weak acid  D. a weak base

57. Which acts as an amphoteric species in aqueous solution?
A. HCO\(_3\)\(^{-}\)  B. HNO\(_3\)  C. PO\(_4\)\(^{3-}\)  D. SO\(_4\)\(^{2-}\)

56. What is the conjugate base of H\(_3\)PO\(_4\)\(_3\)-aq) (aq)?
A. H\(_3\)PO\(_4\)\(_3\)-aq)  B. H\(_2\)PO\(_4\)\(_3\)-aq)  C. HPO\(_4\)\(_3\)^{2-}\(_aq\)  D. PO\(_4\)\(_3\)^{3-}\(_aq\)

55. Which are the Bronsted-Lowry bases in this reaction?
HCOO\(^{-}\) + H\(_3\)O\(^{+}\) \(\rightleftharpoons\) HCOOH + OH\(^{-}\)
A. HCOO\(^{-}\) and HCOOH  B. HCOO\(^{-}\) and OH\(^{-}\)  C. H\(_2\)O and HCOOH  D. H\(_2\)O and OH\(^{-}\)

54. Which statements are characteristic of acids?
1. They turn blue litmus red  3. They taste sour.
2. They react with bases to produce a salt and hydrogen.  4. They neutralize bases.
A. 1 and 4  B. 1, 3, and 4  C. 2 and 4  D. 2, 3, and 4

53. What is the pH of the equivalence point of a titration of HCl(aq) with NaOH(aq)?
A. equals 7  B. greater than 7.0  C. less than 7  D. unknown

52. The Ka values of some monoprotic acids are shown in the table:
<table>
<thead>
<tr>
<th>Acid</th>
<th>K(_a) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>1.8 \times 10^{-5} mol/L</td>
</tr>
<tr>
<td>Benzoic acid</td>
<td>6.4 \times 10^{-9} mol/L</td>
</tr>
<tr>
<td>Formic acid</td>
<td>1.8 \times 10^{-4} mol/L</td>
</tr>
<tr>
<td>Hydrocyanic acid</td>
<td>6.2 \times 10^{-10} mol/L</td>
</tr>
</tbody>
</table>

A 0.10 mol/L solution of which acid would contain the most ions?
A. acetic acid  B. benzoic acid  C. formic acid  D. hydrocyanic acid

51. A 0.1 mol/L solution of which acid would contain the most ions?
A. H\(_3\)PO\(_4\)\(_3\)-aq)  B. 0.1 mol/L CH\(_3\)COOH  C. 0.1 mol/L HCl(aq)  D. 0.1 mol/L NH\(_3\)(aq)

50. What is the pH of seawater that has a pH of 8.10?
A. 7.9 \times 10^{-9} mol/L  B. 1.0 \times 10^{-8} mol/L  C. 1.3 \times 10^{-6} mol/L  D. 8.0 \times 10^{-5} mol/L

49. A solution of milk of magnesia, Mg(OH)\(_2\)(aq), has a pH of 10.40. What is its [OH\(^{-}\)]?
A. 4.0 \times 10^{-11} mol/L  B. 1.0 \times 10^{-7} mol/L  C. 1.0 \times 10^{-4} mol/L  D. 2.5 \times 10^{-4} mol/L

48. Which of the following solutions has the greatest hydroxide ion concentration?
A. a buffer solution with pH = 5  B. a strong base  C. a weak acid  D. a weak base

47. What is the main reaction that occurs when hydrochloric acid is added to the Na\(_2\)H\(_2\)COO-CH\(_3\)COOH buffer?
A. CH\(_3\)COOH(aq) + Cl\(^{-}\) \(\rightleftharpoons\) HCl(aq) + CH\(_3\)COO\(^{-}\)
B. HCl(aq) + OH\(^{-}\) \(\rightleftharpoons\) H\(_2\)O(l) + Cl\(^{-}\)
C. H\(_2\)O\(^{+}\) + Cl\(^{-}\) \(\rightleftharpoons\) HCl(aq) + CH\(_3\)COO\(^{-}\)

46. Why does the addition of a small volume of dilute HCl(aq) to a mixture of aqueous solutions of CH\(_3\)COOH and NaCH\(_3\)COO have little effect on the pH?
A. H\(_3\)O\(^{+}\) ions in the buffer solution inhibit the ionization of the HCl(aq)
B. The CH\(_3\)COO\(^{-}\) ions in the buffer solution react with the H\(_3\)O\(^{+}\) ions from the HCl(aq)
C. The quantity of H\(_3\)O\(^{+}\) ions produced by the CH\(_3\)COOH(aq) approximately equals the H\(_3\)O\(^{+}\) ions produced by the HCl(aq)

45. Which of the following is amphiprotic (amphoteric)?
A. Cl\(^{-}\)  B. HCO\(_3\)\(^{-}\)  C. HCl  D. NH\(_4\)\(^{+}\)

44. What is the pH of a solution that contains 0.25 mol of HBr in 750 mL of solution?
A. 0.33  B. 0.48  C. 0.60  D. 3.5

43. A solution of sodium hydroxide, NaOH(aq), contains the indicator bromothymol blue. If hydrochloric acid, HCl(aq), is added drop by drop to the NaOH(aq), what will be the order of the color changes?
A. blue to green to yellow  B. blue to yellow to green  C. green to blue to yellow  D. yellow to green to blue

42. The juice of the lime has a hydronium ion concentration which is about 100,000 times greater than that of pure water. What is the approximate pH of lime juice?
A. 1.0  B. 2.1  C. 3.6  D. 5.2