Pearson

Chapter Summary and Review

Key Learning Outcomes

Chapter Objectives	Assessment
Identify Brønsted–Lowry Acids and Bases and Their Conjugates (16.3)	• Example 16.1 For Practice 16.1 Exercises 33, 34
Determine Relative Acid Strength from Molecular Structure (16.4)	• Exercises 39, 40, 41, 42
Use K_w in Calculations (16.6)	• Example 16.2 For Practice 16.2 Exercises 49, 50
Calculate pH from $[H_3O^+]$ or $[OH^-]$ (16.6)	• Examples 16.3, 16.4 For Practice 16.3, 16.4 Exercises 51, 52, 53, 54
Find the pH of a Weak Acid Solution (16.7)	• Examples 16.5, 16.6, 16.7 For Practice 16.5, 16.6, 16.7 Exercises 65, 66, 67, 68, 69, 70
Find the Acid Ionization Constant from pH (16.7)	• Example 16.8 For Practice 16.8 Exercises 71, 72
Find the Percent Ionization of a Weak Acid (16.7)	• Example 16.9 For Practice 16.9 Exercises 73, 74, 75, 76
Find the pH in Mixtures of Weak Acids (16.7)	• Example 16.10 For Practice 16.10 Exercises 81, 82
Find the $[OH^-]$ and pH of a Strong Base Solution (16.8)	• Example 16.11 For Practice 16.11 Exercises 83, 84
Find the $[OH^-]$ and pH of a Weak Base Solution (16.8)	• Example 16.12 For Practice 16.12 Exercises 91, 92
Determine Whether an Anion Is Basic or Neutral (16.9)	• Example 16.13 For Practice 16.13 Exercises 97, 98
Determine the pH of a Solution Containing an Anion Acting as a Base (16.9)	• Example 16.14 For Practice 16.14 Exercises 99, 100
Determine Whether a Cation Is Acidic or Neutral (16.9)	• Example 16.15 For Practice 16.15 Exercises 101, 102
Determine the Overall Acidity or Basicity of Salt Solutions (16.9)	• Example 16.16 For Practice 16.16 Exercises 103, 104

Find the pH of a Polyprotic Acid Solution (16.10)	• Example 16.17 For Practice 16.17 Exercises 115, 116
Find the $[H_3O^+]$ in Dilute H_2SO_4 Solutions (16.10)	• Example 16.18 For Practice 16.18 Exercise 119
Find the Concentration of the Anions for a Weak Diprotic Acid Solution (16.10)	• Example 16.19 For Practice 16.19 Exercises 117, 118

Key Terms

Section 16.2

carboxylic acid
alkaloid

Section 16.3

Arrhenius definitions (of acids and bases)
hydronium ion
strong acid
weak acid
strong base
weak base
Brønsted–Lowry definitions (of acids and bases)
amphoteric
conjugate acid–base pair
conjugate acid
conjugate base

Section 16.5

monoprotic acid
diprotic acid
triprotic acid
acid ionization constant (K_a)

Section 16.6

autoionization
ion product constant for water (K_w)
neutral
acidic solution
basic solution
pH

Section 16.7

percent ionization

Section 16.8

base ionization constant (K_b)

Section 16.10

polyprotic acid

Section 16.11

Lewis acid
Lewis base

Key Concepts

The Nature of Acids and Bases (16.2)

- 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 (16.3)

- 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 of acids and bases 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 Molecular Structure (16.4)

- 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.

Acid Strength and the Acid Dissociation Constant (K_a) (16.5)

- In a solution, a strong acid completely ionizes, but a weak acid only partially ionizes.
- 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 (16.6)

- 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 the pH and pOH is always 14.

Finding the $[H_3O^+]$ and pH of Strong and Weak Acid Solutions (16.7)

- 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.

Finding the $[OH^-]$ and pH of Strong and Weak Base Solutions (16.8)

- 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.

The Acid–Base Properties of Ions and Salts (16.9)

- 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.
- A cation is a weak acid if it is the conjugate acid of a weak base; it is neutral if it is the conjugate acid of a strong base.
- To calculate the pH 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 (16.10)

- Polyprotic acids contain two or more ionizable protons.
- Generally, polyprotic acids ionize in successive steps, with the value of K_a becoming 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 acid anion formed in the second ionization step is equivalent to the value of K_{a2}.

Lewis Acids and Bases (16.11)

- 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; therefore, according to this definition, an acid does not have to contain hydrogen. According to this definition, an acid can be a compound with an empty orbital—or one that will rearrange to make an empty orbital—or a cation.

Key Equations and Relationships

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

Expression for the Acid Ionization Constant, K_a (16.5)

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

The Ion Product Constant for Water, K_w (16.6)

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

Expression for the pH Scale (16.6)

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

Expression for the pOH Scale (16.6)

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

Relationship between pH and pOH (16.6)

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

Expression for the pK_a Scale (16.6)

$$pK_a = -\log K_a$$

$$\mathrm{p}K_a = -\log K_a$$

Expression for Percent Ionization (16.7)

$$\begin{aligned} \text{percent ionization} &= \frac{\text{concentration of ionized acid}}{\text{initial concentration of acid}} \times 100\% \\ &= \frac{[\mathrm{H_3O^+}]_{\text{equil}}}{[\mathrm{HA}]_{\text{init}}} \times 100\% \end{aligned}$$

Relationship between $K_a, K_b,$ and K_w (16.9)

$$K_a \times K_b = K_\mathrm{w}$$