Chapter 16 questions

1. Which of the following statements does not accurately describe a characteristic property of an Arrhenius acid?
   a) An Arrhenius acid is a substance that increases the concentration of hydronium ion in water.
   b) An Arrhenius acid reacts with a base to produce a salt and water.
   c) An Arrhenius acid turns red litmus blue.
   d) An Arrhenius acid tastes sour.
   e) An Arrhenius acid neutralizes a base.

2. Which of the following statements is incorrect?
   a) An Arrhenius base is an electron-pair acceptor.
   b) An Arrhenius acid increases the concentration of hydronium ion.
   c) A Brønsted–Lowry base is a proton acceptor.
   d) A Brønsted–Lowry acid is a proton donor.
   e) Acids tend to be sour, and bases tend to be bitter.

3. Which of the following statements does not describe a characteristic of an Arrhenius acid?
   a) An Arrhenius acid is an electrolyte.
   b) An Arrhenius acid turns red litmus blue.
   c) An Arrhenius acid tastes sour.
   d) An Arrhenius acid reacts with an Arrhenius base to produce a salt.
   e) An Arrhenius acid reacts with CaCO₃ to produce CO₂.

4. Which of the following species is not capable of acting as an Arrhenius acid?
   a) H₂SO₃
   b) HSO₃⁻
   c) SO₃²⁻
   d) H₂O
   e) H₃O⁺

5. Which of the following statements is correct concerning the neutralization of sulfurous acid by a strong base?
   2OH⁻(aq) + H₂SO₃(aq) → SO₃²⁻(aq) + 2H₂O(l)
   a) H₂SO₃ is an Arrhenius acid, but not a Brønsted–Lowry acid.
   b) H₂SO₃ is a Brønsted–Lowry acid, but not an Arrhenius acid.
   c) H₂SO₃ is both an Arrhenius acid and a Brønsted–Lowry acid.
   d) H₂SO₃ is neither an Arrhenius acid nor a Brønsted–Lowry acid.
   e) H₂SO₃ is a Lewis base.

6. Which are the Brønsted–Lowry bases in the following equilibrium?
   HCOO⁻(aq) + H₂O(l) ⇋ HCOOH(aq) + OH⁻(aq)
7. Which of the following pairs of species is not a conjugate acid–base pair?
   a) O$_2^-$, OH$^-$
   b) H$_2$CO$_3$, HCO$_3^-$
   c) HNO$_2$, NO$_2^+$
   d) HOCl, OCl$^-$
   e) HSO$_4^-$, SO$_4^{2-}$

8. What is a conjugate acid–base pair for the following equilibrium?
   H$_2$O(l) + HPO$_4^{2-}$(aq) $\rightleftharpoons$ H$_2$PO$_4^-$ (aq) + OH$^-$(aq)
   a) H$_2$O is an acid and OH$^-$ is its conjugate base.
   b) H$_2$O is an acid and HPO$_4^{2-}$ is its conjugate base.
   c) HPO$_4^{2-}$ is an acid and OH$^-$ is its conjugate base.
   d) HPO$_4^{2-}$ is an acid and H$_2$PO$_4^-$ is its conjugate base.
   e) HPO$_4^{2-}$ is an acid and H$_2$O is its conjugate base.

9. What is the conjugate acid of H$_2$PO$_4^-$(aq)?
   a) H$_3$O$^+$
   b) H$_3$PO$_4$
   c) HPO$_4^{2-}$
   d) H$_3$P
   e) PO$_4^{3-}$

10. What is a conjugate acid–base pair for the following equilibrium?
    H$_2$O(l) + NH$_4^+$(aq) $\rightleftharpoons$ NH$_3$(aq) + H$_3$O$(aq)$
    a) H$_2$O is an acid and H$_3$O$^+$ is its conjugate base.
    b) b) NH$_4^+$ is an acid and NH$_3$ is its conjugate base.
    c) c) H$_2$O is an acid and NH$_3$ is its conjugate base.
    d) d) H$_2$O is a base and NH$_3$ is its conjugate acid.
    e) e) H$_2$O is a base and NH$_4^+$ is its conjugate acid.
11. What is the conjugate base of \( \text{H}_2\text{PO}_4^- (aq) \)?
   a) \( \text{H}_3\text{O}^+ \)
   b) \( \text{H}_3\text{PO}_4 \)
   c) \( \text{HPO}_4^{2-} \)
   d) \( \text{H}_3\text{P} \)
   e) \( \text{PO}_4^{3-} \)

12. Which of the following species is not amphiprotic?
   a) \( \text{N}_2\text{H}_6^{2+} \)
   b) \( \text{N}_2\text{H}_5^+ \)
   c) \( \text{H}_2\text{PO}_4^- \)
   d) \( \text{HPO}_4^{2-} \)
   e) \( \text{HSO}_3^- \)

13. Which of the following species cannot act as a Lewis base?
   a) \( \text{S}^{2-} \)
   b) \( \text{SH}^- \)
   c) \( \text{Al}^{3+} \)
   d) \( \text{H}_2\text{O} \)
   e) \( \text{H}_2\text{S} \)

14. Which of the following species cannot act as a Lewis base?
   a) \( \text{Be}^{2+} \)
   b) \( \text{O}^{2-} \)
   c) \( \text{OH}^- \)
   d) \( \text{H}_2\text{O} \)
   e) \( \text{H}_2\text{O}_2 \)

15. Which of the following species cannot act as a Lewis base?
   a) \( \text{N}^{3-} \)
   b) \( \text{NH}^{2-} \)
   c) \( \text{NH}_2^- \)
   d) \( \text{NH}_3 \)
   e) \( \text{NH}_4^+ \)

16. Which of the following species cannot act as a Lewis acid?
   a) \( \text{K}^+ \)
   b) \( \text{Mg}^{2+} \)
   c) \( \text{Al}^{3+} \)
   d) \( \text{H}^+ \)
   e) \( \text{H}^- \)

17. In the reaction
   \( \text{CuO(s)} + \text{SO}_2(g) \rightarrow \text{CuSO}_3(s), \)
a) \( \text{Cu}^{2+} \) acts as a Lewis acid and \( \text{SO}_3^{2-} \) acts as a Lewis base.

b) \( \text{O}_2^- \) acts as a Lewis base and \( \text{SO}_2 \) acts as a Lewis acid.

c) \( \text{O}_2^- \) acts as a Lewis base and \( \text{Cu}^{2+} \) acts as a Lewis acid.

d) \( \text{CuO} \) is the Lewis acid and \( \text{CuSO}_3 \) is its conjugate base.

e) \( \text{SO}_2 \) is the Lewis acid and \( \text{CuSO}_3 \) is its conjugate base.

18. Consider the following reaction:
\[
\text{AgBr}(s) + 2\text{CN}^-(aq) \rightarrow \text{Ag(CN)}_2^-(aq) + \text{Br}^-(aq)
\]
The species that are acting as a Lewis acid and Lewis base, respectively, are

a) \( \text{AgBr} \) and \( \text{Ag(CN)}_2^- \).

b) \( \text{Ag(CN)}_2^- \) and \( \text{Ag}^+ \).

c) \( \text{Ag}^+ \) and \( \text{Br}^- \).

d) \( \text{Br}^- \) and \( \text{CN}^- \).

e) \( \text{Ag}^+ \) and \( \text{CN}^- \).

19. Which of the following is not an example of an acid–base reaction?

a) \( \text{Al(OH)}_3(s) + 3\text{H}^+(aq) \rightarrow \text{Al}^{3+}(aq) + 3\text{H}_2\text{O} \)

b) \( \text{Al(OH)}_3(s) + \text{OH}^-(aq) \rightarrow \text{Al(OH)}_4^-(aq) \)

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

d) \( \text{MgO}(s) + \text{CO}_2(g) \rightarrow \text{MgCO}_3(s) \)

e) \( \text{C}_2\text{H}_6(g) \rightarrow \text{C}_2\text{H}_4(g) + \text{H}_2(g) \)

20. Which of the following species cannot act as a Lewis acid?

a) \( \text{NH}_4^+ \)

b) \( \text{H}^+ \)

c) \( \text{BF}_3 \)

d) \( \text{BeCl}_2 \)

e) \( \text{Ag}^+ \)

21. Which acid has the strongest conjugate base?

a) \( \text{HNO}_3 \)

b) \( \text{HOCl} \)

c) \( \text{HOI} \)

d) \( \text{HI} \)

e) \( \text{H}_2\text{SO}_4 \)

22. Which of the following acids has the weakest conjugate base?

a) \( \text{HF} \)

b) \( \text{HI} \)

c) \( \text{CH}_3\text{COOH} \)

d) \( \text{HNO}_2 \)

e) \( \text{HOCl} \)
23. Which of the following acids has the strongest conjugate base?
   a) HClO₄
   b) HClO₃
   c) HClO₂
   d) HClO
   e) HCl

24. The acid strength decreases in the series HBr > HSO₄⁻ > CH₃COOH > HCN > HCO₃⁻. Which of the following is the strongest base?
   a) CO₃²⁻
   b) CN⁻
   c) CH₃COO⁻
   d) SO₄²⁻
   e) Br⁻

25. What is the leveling effect?
   a) All acids are 100% ionized in solvents other than water.
   b) All strong acids are 100% ionized in water.
   c) An acid with a higher concentration in water has a lower pH than an acid with a lower concentration in water.
   d) A base with a higher concentration in water has a lower pH than a base with a lower concentration in water.
   e) All bases are 100% ionized in water.

26. Which of the following reactions is not product-favored?
   a) HCl(aq) + H₂O(l) → H₃O⁺(aq) + Cl⁻(aq)
   b) HClO₄(aq) + H₂O(l) → H₃O⁺(aq) + ClO₄⁻(aq)
   c) NH₃(aq) + H₂O(l) → NH₄⁺(aq) + OH⁻(aq)
   d) NaOH(aq) → Na⁺(aq) + OH⁻(aq)
   e) H₂SO₄(aq) + H₂O(l) → H₃O⁺(aq) + HSO₄⁻(aq)

27. The reaction of which acid with water is product-favored?
   a) nitric acid
   b) chloric acid
   c) nitrous acid
   d) chlorous acid
   e) phosphorous acid

28. Which of the following statements is true concerning an aqueous solution of the weak base NH₃?
   a) NH₄⁺ is a stronger acid than H₂O.
   b) H₂O is a stronger acid than H₃O⁺.
   c) OH⁻ is a stronger acid than NH₄⁺.
   d) OH⁻ is a stronger base than NH₃.
   e) NH₃ is a weaker base than H₂O.
29. Which of the following statements is true concerning an aqueous solution of the strong acid HBr?
   a) \( \text{H}_2\text{O} \) is a stronger acid than HBr.
   b) \( \text{H}_3\text{O}^+ \) is a stronger acid than HBr.
   c) \( \text{H}_2\text{O} \) is a stronger base than \( \text{Br}^- \).
   d) \( \text{Br}^- \) is a stronger acid than \( \text{H}_2\text{O} \).
   e) \( \text{Br}^- \) is a stronger base than \( \text{OH}^- \).

30. Which is the strongest acid?
   a) BH₃
   b) CH₄
   c) NH₃
   d) H₂O
   e) HF

31. Which of the following statements is incorrect?
   a) One reason why HCl is a stronger acid than HF is that Cl has a larger atomic radius than F.
   b) One reason why HCl is a stronger acid than HF is that the H–Cl bond is weaker than the H–F bond.
   c) One reason why HCl is a stronger acid than HF is that Cl is more electronegative than F.
   d) The acids HBr and HI both appear equally strong in water.
   e) \( \text{F}^- \) is a stronger base than \( \text{Cl}^- \).

32. Which solution has the highest pH?
   a) 0.10 M HF(aq)
   b) 0.10 M HCl(aq)
   c) 0.10 M HBr(aq)
   d) 0.10 M HI(aq)
   e) 0.10 M HClO₄(aq)

33. Which of the following is the strongest acid in aqueous solution?
   a) \( \text{H}_3\text{PO}_4 \)
   b) \( \text{H}_3\text{AsO}_4 \)
   c) \( \text{H}_3\text{PO}_3 \)
   d) \( \text{H}_3\text{AsO}_3 \)
   e) \( \text{H}_3\text{SbO}_4 \)

34. Which of the following is the strongest acid?
   a) HClO₄
   b) HClO₃
   c) HClO₂
   d) HClO
   e) HCl
35. Which of the following solutes, dissolved in 1.0 kg of water, would be expected to provide the fewest particles and to freeze at the highest temperature?
   a) 0.10 mol HClO₄
   b) 0.10 mol HClO₃
   c) 0.10 mol HClO₂
   d) 0.10 mol HClO
   e) 0.10 mol HCl

36. Rank H₃PO₄, H₂PO₄⁻, and HPO₄²⁻ in order of increasing acid strength.
   a) H₃PO₄ < H₂PO₄⁻ < HPO₄²⁻
   b) H₂PO₄⁻ < HPO₄²⁻ < H₃PO₄
   c) HPO₄²⁻ < H₂PO₄⁻ < H₃PO₄
   d) H₂PO₄⁻ < H₃PO₄ < HPO₄²⁻
   e) HPO₄²⁻ < H₃PO₄ < H₂PO₄⁻

37. The ionization constant of water at a temperature above 25°C is 3.3 × 10⁻¹⁴. What is the pH of pure water at this temperature?
   \( 2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq) \)
   a) 13.52
   b) 6.74
   c) 7.00
   d) 7.74
   e) 5.54

38. The autoionization of water, as represented by the equation below, is known to be endothermic. Which of the following correctly states what occurs as the temperature of water is raised?
   \( H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq) \)
   a) The pH of the water does not change, and the water remains neutral.
   b) The pH of the water decreases, and the water becomes more acidic.
   c) The pH of the water decreases, and the water remains neutral.
   d) The pH of the water increases, and the water becomes more acidic.
   e) The pH of the water increases, and the water remains neutral.

39. What is the equilibrium concentration of amide ion (NH₂⁻) in liquid ammonia at 25°C? ("am" = dissolved in ammonia)
   \( 2NH_3(l) \rightleftharpoons NH_4^+(am) + NH_2^-(am); K_c = 1.8 \times 10^{-24} \) at 25°C
   a) 3.6 \times 10^{-24} M
   b) 1.8 \times 10^{-24} M
   c) 9.0 \times 10^{-25} M
   d) 2.6 \times 10^{-12} M
   e) 1.3 \times 10^{-12} M
40. What is the hydronium-ion concentration in a solution formed by combining 450 mL of 0.10 M NaOH with 150 mL of 0.30 M HCl?

\[
\text{Ba(OH)}_2(aq) + 2\text{HCl}(aq) \rightarrow \text{BaCl}_2(aq) + 2\text{H}_2\text{O}
\]

a) 0.045 M
b) 0.10 M
c) 0.30 M
d) \(1.0 \times 10^{-7}\) M
e) \(1.7 \times 10^{-13}\) M

41. At 0°C, the ion-product constant of water, \(K_w\), is \(1.20 \times 10^{-15}\). What is the pH of pure water at 0°C?

g) 7.000
h) 7.560
i) 6.880
j) 7.460
k) none of these

42. The concentration of \(\text{H}_3\text{O}^+\) in a solution is \(8 \times 10^{-4}\) M at 25°C. What is its hydroxide-ion concentration?

m) \(8 \times 10^{-4}\) M
n) \(1 \times 10^{-10}\) M
o) \(2 \times 10^{-10}\) M
p) \(2 \times 10^{-10}\) M
q) \(1 \times 10^{-11}\) M

46. Which of the following expressions is not equivalent to pH?

s) \(\log \frac{1}{[\text{H}^+(aq)]}\)
t) \(14.0 - \text{pOH}\)
u) \(-\log [\text{H}^+(aq)]\)
v) \(-\log \frac{K_w}{[\text{OH}^-]}\)
w) \(-\log K_w\)

47. A solution in which the pOH is 12.5 would be described as

x) very acidic.
y) slightly acidic.
z) neutral.
aa) very basic.
b) slightly basic.
48. A solution has a hydroxide-ion concentration of 0.0050 \( M \). What is the pOH of the solution?
   a) 2.3  
   b) 7.0  
   c) 11.7  
   d) 5.3  
   e) 8.7  

49. What is the pH of a 0.075 \( M \) HClO₄ solution?
   a) 15.12  
   b) 1.12  
   c) 12.88  
   d) 11.41  
   e) 2.59  

50. What is the pOH of a 0.047 \( M \) HI solution?
   a) 15.33  
   b) 1.33  
   c) 10.94  
   d) 12.67  
   e) 3.06  

51. What is the pH of the final solution when 25 mL of 0.021 \( M \) HCl has been added to 35 mL of 0.037 \( M \) HCl at 25ºC?
   a) 1.9  
   b) 1.5  
   c) 3.5  
   d) 3.3  
   e) 2.7  

52. What is the pH of a 0.0088 \( M \) hydrochloric acid solution?
   a) 9.27  
   b) 2.06  
   c) 11.94  
   d) 4.73  
   e) 7.00  

53. The hydronium-ion concentration of a solution is \( 4.6 \times 10^{-6} \) \( M \). What is the pH of the solution?
   a) 9.99  
   b) 5.34  
   c) 6.55  
   d) 3.51  
   e) 2.00  

54. At 25ºC, what is the pH of a 10.0 \( M \) HNO₃ solution?
   a) −1.0
b) 0.0
c) 1.0
d) 10.0
e) 14.0

55. What is the approximate pH of a 0.1 \( M \) \( \text{NH}_3(aq) \) solution?
   a) 1
   b) 3
   c) 7
   d) 11
   e) 13

56. What pH should a solution have if its pH is about the same as that of vinegar?
   a) about 1
   b) about 3
   c) about 6
   d) about 8
   e) about 11

57. A solution has a pH value of 3.36. What is the pOH for this solution?
   a) 10.64
   b) 4.17
   c) 7.00
   d) 3.36
   e) 4.37

58. Which solution has the highest pH?
   a) 0.1 \( M \) HCl
   b) 0.1 \( M \) \( \text{Ba(OH)}_2 \)
   c) 0.1 \( M \) \( \text{NH}_3 \)
   d) 0.1 \( M \) \( \text{CH}_3\text{COOH} \)
   e) 0.1 \( M \) \( \text{NaOH} \)

59. The pOH of a solution is 5.24. What is the pH of the solution?
   a) 7.00
   b) 8.76
   c) 2.67
   d) 5.24
   e) 5.75

60. What is the pH of a 0.0041 \( M \) \( \text{Ba(OH)}_2 \) solution?
   a) 2.09
   b) 11.61
   c) 2.39
   d) 9.20
   e) 11.91

61. What is the pOH of a 0.0029 \( M \) \( \text{Ba(OH)}_2 \) solution?
62. A solution has a hydronium-ion concentration of 0.0080 M. What is its pOH?
   a) 4.83  
   b) 2.10  
   c) 16.10 
   d) 11.90 
   e) 9.17

63. A solution has a hydroxide-ion concentration of 0.026 M. What is its pH?
   a) 12.41 
   b) 17.65 
   c) 15.59 
   d) 1.59  
   e) 7.00

64. What is the pOH of a 0.024 M HNO₃ solution?
   a) 15.62 
   b) 1.62  
   c) 12.38 
   d) 10.27 
   e) 3.73

65. What is the pH of a 0.0074 M LiOH solution?
   a) 4.91  
   b) 16.13 
   c) 2.13  
   d) 11.87 
   e) 9.09

66. What is the pOH of a 0.0042 M LiOH solution?
   a) 5.47  
   b) 16.38 
   c) 2.38  
   d) 11.62 
   e) 8.53

67. What is the pH of a solution prepared by dissolving 0.832 g of NaOH(s) in 6.50 L of water?
   a) 2.495 
   b) 12.318 
   c) 1.682 
   d) 7.000 
   e) 11.505
68. What is the pOH of a solution prepared by dissolving 0.578 g of KOH(s) in 6.00 L of water?
   a) 2.765
   b) 12.013
   c) 1.987
   d) 7.000
   e) 11.235

69. What is the pH of a solution prepared by dissolving 0.300 L of HCl(g), measured at STP, in
    enough water such that the total volume of the solution is 2.50 L? \( R = 0.0821 \text{ L \cdot atm/(K \cdot mol)} \)
   a) 12.127
   b) 2.271
   c) 11.729
   d) 7.000
   e) 1.873

70. What is the pOH of a solution prepared by dissolving 0.664 L of HCl(g), measured at STP, in
    enough water such that the total volume of the solution is 6.00 L? \( R = 0.0821 \text{ L \cdot atm/(K \cdot mol)} \)
   a) 12.472
   b) 2.306
   c) 11.694
   d) 7.000
   e) 1.528

71. Which of the following solutions has the highest hydroxide-ion concentration?
   a) 0.1 M HCl
   b) 0.1 M H_2SO_4
   c) a buffer solution with pH = 5
   d) a buffer solution with pOH = 12
   e) pure water

72. A solution has a pH of 10.7 at 25°C. What is the hydroxide-ion concentration at 25°C?
   a) \( 1.0 \times 10^{-7} \text{ M} \)
   b) \( 5.0 \times 10^{-8} \text{ M} \)
   c) \( 2.0 \times 10^{-11} \text{ M} \)
   d) \( 3.7 \times 10^{-2} \text{ M} \)
   e) \( 3.3 \text{ M} \)

73. A solution has a pOH of 5.44. What is its hydroxide-ion concentration?
   a) \( 1.9 \times 10^{-4} \text{ M} \)
   b) \( 4.3 \times 10^{-3} \text{ M} \)
   c) \( 2.8 \times 10^{-9} \text{ M} \)
   d) \( 3.6 \times 10^{-6} \text{ M} \)
   e) \( 5.4 \text{ M} \)

74. The pOH of a solution is 5.30. What is its hydronium-ion concentration?
75. The pH of a solution of a strong base is 10.38 at 25ºC. What is its hydronium-ion concentration?
   a) $1.3 \times 10^{-2} \text{ M}$
   b) $3.4 \times 10^{-3} \text{ M}$
   c) $2.4 \times 10^{-9} \text{ M}$
   d) $1.9 \times 10^{-4} \text{ M}$
   e) $4.2 \times 10^{-11} \text{ M}$

76. What is the hydroxide-ion concentration in a solution formed by combining 200. mL of 0.16 M HCl with 300. mL of 0.091 M NaOH at 25ºC?
   HCl($aq$) + NaOH($aq$) $\rightarrow$ NaCl($aq$) + H$_2$O($l$)
   a) $1.1 \times 10^{-12} \text{ M}$
   b) $1.6 \times 10^{-13} \text{ M}$
   c) $1.0 \times 10^{-7} \text{ M}$
   d) 0.055 M
   e) 0.091 M

77. Which solution would cause blue litmus to turn red?
   a) a solution of pH 10
   b) a solution of pOH 4
   c) a solution of 0.10 M NaOH
   d) a solution of 0.01 M NH$_3$
   e) a solution of 0.005 M CH$_3$COOH