Pearson

Exercises

Review Questions

1. In the opening section of this chapter text, we see that in the Batman comic book series, Batman treats a strong acid burn with a strong base. What is problematic about this treatment?
2. What are the general physical and chemical properties of acids? Of bases?
3. What is a carboxylic acid? Give an example.
4. What is the Arrhenius definition of an acid? Of a base?
5. What is a hydronium ion? Does H^+ exist in solution by itself?
6. What is the Brønsted–Lowry definition of an acid? Of a base?
7. Why is there more than one definition of acid–base behavior? Which definition is the right one?
8. Describe amphoteric behavior and give an example.
9. What is a conjugate acid–base pair? Provide an example.
10. Explain the difference between a strong acid and a weak acid and list one example of each.
11. For a binary acid, H—Y, which factors affect the relative ease with which the acid ionizes?
12. Which factors affect the relative acidity of an oxyacid?
13. What are diprotic and triprotic acids? List an example of each.
14. Define the acid ionization constant and explain its significance.
15. Write an equation for the autoionization of water and an expression for the ion product constant for water $\left(K_w\right)$. What is the value of K_w at 25 °C?
16. What happens to the $\left[OH^-\right]$ of a solution when the $\left[H_3O^+\right]$ is increased? Decreased?
17. Define pH. What pH range is considered acidic? Basic? Neutral?
18. Define pOH. What pOH range is considered acidic? Basic? Neutral?
19. In most solutions containing a strong or weak acid, the autoionization of water can be neglected when calculating $\left[H_3O^+\right]$. Explain why this statement is valid.
20. When calculating $\left[H_3O^+\right]$ for weak acid solutions, we can often use the *x is small* approximation. Explain the nature of this approximation and why it is valid.
21. What is the percent ionization of an acid? Explain what happens to the percent ionization of a weak acid as a function of the concentration of the weak acid solution.
22. In calculating $\left[H_3O^+\right]$ for a mixture of a strong acid and weak acid, the weak acid can often be neglected. Explain why this statement is valid.
23. Write a generic equation showing how a weak base ionizes water.
24. How can you determine if an anion will act as a weak base? Write a generic equation showing the reaction by which an anion, A^-, acts as a weak base.
25. What is the relationship between the acid ionization constant for a weak acid $\left(K_a\right)$ and the base ionization constant for its conjugate base $\left(K_b\right)$?
26. What kinds of cations act as weak acids? List some examples.
27. When calculating the $\left[H_3O^+\right]$ for a polyprotic acid, the second ionization step can often be neglected. Explain why this statement is valid.
28. For a weak diprotic acid H_2X, what is the relationship between $\left[X^{2-}\right]$ and K_{a_2}? Under what conditions does this relationship exist?
29. What is the Lewis definition of an acid? Of a base?
30. What is a general characteristic of a Lewis acid? Of a Lewis base?

Problems by Topic

Note: Answers to all odd-numbered Problems, can be found in Appendix III. Exercises in the Problems by Topic section are paired, with each odd-numbered problem followed by a similar even-numbered problem. Exercises in the Cumulative Problems section are also paired but more loosely. Because of their nature, Challenge Problems and Conceptual Problems are unpaired.

The Nature and Definitions of Acids and Base

31. Identify each substance as an acid or a base and write a chemical equation showing how it is an acid or a base according to the Arrhenius definition.

a. $HNO_3(aq)$

b. $NH_4^+(aq)$

c. $KOH(aq)$

d. $HC_2H_3O_2(aq)$

32. Identify each substance as an acid or a base and write a chemical equation showing how it is an acid or a base according to the Arrhenius definition.

a. $NaOH(aq)$

b. $H_2SO_4(aq)$

c. $HBr(aq)$

d. $Sr(OH)_2(aq)$

33. In each reaction, identify the Brønsted–Lowry acid, the Brønsted–Lowry base, the conjugate acid, and the conjugate base.

a. $H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$

b. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

c. $HNO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$

d. $C_5H_5N(aq) + H_2O(l) \rightleftharpoons C_5H_5NH^+(aq) + OH^-(aq)$

34. In each reaction, identify the Brønsted–Lowry acid, the Brønsted–Lowry base, the conjugate acid, and the conjugate base.

a. $HI(aq) + H_2O(l) \rightarrow H_3O^+(aq) + I^-(aq)$

b. $CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3 + (aq) + OH^-(aq)$

c. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$

d. $HBr(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Br^-(aq)$

35. Write the formula for the conjugate base of each acid.

a. HCl

b. H_2SO_3

c. $HCHO_2$

d. HF

36. Write the formula for the conjugate acid of each base.

a. NH_3

b. ClO_4^-

c. HSO_4^-

d. ClO_3^{2-}

37. Both H_2O and $H_2PO_4^-$ are amphoteric. Write an equation to show how each substance can act as an acid, and another equation to show how each can act as a base.

38. Both HCO_3^- and HS^- are amphoteric. Write an equation to show how each substance can act as an acid, and another equation to show how each can act as a base.

Acid Strength and Molecular Structure

39. Based on their molecular structure, pick the stronger acid from each pair of binary acids. Explain your choice.

a. HF and HCl

b. H_2O or HF

c. H_2Se or H_2S

40. Based on molecular structure, arrange the binary compounds in order of increasing acid strength. Explain your choice.

$$H_2Te, HI, H_2S, NaH$$

41. Based on their molecular structure, pick the stronger acid from each pair of oxyacids. Explain your choice.

a. H_2SO_4 or H_2SO_3

b. $HClO_2$ or $HClO$

c. HClO or HBrO

d. CCl_3COOH or CH_3COOH

42. Based on molecular structure, arrange the oxyacids in order of increasing acid strength. Explain your choice.

$$HClO_3, HIO_3, HBrO_3$$

43. Which is a stronger base, S^{2-} or Se^{2-} Explain.

44. Which is a stronger base, PO_4^{3-} or AsO_4^{3-}? Explain.

Acid Strength and K_a

45. Classify each acid as strong or weak. If the acid is weak, write an expression for the acid ionization constant (K_a).

a. HNO_3

b. HCl

c. HBr

d. H_2SO_3

46. Classify each acid as strong or weak. If the acid is weak, write an expression for the acid ionization constant (K_a).

a. HF

b. $HCHO_2$

c. H_2SO_4

d. H_2CO_3

47. The three diagrams represent three different solutions of the binary acid HA. Water molecules have been omitted for clarity, and hydronium ions (H_3O^+) are represented by hydrogen ions (H^+). Rank the acids in order of decreasing acid strength.

a. b. c.

48. Rank the solutions in order of decreasing $[H_3O^+]$: 0.10 M HCl; 0.10 M HF; 0.10 M HClO; 0.10 M HC_6H_5O.

Autoionization of Water and pH

49. Calculate $[OH^-]$ in each aqueous solution at 25 °C, and classify the solution as acidic or basic.

a. $[H_3O^+] = 1.2 \times 10^{-8} M$

b. $[H_3O^+] = 8.5 \times 10^{-5} M$

c. $[H_3O^+] = 3.5 \times 10^{-2} M$

50. Calculate $[H_3O^+]$ in each aqueous solution at 25 °C, and classify each solution as acidic or basic.

a. $[OH^-] = 1.1 \times 10^{-9} M$

b. $[OH^-] = 2.9 \times 10^{-2} M$

c. $[OH^-] = 6.9 \times 10^{-12} M$

51. Calculate the pH and pOH of each solution.

a. $[H_3O^+] = 1.7 \times 10^{-8} M$

b. $[H_3O^+] = 1.0 \times 10^{-7} M$

c. $[H_3O^+] = 2.2 \times 10^{-6} M$

52. Calculate $[H_3O^+]$ and $[OH^-]$ for each solution.

a. pH = 8.55

b. pH = 11.23

c. pH = 2.87

53. Complete the table. (All solutions are at 25 °C.)

$[H_3O^+]$	$[OH^-]$	pH	Acidic or Basic
________	________	3.15	________
3.7×10^{-9} M	________	________	________
________	________	11.1	________
________	1.6×10^{-11} M	________	________

54. Complete the table. (All solutions are at 25 °C.)

$[H_3O^+]$	$[OH^-]$	pH	Acidic or Basic
3.5×10^{-3} M	________	________	________
________	3.8×10^{-7} M	________	________
1.8×10^{-9} M	________	________	________
________	________	7.15	________

55. Like all equilibrium constants, the value of K_w depends on temperature. At body temperature (37°C), $K_w = 2.4 \times 10^{-14}$. What are the $[H_3O^+]$ and pH of pure water at body temperature?

56. The value of K_w increases with increasing temperature. Is the autoionization of water endothermic or exothermic?

57. Calculate the pH of each acid solution. Explain how the pH values you calculate demonstrate that the pH of an acid solution should carry as many digits to the right of the decimal place as the number of significant figures in the concentration of the solution.

$$H_3O^+ = 0.044 \text{ M}$$
$$H_3O^+ = 0.045 \text{ M}$$
$$H_3O^+ = 0.046 \text{ M}$$

58. Find the concentration of H_3O^+, to the correct number of significant figures, in a solution with each pH. Describe how your calculations show the relationship between the number of digits to the right of the decimal place in pH and the number of significant figures in concentration.

$$pH = 2.50$$
$$pH = 2.51$$
$$pH = 2.52$$

Acid Solutions

59. For each strong acid solution, determine $[H_3O^+]$, $[OH^-]$, and pH.

a. 0.25 M HCl

b. 0.015 M HNO_3

c. a solution that is 0.052 M in HBr and 0.020 M in HNO_3

c. a solution that is 0.052 M in HBr and 0.020 M in HNO_3

d. a solution that is 0.655% HNO_3 by mass (Assume a density of 1.01 g/mL for the solution.)

60. Determine the pH of each solution.

a. 0.048 M HI

b. 0.0895 M $HClO_4$

c. a solution that is 0.045 M in $HClO_4$ and 0.048 M in HCl

d. a solution that is 1.09% HCl by mass (Assume a density of 1.01 g/mL for the solution.)

61. What mass of HI should be present in 0.250 L of solution to obtain a solution with each pH value?

a. $pH = 1.25$

b. $pH = 1.75$

c. $pH = 2.85$

62. What mass of $HClO_4$ should be present in 0.500 L of solution to obtain a solution with each pH value?

a. $pH = 2.50$

b. $pH = 1.50$

c. $pH = 0.50$

63. What is the pH of a solution in which 224 mL of HCl(*g*), measured at 27.2 °C and 1.02 atm, is dissolved in 1.5 L of aqueous solution? (*Hint*: Use the ideal gas law to find moles of HCl first.)

64. What volume of a concentrated HCl solution, which is 36.0% HCl by mass and has a density of 1.179 g/mL, should you use to make 5.00 L of an HCl solution with a pH of 1.8?

65. Determine the $\left[H_3O^+\right]$ and pH of a 0.100 M solution of benzoic acid.

66. Determine the $\left[H_3O^+\right]$ and pH of a 0.200 M solution of formic acid.

67. Determine the pH of an HNO_2 solution of each concentration. In which cases can you *not* make the assumption that *x is small*?

a. 0.500 M

b. 0.100 M

c. 0.0100 M

68. Determine the pH of an HF solution of each concentration. In which cases can you *not* make the assumption that *x is small*?

a. 0.250 M

b. 0.0500 M

c. 0.0250 M

69. If 15.0 mL of glacial acetic acid (pure $HC_2H_3O_2$) is diluted to 1.50 L with water, what is the pH of the resulting solution? The density of glacial acetic acid is 1.05 g/mL.

70. Calculate the pH of a formic acid solution that contains 1.35% formic acid by mass. (Assume a density 1.01 g/mL for the solution.)

71. A 0.185 M solution of a weak acid (HA) has a pH of 2.95. Calculate the acid ionization constant $\left(K_a\right)$ for the acid.

72. A 0.115 M solution of a weak acid (HA) has a pH of 3.29. Calculate the acid ionization constant $\left(K_a\right)$ for the acid.

73. Determine the percent ionization of a 0.125 M HCN solution.

74. Determine the percent ionization of a 0.225 M solution of benzoic acid.

75. Calculate the percent ionization of an acetic acid solution having the given concentrations.

a. 1.00 M

b. 0.500 M

c. 0.100 M

d. 0.0500 M

76. Calculate the percent ionization of a formic acid solution having the given concentrations.

a. 1.00 M

b. 0.500 M

c. 0.100 M

d. 0.0500 M

77. A 0.148 M solution of a monoprotic acid has a percent ionization of 1.55%. Determine the acid ionization constant $\left(K_a\right)$ for the acid.

78. A 0.085 M solution of a monoprotic acid has a percent ionization of 0.59%. Determine the acid ionization constant $\left(K_a\right)$ for the acid.

79. Find the pH and percent ionization of each HF solution. (K_a for HF is 6.8×10^{-4})

a. 0.250 M HF

b. 0.100 M HF

c. 0.050 M HF

80. Find the pH and percent ionization of a 0.100 M solution of a weak monoprotic acid having the given K_a values.

a. $K_a = 1.0 \times 10^{-5}$

b. $K_a = 1.0 \times 10^{-3}$

c. $K_a = 1.0 \times 10^{-1}$

81. Find the pH of each mixture of acids.

a. 0.115 M in HBr and 0.125 M in $HCHO_2$

b. 0.150 M in HNO_2 and 0.085 M in HNO_3

c. 0.185 M in $HCHO_2$ and 0.225 M in $HC_2H_3O_2$

d. 0.050 M in acetic acid and 0.050 M in hydrocyanic acid

82. Find the pH of each mixture of acids.

a. 0.075 M in HNO_3 and 0.175 M in $HC_7H_5O_2$

b. 0.020 M in HBr and 0.015 M in $HClO_4$

c. 0.095 M in HF and 0.225 M in HC_6H_5O

d. 0.100 M in formic acid and 0.050 M in hypochlorous acid

Base Solutions

83. For each strong base solution, determine $[OH^-]$, $[H_3O^+]$, pH, and pOH.

a. 0.15 M NaOH

b. $1.5 \times 10^{-3} M\ Ca(OH)_2$

c. $4.8 \times 10^{-4} MSr(OH)_2$

d. $8.7 \times 10^{-5} KOH$

84. For each strong base solution, determine $[OH^-]$, $[H_3O^+]$, and pOH.

a. 8.7×10^{-3} M LiOH

b. 0.0112 M $Ba(OH)_2$

c. 1.9×10^{-4}M KOH

d. 5.0×10^{-4}M $Ca(OH)_2$

85. Determine the pH of a solution that is 3.85% KOH by mass. Assume that the solution has density of 1.01 g/mL.

86. Determine the pH of a solution that is 1.55% NaOH by mass. Assume that the solution has density of 1.01 g/mL.

87. What volume of 0.855 M KOH solution do you need to make 3.55 L of a solution with pH of 12.4?

88. What volume of a 15.0% by mass NaOH solution, which has a density of 1.116 g/mL, should you use to make 5.00 L of an NaOH solution with a pH of 10.8?

89. Write equations showing how each weak base ionizes water to form OH^-. Also write the corresponding expression for K_b.

a. NH_3

b. HCO_3^-

c. CH_3NH_2

90. Write equations showing how each weak base ionizes water to form OH^-. Also write the corresponding expression for K_b.

a. CO_3^{2-}

b. $C_6H_5NH_2$

c. $C_2H_5NH_2$

91. Determine the $[OH^-]$, pH, and pOH of a 0.15 M ammonia solution.

92. Determine the $[OH^-]$, pH, and pOH of a solution that is 0.125 M in CO_3^{2-}.

93. Caffeine $(C_8H_{10}N_4O_2)$ is a weak base with a pK_b of 10.4. Calculate the pH of a solution containing a caffeine concentration of 455 mg/L.

94. Amphetamine $(C_9H_{13}N)$ is a weak base with a pK_b of 4.2. Calculate the pH of a solution containing an amphetamine concentration of 225 mg/L.

95. Morphine is a weak base. A 0.150 M solution of morphine has a pH of 10.5. What is K_b for morphine?

96. A 0.135 M solution of a weak base has a pH of 11.23. Determine K_b for the base.

Acid–Base Properties of Ions and Salts

97. Determine if each anion acts as a weak base in solution. For the anions that are basic, write an equation that shows how the anion acts as a base.

a. Br^-

b. ClO^-

c. CN^-

d. Cl^-

98. Determine whether each anion is basic or neutral. For the anions that are basic, write an equation that shows how the anion acts as a base.

a. $C_7H_5O_2^-$

b. I^-

c. NO_3^-

d. F^-

99. Determine the $[OH^-]$ and pH of a solution that is 0.140 M in F^-.

100. Determine the $[OH^-]$ and pH of a solution that is 0.250 M in HCO_3^-

101. Determine whether each cation is acidic or pH-neutral. For the cations that are acidic, write an equation that shows how the cation acts as an acid.

a. NH_4^+

b. Na^+

c. Co^{3+}

d. $CH_3NH_3^+$

102. Determine whether each cation is acidic or pH-neutral. For the cations that are acidic, write an equation that shows how the cation acts as an acid.

a. Sr^{2+}

b. Mn^{3+}

c. $C_5H_5NH^+$

d. Li^+

103. Determine if each salt will form a solution that is acidic, basic, or pH-neutral.

a. $FeCl_3$

b. NaF

c. $CaBr_2$

d. NH_4Br

e. $C_6H_5NH_3NO_2$

104. Determine if each salt will form a solution that is acidic, basic, or pH-neutral.

a. $Al(NO_3)_3$

b. $C_2H_5NH_3NO_3$

c. K_2CO_3

d. RbI

e. NH_4ClO

105. Arrange the solutions in order of increasing acidity.

$$NaCl,\ NH_4Cl,\ NaHCO_3,\ NH_4ClO_2,\ NaOH$$

106. Arrange the solutions in order of increasing basicity.

$$CH_3NH_3Br,\ KOH,\ KBr,\ KCN,\ C_5H_5NHNO_2$$

107. Determine the pH of each solution.

a. $0.10\ M\ NH_4Cl$

b. $0.10\ M\ NaC_2H_3O_2$

c. 0.10 M NaCl

108. Determine the pH of each solution.

a. $0.20\ M\ KCHO_2$

b. $0.20\ M\ CH_3NH_3I$

c. 0.20 M KI

109. Calculate the concentration of all species in a 0.15 M KF solution.

110. Calculate the concentration of all species in a 0.225 M $C_6H_5NH_3Cl$ solution.

111. Pick the stronger base from each pair.

a. F^- or Cl^-

b. NO_2^- or NO_3^-

c. F^- or ClO^-

112. Pick the stronger base from each pair.

a. ClO_4^- or ClO_2^-

b. Cl^- or H_2O

c. CN^- or ClO^-

Polyprotic Acids

113. Write chemical equations and corresponding equilibrium expressions for each of the three ionization steps of phosphoric acid.

114. Write chemical equations and corresponding equilibrium expressions for each of the two ionization steps of carbonic acid.

115. Calculate the $\left[H_3O^+\right]$ and pH of each polyprotic acid solution.

a. 0.350 M H_3PO_4

b. 0.350 M $H_2C_2O_4$

116. Calculate the $\left[H_3O^+\right]$ and pH of each polyprotic acid solution.

a. 0.125 M H_2CO_3

b. 0.125 M $H_3C_6H_5O_7$

117. Calculate the concentration of each species in a 0.500 M solution of H_2SO_3.

118. Calculate the concentration of each species in a 0.155 M solution of H_2CO_3.

119. Calculate the $\left[H_3O^+\right]$ and pH of each H_2SO_4 solution. At approximately what concentration does the *x is small* approximation break down?

a. 0.50 M

b. 0.10 M

c. 0.050 M

120. Consider a 0.10 M solution of a weak polyprotic acid $\left(H_2A\right)$ with the possible values of K_{a1} and K_{a2} given here.

a. $K_{a_1} = 1.0 \times 10^{-4}$; $K_{a_2} = 1.0 \times 10^{-5}$

b. $K_{a_1} = 1.0 \times 10^{-4}$; $K_{a_2} = 1.0 \times 10^{-5}$

c. $K_{a_1} = 1.0 \times 10^{-4}$; $K_{a_2} = 1.0 \times 10^{-6}$

Calculate the contributions to $\left[H_3O^+\right]$ from each ionization step. At what point can the contribution of the second step be neglected?

Lewis Acids and Bases

121. Classify each species as a Lewis acid or a Lewis base.

a. Fe^{3+}

b. BH_3

c. NH_3

d. F^-

122. Classify each species as a Lewis acid or a Lewis base.

a. $BeCl_2$

b. OH^-

c. $B(OH)_3$

d. CN^-

123. Identify the Lewis acid and Lewis base among the reactants in each equation.

a. $Fe^{3+}(aq) + 6H_2O(l) \rightleftharpoons Fe\left(H_2O\right)_6^{3+}(aq)$

b. $Zn^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Zn\left(NH_3\right)_4^{2+}(aq)$

c. $\left(CH_3\right)_3N(g) + BF_3(g) \rightleftharpoons \left(CH_3\right)_3NBF_3(s)$

124. Identify the Lewis acid and Lewis base among the reactants in each equation.

124. Identify the Lewis acid and Lewis base among the reactants in each equation.

a. $Ag^{+}(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^{+}(aq)$

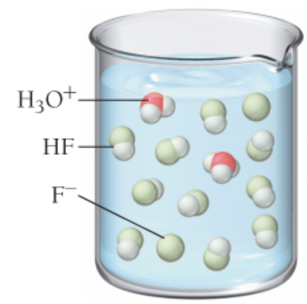
b. $AlBr_3 + NH_3 \rightleftharpoons H_3NAlBr_3$

c. $F^{-}(aq) + BF_3(aq) \rightleftharpoons BF_4^{-}(aq)$

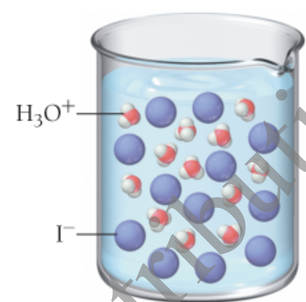
Cumulative Problems

125. Based on these molecular views, determine whether each pictured acid is weak or strong.

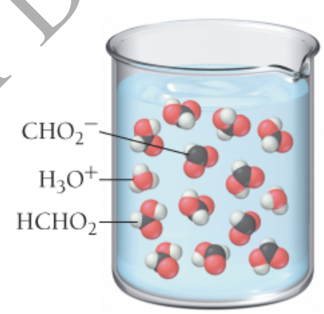
a.



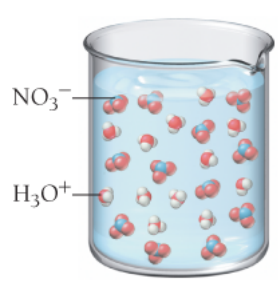
b.



c.

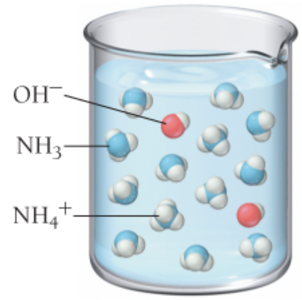


d.



126. Based on these molecular views, determine whether each pictured base is weak or strong.

a.



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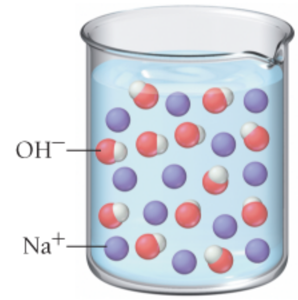
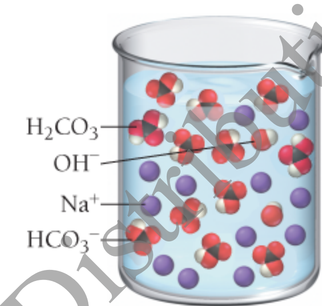
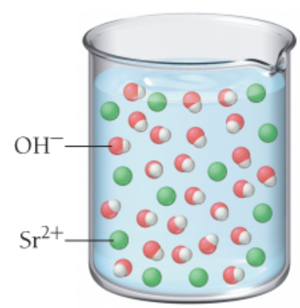


c.



d.



127. The binding of oxygen by hemoglobin in the blood involves the equilibrium reaction:

$$HbH^+(aq) + O_2(aq) \rightleftharpoons HbO_2(aq) + H^+(aq)$$

In this equation, Hb is hemoglobin. The pH of normal human blood is highly controlled within a range of 7.35 to 7.45. Given the above equilibrium, why is this important? What would happen to the oxygen-carrying capacity of hemoglobin if blood became too acidic (a dangerous condition known as acidosis)?

128. Carbon dioxide dissolves in water according to the equations:

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

Carbon dioxide levels in the atmosphere have increased about 20% over the last century. Given that Earth's oceans are exposed to atmospheric carbon dioxide, what effect might the increased CO_2 have on the pH of the world's oceans? What effect might this change have on the limestone structures (primarily $CaCO_3$) of coral reefs and marine shells?

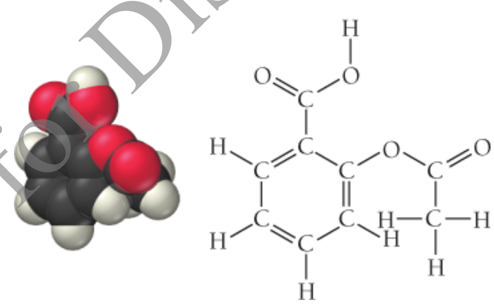
129. People often take Milk of Magnesia to reduce the discomfort associated with acid stomach or heartburn. The recommended dose is 1 teaspoon, which contains 4.00×10^2 mg of $Mg(OH)_2$. What volume of an HCl solution with a pH of 1.3 can be neutralized by one dose of Milk of Magnesia? If the stomach contains 2.00×10^2 mL of pH 1.3 solution, will all the acid be neutralized? If not, what fraction is neutralized?

130. Lakes that have been acidified by acid rain (which is caused by air pollutants) can be neutralized by liming, the addition of limestone $\left(CaCO_3\right)$. How much limestone (in kg) is required to completely neutralize a 4.3 billion liter lake with a pH of 5.5?

131. Acid rain over the Great Lakes has a pH of about 4.5. Calculate the $\left[H_3O^+\right]$ of this rain and compare that value to the $\left[H_3O^+\right]$ of rain over the West Coast that has a pH of 5.4. How many times more concentrated is the acid in rain over the Great Lakes?

132. White wines tend to be more acidic than red wines. Find the $\left[H_3O^+\right]$ in a Sauvignon Blanc with a pH of 3.23 and a Cabernet Sauvignon with a pH of 3.64. How many times more acidic is the Sauvignon Blanc?

133. Common aspirin is acetylsalicylic acid, which has the structure shown here and a pK_a of 3.5.



Calculate the pH of a solution in which one normal adult dose of aspirin $\left(6.5 \times 10^2 \text{mg}\right)$ is dissolved in 8.0 ounces of water.

134. The AIDS drug zalcitabine (also known as ddC) is a weak base with a pK_b of 9.8. What percentage of the base is protonated (in the form BH^+) in an aqueous zalcitabine solution containing 565 mg/L?

135. Determine the pH of each solution.

a. 0.0100 M $HClO_4$

b. 0.115 M $HClO_2$

c. 0.045 M $Sr(OH)_2$

d. 0.0852 M KCN

e. 0.155 M NH_4Cl

136. Determine the pH of each solution.

a. 0.0650 M HNO_3

b. 0.150 M HNO_2

c. 0.0195 M KOH

d. 0.245 M CH_3NH_3I

e. 0.318 M KC_6H_5O

137. Determine the pH of each two-component solution.

a. 0.0550 M in HI and 0.00850 M in HF

b. 0.112 M in NaCl and 0.0953 M in KF

c. 0.132 M in NH_4Cl and 0.150 M HNO_3

d. 0.0887 M in sodium benzoate and 0.225 M in potassium bromide

e. 0.0450 M in HCl and 0.0225 M in HNO_3

138. Determine the pH of each two-component solution.

a. 0.050 M KOH and 0.015 M $Ba(OH)_2$

b. 0.265 M NH_4NO_3 and 0.102 M HCN

c. 0.075 M RbOH and 0.100 M $NaHCO_3$

d. 0.088 M $HClO_4$ and 0.022 M KOH

e. 0.115 M NaClO and 0.0500 M KI

139. Write net ionic equations for the reactions that take place when aqueous solutions of each pair of substances are mixed.

a. sodium cyanide and nitric acid

b. ammonium chloride and sodium hydroxide

c. sodium cyanide and ammonium bromide

d. potassium hydrogen sulfate and lithium acetate

e. sodium hypochlorite and ammonia

140. Morphine has the formula $C_{17}H_{19}NO_3$. It is a base and accepts one proton per molecule. It is isolated from opium. A 0.682-g sample of opium is found to require 8.92 mL of a 0.0116 M solution of sulfuric acid for neutralization. Assuming that morphine is the only acid or base present in opium, calculate the percent morphine in the sample of opium.

141. The pH of a 1.00 M solution of urea, a weak organic base, is 7.050. Calculate the K_a of protonated urea (i.e., the conjugate acid of urea).

142. A solution is prepared by dissolving 0.10 mol of acetic acid and 0.10 mol of ammonium chloride in enough water to make 1.0 L of solution. Find the concentration of ammonia in the solution.

143. Lactic acid is a weak acid found in milk. Its calcium salt is a source of calcium for growing animals. A saturated solution of this salt, which we can represent as $Ca(Lact)_2$, has a $\left[Ca^{2+}\right] = 0.26$ and a pH = 8.40. Assuming the salt is completely dissociated, calculate the K_a of lactic acid.

144. A solution of 0.23 mol of the chloride salt of protonated quinine $\left(QH^+\right)$, a weak organic base, in 1.0 L of solution has pH = 4.58. Find the K_b of quinine (Q).

Challenge Problems

145. A student mistakenly calculates the pH of a 1.0×10^{-7} HI solution to be 7.0. Explain why the student is incorrect and calculate the correct pH.

146. When 2.55 g of an unknown weak acid (HA) with a molar mass of 85.0 g/mol is dissolved in 250.0 g of water, the freezing point of the resulting solution is $-0.257 \circ C$. Calculate K_a for the unknown weak acid.

147. Calculate the pH of a solution that is 0.00115 M in HCl and 0.0100 M in $HClO_2$.

148. To what volume should you dilute 1 L of a solution of a weak acid HA to reduce the $\left[H^+\right]$ to one-half of that in the original solution?

149. HA, a weak acid, with $K_a = 1.0 \times 10^{-8}$, also forms the ion HA_2^-. The reaction is $HA(aq) + A^-(aq) \rightleftharpoons HA_2^-(aq)$ and its $K_a = 4.0$ Calculate the $\left[H^+\right]$, $\left[A^-\right]$, and $\left[HA_2^-\right]$ in a 1.0 M solution of HA.

150. Basicity in the gas phase can be defined as the proton affinity of the base, for example, $CH_3NH_2(g) + H^+(g) \rightleftharpoons CH_3NH_3^+(g)$. In the gas phase, $\left(CH_3\right)_3N$ is more basic than CH_3NH_2, while in solution the reverse is true. Explain this observation.

151. Calculate the pH of a solution prepared from 0.200 mol of NH_4CN and enough water to make 1.00 L of solution.

152. To 1.0 L of a 0.30 M solution of $HClO_2$ is added 0.20 mol of NaF. Calculate the $\left[HClO_2\right]$ at equilibrium.

153. A mixture of Na_2CO_3 and $NaHCO_3$ has a mass of 82.2 g. It is dissolved in 1.00 L of water, and the pH is found to be 9.95. Determine the mass of $NaHCO_3$ in the mixture.

154. A mixture of NaCN and $NaHSO_4$ consists of a total of 0.60 mol. When the mixture is dissolved in 1.0 L of water and comes to equilibrium, the pH is found to be 9.9. Determine the amount of NaCN in the mixture.

Conceptual Problems

155. Without doing any calculations, determine which solution in each pair is more acidic.

a. 0.0100 M in HCl and 0.0100 M in KOH

b. 0.0100 M in HF and 0.0100 in KBr

c. 0.0100 M in NH_4Cl and 0.0100 M in CH_3NH_3Br

d. 0.100 M in NaCN and 0.100 M in $CaCl_2$

156. Without doing any calculations, determine which solution in each pair is more basic.

a. 0.100 M in NaClO and 0.100 M in NaF

b. 0.0100 M in KCl and 0.0100 M in $KClO_2$

c. 0.0100 M in HNO_3 and 0.0100 M in NaOH

d. 0.0100 M in NH_4Cl and 0.0100 M in HCN

157. Rank the acids in order of increasing acid strength.

$$CH_3COOH\ CH_2ClCOOH\ CHCl_2COOH\ CCl_3COOH$$

158. Without using a calculator, determine the pH and pOH of each solution. Rank the solutions from most acidic to most basic.

a. 1.0×10^{-2} M HCl

b. 1.0×10^{-4} M HCl

c. 1.0×10^{-2}M NaOH

d. 1.0×10^{-4}M NaOH

Questions for Group Work

Active Classroom Learning

Discuss these questions with the group and record your consensus answer.

159. Without referring to the text, go around your group and have each member mention a different property of either an acid or a base, such as "Acids turn blue litmus paper red." Record as many properties as you can.

160. Have each group member make two flashcards with an acid or a base on one side and its conjugate on the other side. Check each other's cards and quiz each other until each group member is proficient at identifying conjugate pairs.

161. Answer the following in a complete sentence or two:

a. How do you know if an acid is strong or weak?

b. How do you calculate the pH of a strong acid?

c. How do you calculate the pH of a weak acid solution?

d. If you know the K_a of an acid, how do you determine the K_b of its conjugate base?

e. If you know $\left[OH^-\right]$ for a solution, how do you determine $[H_3O^+]$?

162. Solve the following problem, taking turns in your group to explain how to do the next step: What is the pH when 5.3 g of sodium acetate, $NaCH_3CO_2$, is dissolved in 100.0 mL of water? (The K_a of acetic acid, HCH_3CO_2, is 1.8×10^{-5}.)

163. Define each of the following with complete sentences, and provide an example chemical equation: an Arrhenius acid, a Brønsted–Lowry base, and a Lewis acid.

Data Analysis and Interpretation

164. Sulfur dioxide is a common preservative in wine; it prevents oxidation and bacterial growth. When SO_2 is added to wine, it reacts with water to form an equilibrium system with the the bisulfite ion:

$$SO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$$

In this equilibrium system, SO_2 is called "molecular SO_2"; in its HSO_3^- form, it is called "free SO_2." Only molecular SO_2 acts as a preservative. The amount of molecular SO_2 in the equilibrium system is highly pH dependent—the lower the pH, the more the equilibrium shifts to the left and the greater the amount of free SO_2. The recommended amount of free SO_2 is 0.8 ppm for white wine and 0.5 ppm for red wine. The table shows the amount of free SO_2 required to obtain the correct amount of molecular SO_2 as a function of pH for both red and white wine. For dilute solutions such as these, 1 ppm = 1 mg/L. Study the table and answer the questions.

pH	White Wine 0.8 ppm molecular SO_2	Red Wine 0.5 ppm molecular SO_2
3	13	8
3.05	15	9
3.1	16	10
3.15	19	12
3.2	21	13
3.25	23	15
3.3	26	16
3.35	29	18
3.4	32	20
3.45	37	23
3.5	40	25
3.55	46	29
3.6	50	31
3.65	57	36
3.7	63	39
3.75	72	45
3.8	79	49
3.85	91	57
3.9	99	62

Amount of Free SO_2 Required to Maintain Correct Amount of Molecular SO_2 in White and Red Wine

a. A 225-L barrel of white wine has an initial free SO_2 concentration of 22 ppm and a pH of 3.70. How much SO_2 (in grams) should be added to the barrel to result in the required SO_2 level?

b. A 225-L barrel of red wine has an initial free SO_2 concentration of 11 ppm and a pH of 3.80. How much SO_2 (in grams) should be added to this barrel to result in the required SO_2 level?

c. Gaseous SO_2 is highly toxic and can be difficult to handle, so winemakers often use potassium metabisulfite $\left(K_2S_2O_5\right)$, also known as KMBS, as a source of SO_2 in wine. When KMBS is added to wine, the metabisulfite ion $\left(S_2O_5^{2-}\right)$ reacts with water to form the bisulfite ion $\left(HSO_3^-\right)$. Write the balanced equation for the reaction that occurs when the metabisulfite ion reacts with water.

d. Determine the percent by mass of SO_2 in KMBS.

e. How much KMBS must a winemaker add to the barrels of wine in problems (a) and (b) to achieve the required amount of molecular SO_2?

Answers to Conceptual Connections

Cc 16.1 (**b**) $H_2SO_4$and $H_2SO_3$are both acids; this is not a conjugate acid–base pair.

Cc 16.2 (**a**) Because the carbon atom in (**a**) is bonded to another oxygen atom that draws electron density away from the O—H bond (weakening and polarizing it), and the carbon atom in (**b**) is bonded only to other hydrogen atoms, the proton in structure (**a**) is more acidic.

Cc 16.3 HB has the largest K_a.

Cc 16.4 The larger ionization constant indicates that HF is stronger.

Cc 16.5 (**b**) As pH increases, acidity decreases.

Cc 16.6 (**c**) The validity of the *x is small* approximation depends on both the value of the equilibrium constant and the initial concentration—the closer these are to one another, the less likely the approximation will be valid.

Cc 16.7 (**a**) A weak acid solution will usually be less than 5% dissociated. Since HCl is a strong acid, the 0.10 M solution is much more acidic than either a weak acid with the same concentration or even a weak acid that is twice as concentrated.

Cc 16.8 Solution (**c**) has the greatest percent ionization because percent ionization increases with decreasing weak acid concentration. Solution (**b**) has the lowest pH because the equilibrium H_3O^+concentration increases with increasing weak acid concentration.

Cc 16.9 (**a**) A weak acid solution will usually be less than 5% dissociated. Therefore, because HCl is the only strong acid, the 1.0 M solution is much more acidic than either a weak acid that is twice as concentrated or a combination of two weak acids with the same concentrations.