Continued—

Q8. Calculate the percent ionization of 1.45 M aqueous acetic acid solution. For acetic acid, $K_a = 1.8 \times 10^{-5}$.
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.9*

a) 0.35%
b) 0.0018%
c) 0.29%
d) 0.0051%

Q9. Consider two aqueous solutions of nitrous acid (HNO_2). Solution A has a concentration of $[HNO_2] = 0.55$ M and solution B has a concentration of $[HNO_2] = 1.25$ M. Which statement about the two solutions is true?
MISSED THIS? *Read Section 17.6*

a) Solution A has the higher percent ionization and the higher pH.
b) Solution B has the higher percent ionization and the higher pH.
c) Solution A has the higher percent ionization and solution B has the higher pH.
d) Solution B has the higher percent ionization and solution A has the higher pH.

Q10. Find the $[OH^-]$ in a 0.200 M solution of ethylamine ($C_2H_5NH_2$). For ethylamine, $K_b = 5.6 \times 10^{-4}$.
MISSED THIS? *Read Section 17.7; Watch IWE 17.12*

a) 11.52 M
b) 2.48 M
c) 0.033 M
d) 0.011 M

Q11. Which ion forms a basic solution when dissolved in water?
MISSED THIS? *Read Section 17.8; Watch KCV 17.8*

a) Br^-
b) NO_3^-
c) HSO_4^-
d) SO_3^{2-}

Q12. Which compound forms an acidic solution when dissolved in water?
MISSED THIS? *Read Section 17.8; Watch KCV 17.8, IWE 17.16*

a) NH_4Cl
b) NaCl
c) KNO_2
d) $Ca(NO_3)_2$

Q13. Find the pH of 0.175 M NaCN solution. For HCN, $K_a = 4.9 \times 10^{-10}$.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8, IWE 17.14*

a) 5.03
b) 11.28
c) 2.31
d) 8.97

Q14. What is the concentration of X^{2-} in a 0.150 M solution of the diprotic acid H_2X? For H_2X, $K_{a_1} = 4.5 \times 10^{-6}$ and $K_{a_2} = 1.2 \times 10^{-11}$.
MISSED THIS? *Read Section 17.9*

a) 9.9×10^{-8} M
b) 2.0×10^{-9} M
c) 8.2×10^{-4} M
d) 1.2×10^{-11} M

Q15. Which acid has the largest K_a: $HClO_2(aq)$, $HBrO_2(aq)$, or $HIO_2(aq)$?
MISSED THIS? *Read Section 17.10*

a) $HClO_2(aq)$
b) $HBrO_2(aq)$
c) $HIO_2(aq)$
d) All three acids have the same K_a.

Answers: **1.** (d) **2.** (a) **3.** (d) **4.** (b) **5.** (d) **6.** (c) **7.** (b) **8.** (a) **9.** (a) **10.** (d) **11.** (d) **12.** (a) **13.** (b) **14.** (d) **15.** (a)

CHAPTER 17 IN REVIEW

TERMS

Section 17.2
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alkaloid (734)
conjugate acid–base pair (736)
conjugate acid (736)
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Section 17.3
Arrhenius definitions (of acids and bases) (735)
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Section 17.4
strong acid (737)
weak acid (737)
monoprotic acid (737)
diprotic acid (737)
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Section 17.5
autoionization (740)
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Section 17.7
strong base (754)
weak base (754)
base ionization constant (K_b) (755)

Section 17.9
polyprotic acid (765)

Section 17.11
Lewis acid (772)
Lewis base (772)

CONCEPTS

Heartburn (17.1)
- Hydrochloric acid from the stomach sometimes comes in contact with the esophageal lining, resulting in irritation, called heartburn. Heartburn is treated with antacids, bases that neutralize stomach acid.

The Nature of Acids and Bases (17.2)
- Acids generally taste sour, dissolve metals, turn blue litmus paper red, and neutralize bases. Common acids are hydrochloric, sulfuric, nitric, and carboxylic acids.

- Bases generally taste bitter, feel slippery, turn red litmus paper blue, and neutralize acids. Common bases are sodium hydroxide, sodium bicarbonate, and potassium hydroxide.

Definitions of Acids and Bases (17.3)

- The Arrhenius definition of acids and bases states that in an aqueous solution, an acid produces hydrogen ions and a base produces hydroxide ions.
- The Brønsted–Lowry definition states that an acid is a proton (hydrogen ion) donor and a base is a proton acceptor. According to the Brønsted–Lowry definition, two substances related by the transfer of a proton are a conjugate acid–base pair.

Acid Strength and the Acid Dissociation Constant, K_a (17.4)

- In a solution, a strong acid completely ionizes but a weak acid only partially ionizes.
- Generally, the stronger the acid, the weaker the conjugate base, and vice versa.
- The extent of dissociation of a weak acid is quantified by the acid dissociation constant, K_a, which is the equilibrium constant for the ionization of the weak acid.

Autoionization of Water and pH (17.5)

- In an acidic solution, the concentration of hydrogen ions is always greater than the concentration of hydroxide ions. $[H_3O^+]$ multiplied by $[OH^-]$ is always constant at a constant temperature.
- There are two types of logarithmic acid–base scales: pH and pOH. At 25 °C, the sum of a solution's pH and pOH is always 14.

Finding the $[H_3O^+]$ and pH of Strong and Weak Acid Solutions (17.6)

- In a strong acid solution, the hydrogen ion concentration equals the initial concentration of the acid.
- In a weak acid solution, the hydrogen ion concentration—which can be determined by solving an equilibrium problem—is lower than the initial acid concentration.
- The percent ionization of weak acids decreases as the acid (and hydrogen ion) concentration increases.
- In mixtures of two acids with large K_a differences, the concentration of hydrogen ions can usually be determined by considering only the stronger of the two acids.

Base Solutions (17.7)

- A strong base dissociates completely; a weak base does not.
- Most weak bases produce hydroxide ions through the ionization of water. The base ionization constant, K_b, indicates the extent of ionization.

Ions as Acids and Bases (17.8)

- A cation is a weak acid if it is the conjugate acid of a weak base; it is neutral if it is the counterion of a strong base.
- An anion is a weak base if it is the conjugate base of a weak acid; it is neutral if it is the conjugate base of a strong acid.
- To calculate the pH of a solution of an acidic cation or basic anion, we determine K_a or K_b from the equation $K_a \times K_b = K_w$.

Polyprotic Acids (17.9)

- Polyprotic acids contain two or more ionizable protons.
- Generally, polyprotic acids ionize in successive steps, and the value of K_a becomes smaller for each step.
- In many cases, we can determine the $[H_3O^+]$ of a polyprotic acid solution by considering only the first ionization step; then, the concentration of the anion formed in the second ionization step is equivalent to the value of K_{a_2}.

Acid Strength and Molecular Structure (17.10)

- For binary acids, acid strength decreases with increasing bond energy and increases with increasing bond polarity.
- For oxyacids, acid strength increases with the electronegativity of the atoms bonded to the oxygen atom and also increases with the number of oxygen atoms in the molecule.

Lewis Acids and Bases (17.11)

- A third model of acids and bases, the Lewis model, defines a base as an electron pair donor and an acid as an electron pair acceptor. According to this definition, an acid does not have to contain hydrogen. A Lewis acid can be a compound with an empty orbital—or one that will rearrange to make an empty orbital—or a cation.

Acid Rain (17.12)

- The combustion of fossil fuels produces oxides of sulfur and nitrogen, which react with oxygen and water to form sulfuric and nitric acids. These acids combine with rain to form acid rain.
- Acid rain corrodes human-made structures and damages aquatic environments and forests. Environmental legislation has helped stabilize the amount of acid rain being produced.

EQUATIONS AND RELATIONSHIPS

Note: In all of these equations $[H^+]$ is interchangeable with $[H_3O^+]$.

Expression for the Acid Ionization Constant, K_a (17.4)

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

The Ion Product Constant for Water, K_w (17.5)

$$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14} \text{ (at 25 °C)}$$

Expression for the pH Scale (17.5)

$$\text{pH} = -\log[H_3O^+]$$

Expression for the pOH Scale (17.5)

$$\text{pOH} = -\log[OH^-]$$

Relationship between pH and pOH (17.5)

$$\text{pH} + \text{pOH} = 14.00$$

Expression for the pK_a Scale (17.5)

$$pK_a = -\log K_a$$

Expression for Percent Ionization (17.6)

$$\text{Percent ionization} = \frac{\text{concentration of ionized acid}}{\text{initial concentration of acid}} \times 100\%$$

$$= \frac{[H_3O^+]_{equil}}{[HA]_{init}} \times 100\%$$

Relationship between K_a, K_b, and K_w (17.8)

$$K_a \times K_b = K_w$$

LEARNING OUTCOMES

Chapter Objectives	Assessment
Analyze acids and bases by definition (Arrhenius or Brønsted–Lowry) and their corresponding properties (17.2, 17.3)	Example 17.1 **For Practice** 17.1 **Exercises** 33–40
Perform calculations involving K_a (17.4)	**Exercises** 41–46
Perform calculations involving K_w (17.5)	Example 17.2 **For Practice** 17.2 **Exercises** 47–48
Quantify the acidity of a solution using the pH scale (17.5)	Examples 17.3, 17.4 **For Practice** 17.3, 17.4 **Exercises** 49–56
Perform pH calculations of strong acids and weak acids (17.6)	Examples 17.5–17.8 **For Practice** 17.5–17.8 **Exercises** 57–70
Perform percent ionization calculations for acids (17.6)	Example 17.9 **For Practice** 17.9 **Exercises** 71–78
Perform pH calculations for mixtures of acids (17.6)	Example 17.10 **For Practice** 17.10 **Exercises** 79–80
Perform pH calculations for a strong base (17.7)	Example 17.11 **For Practice** 17.11 **Exercises** 81–86
Perform pH calculations for a weak base (17.7)	Example 17.12 **For Practice** 17.12 **Exercises** 87–94
Classify an anion in solution as basic or neutral (17.8)	Example 17.13 **For Practice** 17.13 **Exercises** 95–96
Perform pH calculations for solutions containing anions that act as a base (17.8)	Example 17.14 **For Practice** 17.14 **Exercises** 97–98
Classify a cation in solution as acidic or neutral (17.8)	Example 17.15 **For Practice** 17.15 **Exercises** 99–100
Classify salts solutions as acidic, basic, or neutral (17.8)	Example 17.16 **For Practice** 17.16 **Exercises** 101–108
Perform pH calculations of polyprotic acid solutions (17.9)	Examples 17.17, 17.18 **For Practice** 17.17, 17.18 **Exercises** 109–112
Calculate the concentration of anions for weak diprotic acid solutions (17.9)	Example 17.19 **For Practice** 17.19 **Exercises** 113–116
Predict acidity based on molecular structure (17.10)	**Exercises** 117–122
Analyze acids and bases in terms of the Lewis model definition (17.11)	**Exercises** 123–126

EXERCISES

Mastering Chemistry provides end-of-chapter exercises, feedback-enriched tutorial problems, animations, and interactive activities to encourage problem-solving practice and deeper understanding of key concepts and topics.

REVIEW QUESTIONS

1. What causes heartburn? What are some possible ways to alleviate heartburn?

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. What are diprotic and triprotic acids? List an example of each.

12. Define the acid ionization constant and explain its significance.

13. Write an equation for the autoionization of water and an expression for the ion product constant for water (K_w). What is the value of K_w at 25 °C?

14. What happens to the $[OH^-]$ of a solution when the $[H_3O^+]$ is increased? Decreased?

15. Define pH. What pH range is considered acidic? Basic? Neutral? (Assume 25 °C.)

16. Define pOH. What pOH range is considered acidic? Basic? Neutral? (Assume 25 °C.)

17. In most solutions containing a strong or weak acid, the autoionization of water can be neglected when calculating $[H_3O^+]$. Explain why this statement is valid.

18. When calculating $[H_3O^+]$ for weak acid solutions, we can often use the *x is small* approximation. Explain the nature of this approximation and why it is valid.

19. 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.

20. In calculating $[H_3O^+]$ for a mixture of a strong acid and weak acid, the weak acid can often be neglected. Explain why this statement is valid.

21. Write a generic equation showing how a weak base ionizes water.

22. 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.

23. What is the relationship between the acid ionization constant for a weak acid (K_a) and the base ionization constant for its conjugate base (K_b)?

24. What kinds of cations act as weak acids? List some examples.

25. When calculating the $[H_3O^+]$ for a polyprotic acid, the second ionization step can often be neglected. Explain why this statement is valid.

26. For a weak diprotic acid H_2X, what is the relationship between $[X^{2-}]$ and K_{a_2}? Under what conditions does this relationship exist?

27. For a binary acid, H—Y, which factors affect the relative ease with which the acid ionizes?

28. Which factors affect the relative acidity of an oxyacid?

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?

31. What is acid rain? What causes it, and where is the problem the greatest?

32. What are the main detrimental effects of acid rain? What is being done to address the problem of acid rain?

PROBLEMS BY TOPIC

The Nature and Definitions of Acids and Base

33. 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.
MISSED THIS? *Read Section 17.3; Watch KCV 17.3*
a. $HNO_3(aq)$ **b.** $NH_4^+(aq)$
c. $KOH(aq)$ **d.** $HC_2H_3O_2(aq)$

34. Identify each substance as an acid or a base and write a chemical equation showing how it is an acid or a base in aqueous solution according to the Arrhenius definition.
a. $NaOH(aq)$ **b.** $H_2SO_4(aq)$
c. $HBr(aq)$ **d.** $Sr(OH)_2(aq)$

35. In each reaction, identify the Brønsted–Lowry acid, the Brønsted–Lowry base, the conjugate acid, and the conjugate base.
MISSED THIS? *Read Section 17.3; Watch KCV 17.3, IWE 17.1*
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. $HNO_3(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + NO_3^-(aq)$
d. $C_5H_5N(aq) + H_2O(l) \rightleftharpoons C_5H_5NH^+(aq) + OH^-(aq)$

36. In each reaction, identify the Brønsted–Lowry acid, the Brønsted–Lowry base, the conjugate acid, and the conjugate base.
a. $HI(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + I^-(aq)$
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. $HBr(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + Br^-(aq)$

37. Write the formula for the conjugate base of each acid.
MISSED THIS? *Read Section 17.3; Watch KCV 17.3, IWE 17.1*
a. HCl **b.** H_2SO_3 **c.** $HCHO_2$ **d.** HF

38. Write the formula for the conjugate acid of each base.
a. NH_3 **b.** ClO_4^- **c.** HSO_4^- **d.** CO_3^{2-}

39. 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.
MISSED THIS? *Read Sections 17.3, 17.5; Watch KCV 17.3, IWE 17.1*

40. 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 K_a

41. Classify each acid as strong or weak. If the acid is weak, write an expression for the acid ionization constant (K_a).
MISSED THIS? *Read Section 17.4; Watch KCV 17.4*
a. HNO_3 **b.** HCl **c.** HBr **d.** H_2SO_3

42. 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

43. 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.
MISSED THIS? *Read Section 17.4; Watch KCV 17.4*


(a) (b) (c)

44. 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.

45. Pick the stronger base from each pair.
MISSED THIS? *Read Sections 17.4, 17.8*
a. F^- or Cl^- **b.** NO_2^- or NO_3^- **c.** F^- or ClO^-

46. Pick the stronger base from each pair.
a. ClO_4^- or ClO_2^- **b.** Cl^- or H_2O **c.** CN^- or ClO^-

Autoionization of Water and pH

47. Calculate $[OH^-]$ in each aqueous solution at 25 °C, and classify the solution as acidic or basic.
MISSED THIS? *Read Section 17.5*
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

48. 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

49. Calculate the pH and pOH of each solution at 25 °C.
MISSED THIS? *Read Section 17.5; Watch IWE 17.3*
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

50. Calculate $[H_3O^+]$ and $[OH^-]$ for each solution at 25 °C.
a. pH = 8.55 **b.** pH = 11.23 **c.** pH = 2.87

51. Complete the table. (All solutions are at 25 °C.)
MISSED THIS? *Read Section 17.5; Watch IWE 17.3*

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

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

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

53. 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?
MISSED THIS? *Read Sections 17.5, 17.6; Watch KCV 17.6, IWE 17.5*

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

55. Calculate the pH of each acid solution. Explain how the resulting pH values 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.
MISSED THIS? *Read Section 17.5*

$[H_3O^+] = 0.044$ M
$[H_3O^+] = 0.045$ M
$[H_3O^+] = 0.046$ M

56. Determine the concentration of H_3O^+ to the correct number of significant figures in a solution with each pH. Describe how these 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

57. For each strong acid solution, determine $[H_3O^+]$, $[OH^-]$, and pH.
MISSED THIS? *Read Section 17.6*
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
d. a solution that is 0.655% HNO_3 by mass (assume a density of 1.01 g/mL for the solution)

58. 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)

59. What mass of HI must be present in 0.250 L of solution to obtain a solution with each pH value?
MISSED THIS? *Read Section 17.6*
a. pH = 1.25 **b.** pH = 1.75 **c.** pH = 2.85

60. What mass of $HClO_4$ must 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

61. 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?
MISSED THIS? *Read Section 17.6*

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

63. Determine the $[H_3O^+]$ and pH of a 0.100 M solution of benzoic acid. **MISSED THIS?** *Read Section 17.6; Watch KCV 17.6, IWE 17.5*

64. Determine the $[H_3O^+]$ and pH of a 0.200 M solution of formic acid.

65. Determine the pH of an HNO_2 solution of each concentration. In which cases can you *not* make the simplifying assumption that *x is small*?
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.5, 17.7*
a. 0.500 M **b.** 0.100 M **c.** 0.0100 M

66. Determine the pH of an HF solution of each concentration. In which cases can you *not* make the simplifying assumption that *x is small*? (K_a for HF is 6.8×10^{-4}.)
a. 0.250 M **b.** 0.0500 M **c.** 0.0250 M

67. 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.
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.5*

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

69. A 0.185 M solution of a weak acid (HA) has a pH of 2.95. Calculate the acid ionization constant (K_a) for the acid.
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.8*

70. A 0.115 M solution of a weak acid (HA) has a pH of 3.29. Calculate the acid ionization constant (K_a) for the acid.

71. Determine the percent ionization of a 0.125 M HCN solution.
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.9*

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

73. Calculate the percent ionization of an acetic acid solution having the given concentration.
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.9*
a. 1.00 M **b.** 0.500 M **c.** 0.100 M **d.** 0.0500 M

74. Calculate the percent ionization of a formic acid solution having the given concentration.
a. 1.00 M **b.** 0.500 M **c.** 0.100 M **d.** 0.0500 M

75. A 0.148 M solution of a monoprotic acid has a percent ionization of 1.55%. Determine the acid ionization constant (K_a) for the acid.
MISSED THIS? *Read Section 17.6; Watch KCV 17.6, IWE 17.9*

76. A 0.085 M solution of a monoprotic acid has a percent ionization of 0.59%. Determine the acid ionization constant (K_a) for the acid.

77. Find the pH and percent ionization of each HF solution. (K_a for HF is 6.8×10^{-4}.) **MISSED THIS?** *Read Section 17.6; Watch KCV 17.6, IWE 17.5, 17.7, 17.9*
a. 0.250 M HF **b.** 0.100 M HF **c.** 0.050 M HF

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

79. Find the pH of each mixture of acids.
MISSED THIS? *Read Section 17.6*
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

80. 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

81. For each strong base solution, determine $[OH^-]$, $[H_3O^+]$, pH, and pOH. **MISSED THIS?** *Read Section 17.7*
a. 0.15 M NaOH **b.** 1.5×10^{-3} M $Ca(OH)_2$
c. 4.8×10^{-4} M $Sr(OH)_2$ **d.** 8.7×10^{-5} M KOH

82. For each strong base solution, determine $[OH^-]$, $[H_3O^+]$, pH, and pOH.
a. 8.77×10^{-3} M LiOH **b.** 0.0112 M $Ba(OH)_2$
c. 1.9×10^{-4} M KOH **d.** 5.0×10^{-4} M $Ca(OH)_2$

83. Determine the pH of a solution that is 3.85% KOH by mass. Assume that the solution has density of 1.01 g/mL.
MISSED THIS? *Read Section 17.7*

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

85. What volume of 0.855 M KOH solution is required to make 3.55 L of a solution with pH of 12.4?
MISSED THIS? *Read Section 17.7*

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

87. Write equations showing how each weak base ionizes water to form OH^-. Also write the corresponding expression for K_b.
MISSED THIS? *Read Section 17.7*
a. NH_3 **b.** HCO_3^- **c.** CH_3NH_2

88. 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.** $C_2H_5NH_2$

89. Determine the $[OH^-]$, pH, and pOH of a 0.15 M ammonia solution. **MISSED THIS?** *Read Section 17.7; Watch IWE 17.12*

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

91. 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.
MISSED THIS? *Read Section 17.7; Watch IWE 17.12*

92. 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.

93. Morphine is a weak base. A 0.150 M solution of morphine has a pH of 10.7. What is K_b for morphine?
MISSED THIS? *Read Section 17.7; Watch IWE 17.8, 17.12*

94. 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

95. Determine if each anion acts as a weak base in solution. For those anions that are basic, write an equation that shows how the anion acts as a base.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8*
a. Br^- **b.** ClO^- **c.** CN^- **d.** Cl^-

96. Determine whether each anion is basic or neutral. For those 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^-

97. Determine the $[OH^-]$ and pH of a solution that is 0.140 M in F^-.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8, IWE 17.14*

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

99. Determine whether each cation is acidic or pH-neutral. For those cations that are acidic, write an equation that shows how the cation acts as an acid.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8*
a. NH_4^+ **b.** Na^+ **c.** Co^{3+} **d.** $CH_2NH_3^+$

100. Determine whether each cation is acidic or pH-neutral. For each cation that is 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^+

101. Determine if each salt will form a solution that is acidic, basic, or pH-neutral.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8, IWE 17.16*
a. $FeCl_3$ **b.** NaF **c.** $CaBr_2$
d. NH_4Br **e.** $C_6H_5NH_3NO_2$

102. 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

103. Arrange the solutions in order of increasing acidity.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8*
NaCl, NH_4Cl, $NaHCO_3$, NH_4ClO_2, NaOH

104. Arrange the solutions in order of increasing basicity.
CH_3NH_3Br, KOH, KBr, KCN, $C_5H_5NHNO_2$

105. Determine the pH of each solution.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8, 17.14, 17.16*
a. 0.10 M NH_4Cl **b.** 0.10 M $NaC_2H_3O_2$ **c.** 0.10 M NaCl

106. Determine the pH of each solution.
a. 0.20 M $KCHO_2$ **b.** 0.20 M CH_3NH_3I **c.** 0.20 M KI

107. Calculate the concentration of all species in a 0.15 M KF solution.
MISSED THIS? *Read Section 17.8; Watch KCV 17.8, 17.14, 17.16*

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

Polyprotic Acids

109. Write chemical equations and corresponding equilibrium expressions for each of the three ionization steps of phosphoric acid.
MISSED THIS? *Read Section 17.9*

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

111. Calculate the $[H_3O^+]$ and pH of each polyprotic acid solution.
MISSED THIS? *Read Section 17.9*
a. 0.350 M H_3PO_4 **b.** 0.350 M $H_2C_2O_4$

112. Calculate the $[H_3O^+]$ and pH of each polyprotic acid solution.
a. 0.125 M H_2CO_3 **b.** 0.125 M $H_3C_6H_5O_7$

113. Calculate the concentration of all species in a 0.500 M solution of H_2SO_3.
MISSED THIS? *Read Section 17.9*

114. Calculate the concentration of all species in a 0.155 M solution of H_2CO_3.

115. Calculate the $[H_3O^+]$ and pH of each H_2SO_4 solution. At approximately what concentration does the *x is small* approximation break down?
MISSED THIS? *Read Section 17.9*
a. 0.50 M
b. 0.10 M
c. 0.050 M

116. Consider a 0.10 M solution of a weak polyprotic acid (H_2A) with the possible values of K_{a_1} and K_{a_2} given here.
a. $K_{a_1} = 1.0 \times 10^{-4}$; $K_{a_2} = 5.0 \times 10^{-5}$
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 $[H_3O^+]$ from each ionization step. At what point can the contribution of the second step be neglected?

Molecular Structure and Acid Strength

117. Based on their molecular structure, pick the stronger acid from each pair of binary acids. Explain your choice.
MISSED THIS? *Read Section 17.10*
a. HF and HCl
b. H_2O or HF
c. H_2Se or H_2S

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

$$H_2Te, HI, H_2S, NaH$$

119. Based on their molecular structure, pick the stronger acid from each pair of oxyacids. Explain your choice.
MISSED THIS? *Read Section 17.10*
a. H_2SO_4 or H_2SO_3
b. $HClO_2$ or HClO
c. HClO or HBrO
d. CCl_3COOH or CH_3COOH

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

$$HClO_3, HIO_3, HBrO_3$$

121. Which is a stronger base, S^{2-} or Se^{2-}? Explain.
MISSED THIS? *Read Section 17.10*

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

Lewis Acids and Bases

123. Classify each species as either a Lewis acid or a Lewis base.
MISSED THIS? *Read Section 17.11*
a. Fe^{3+}
b. BH_3
c. NH_3
d. F^-

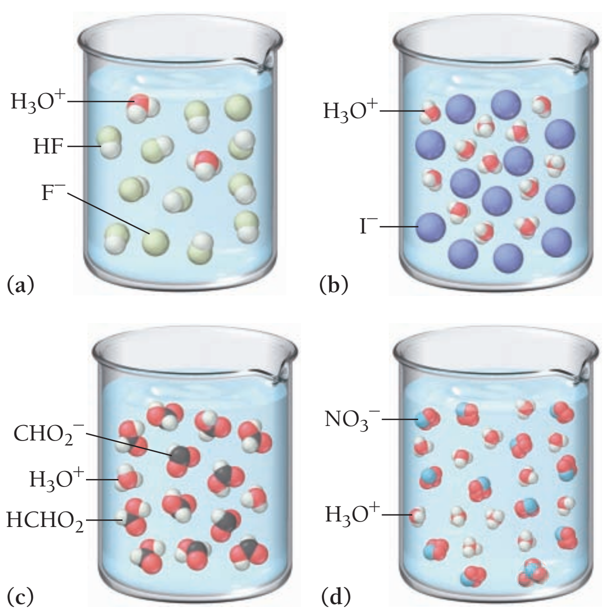
124. Classify each species as either a Lewis acid or a Lewis base.
a. $BeCl_2$ **b.** OH^- **c.** $B(OH)_3$ **d.** CN^-

125. Identify the Lewis acid and Lewis base from among the reactants in each equation.
MISSED THIS? *Read Section 17.11*
a. $Fe^{3+}(aq) + 6\,H_2O(l) \rightleftharpoons Fe(H_2O)_6^{\,3+}(aq)$
b. $Zn^{2+}(aq) + 4\,NH_3(aq) \rightleftharpoons Zn(NH_3)_4^{\,2+}(aq)$
c. $(CH_3)_3N(g) + BF_3(g) \rightleftharpoons (CH_3)_3NBF_3(s)$

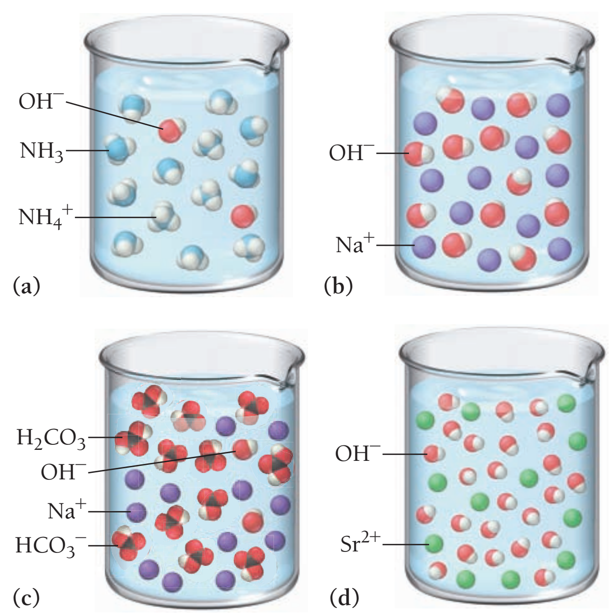
126. Identify the Lewis acid and Lewis base from among the reactants in each equation.
a. $Ag^+(aq) + 2\,NH_3(aq) \rightleftharpoons Ag(NH_3)_2^{\,+}(aq)$
b. $AlBr_3 + NH_3 \rightleftharpoons H_3NAlBr_3$
c. $F^-(aq) + BF_3(aq) \rightleftharpoons BF_4^{\,-}(aq)$

CUMULATIVE PROBLEMS

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



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



129. 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)?

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

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$
$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

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 be having on the pH of the world's oceans? What effect might this change be having on the limestone structures (primarily $CaCO_3$) of coral reefs and marine shells?

131. 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, is all the acid neutralized? If not, what fraction is neutralized?

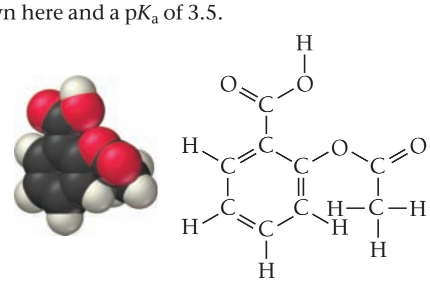
132. Lakes that have been acidified by acid rain can be neutralized by liming, the addition of limestone ($CaCO_3$). How much limestone (in kg) is required to completely neutralize a 4.3 billion liter lake with a pH of 5.5?

▲ Liming a lake.

133. Acid rain over the Great Lakes has a pH of about 4.5. Calculate the $[H_3O^+]$ of this rain and compare that value to the $[H_3O^+]$ 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?

134. White wines tend to be more acidic than red wines. Find the $[H_3O^+]$ 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?

135. 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 (6.5×10^2 mg) is dissolved in 8.0 ounces of water.

136. 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 an aqueous zalcitabine solution containing 565 mg/L?

137. 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

138. 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

139. 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

140. 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

141. Write net ionic equations for the reactions that take place when aqueous solutions of the following 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

142. 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.

143. The pH of a 1.00 M solution of urea, a weak organic base, is 7.050. Calculate the K_a of protonated urea.

144. 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.

145. 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 $[Ca^{2+}] = 0.26$ M and a pH = 8.78. Assuming the salt is completely dissociated, calculate the K_a of lactic acid.

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

CHALLENGE PROBLEMS

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

148. 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 °C. Calculate K_a for the unknown weak acid.

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

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

151. 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 $K = 4.0$. Calculate the $[H^+]$, $[A^-]$, and $[HA_2^-]$ in a 1.0 M solution of HA.

152. 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, $(CH_3)_3N$ is more basic than CH_3NH_2, while in solution the reverse is true. Explain this observation.

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

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

155. 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. Find the mass of $NaHCO_3$ in the mixture.

156. 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. Find the amount of NaCN in the mixture.

CONCEPTUAL PROBLEMS

157. 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 M 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 $CaCl_2$

158. 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

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

CH_3COOH $CH_2ClCOOH$ $CHCl_2COOH$ CCl_3COOH

160. 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.

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

162. Have each group member make two flashcards with an acid or 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.

163. Answer the following questions 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 solution?
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 $[OH^-]$ for a solution, how do you determine $[H_3O^+]$?

164. 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, $NaC_2H_3O_2$, is dissolved in 100.0 mL of water? (The K_a of acetic acid, $HC_2H_3O_2$, is 1.8×10^{-5}.)

165. 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 INTERPRETATION AND ANALYSIS

Sulfur Dioxide in Wine

166. 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 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 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 ($K_2S_2O_5$), also known as KMBS, as a source of SO_2 in wine. When KMBS is added to wine, the metabisulfite ion ($S_2O_5^{2-}$) reacts with water to form the bisulfite ion (HSO_3^-). 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?

Cc ANSWERS TO CONCEPTUAL CONNECTIONS

Acid Properties

17.1 **(c)** Acids typically have a sour taste. The bitter taste is associated with bases.

Conjugate Acid–Base Pairs

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

The Magnitude of the Acid Ionization Constant

17.3 **(b)** HB has the largest K_a.

Relative Strengths of Weak Acids

17.4 **(a)** HF is stronger because it has a larger acid ionization constant.

Acidity of Solutions

17.5 **(a)** Since the H_3O^+ concentration is greater than 10^{-7} M at room temperature, this solution is acidic.

pH and Acidity

17.6 **(b)** As pH increases, acidity decreases.

The *x is small* Approximation

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

Strong and Weak Acids

17.8 **(a)** A weak acid solution is usually 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.

Percent Ionization

17.9 Solution **(c)** has the greatest percent ionization because percent ionization increases with decreasing weak acid concentration.

Judging Relative pH

17.10 **(a)** A weak acid solution is usually less than 5% dissociated. Therefore, since 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.

Anions as Weak Bases

17.11 **(c)** The F^- ion is the conjugate base of a *weak* acid (HF) and is therefore a weak base.

Acidity or Basicity of Ionic Compounds

17.12 **(a)** The NH_4^+ cation is the conjugate acid of a weak base and is therefore a weak acid. The Br^- ion is the conjugate base of a *strong* acid (HBr) and is therefore pH-neutral. Therefore, the compound forms an acidic solution when dissolved in water.

Acid Strength and Molecular Structure

17.13 **(a)** Since the carbon atom in **(a)** is bonded to another oxygen atom, which 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.