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ACIDS, BASES, AND SALTS**SECTION 19.1 ACID–BASE THEORIES (pages 587–593)**

This section compares and contrasts acids and bases as defined by the theories of Arrhenius, Brønsted-Lowry, and Lewis. It also identifies conjugate acid–base pairs in acid–base reactions.

► Properties of Acids and Bases (pages 587–588)

1. Circle the letters of all the terms that complete the sentence correctly.

The properties of acids include _____ .

a. reacting with metals to produce oxygen

b. giving foods a sour taste

c. forming solutions that conduct electricity

d. causing indicators to change color

2. Bases are compounds that react with acids to form _____ **water** _____
and a(n) _____ **salt** _____ .

3. Circle the letters of all the terms that complete the sentence correctly.

The properties of bases include _____ .

a. tasting bitter

b. feeling slippery

c. changing the color of an indicator

d. always acting as a strong electrolyte

► Arrhenius Acids and Bases (pages 588–590)

4. Match the number of ionizable hydrogens with the type of acid.

_____ **c** _____ one

a. diprotic

_____ **a** _____ two

b. triprotic

_____ **b** _____ three

c. monoprotic

5. Is the following sentence true or false? Only the hydrogens in weak polar bonds are ionizable. _____ **false** _____

6. Hydrogen is joined to a very _____ **electronegative** _____ element in a very polar bond.

7. Alkali metals react with water to produce _____ **basic** _____ solutions.

CHAPTER 19, Acids, Bases, and Salts (continued)

8. How do concentrated basic solutions differ from other basic solutions?

They are extremely caustic.

► Brønsted-Lowry Acids and Bases (pages 590–592)

9. How does the Brønsted-Lowry theory define acids and bases?

The Brønsted-Lowry theory defines an acid as a hydrogen-ion donor and a base as a hydrogen-ion acceptor.

10. Is the following sentence true or false? Some of the acids and bases included in the Arrhenius theory are not acids and bases according to the Brønsted-Lowry theory. false

11. Is the following sentence true or false? A conjugate acid is the particle formed when a base gains a hydrogen ion. true

12. A conjugate base is the particle that remains when an acid has donated a hydrogen ion.

13. What is a conjugate acid–base pair? A conjugate acid–base pair consists of two substances related by the loss or gain of a single hydrogen ion.

14. A substance that can act as both an acid and a base is said to be amphoteric.

15. In a reaction with HCl, is water an acid or a base?

Water is a base because it accepts a proton.

► Lewis Acids and Bases (pages 592–593)

16. What is a Lewis acid? A Lewis acid is a substance that can accept a pair of electrons to form a covalent bond.

17. A Lewis base is a substance that can donate a pair of electrons to form a covalent bond.

18. Is the following sentence true or false? All the acids and bases included in the Brønsted-Lowry theory are also acids and bases according to the Lewis theory.

true

19. Complete this table of acid-base definitions.

Acid-Base Definitions		
Type	Acid	Base
Brønsted-Lowry	H ⁺ donor	H ⁺ acceptor
Lewis	electron-pair acceptor	electron-pair donor
Arrhenius	H ⁺ producer	OH ⁻ producer

SECTION 19.2 HYDROGEN IONS AND ACIDITY (pages 594–604)

This section classifies solutions as neutral, acidic, or basic, given the hydrogen-ion or hydroxide-ion concentration. It explains how to convert hydrogen-ion concentrations into pH values and hydroxide-ion concentrations into pOH values.

► Hydrogen Ions from Water (pages 594-595)

- What does a water molecule that loses a hydrogen ion become?
It becomes a negatively charged hydroxide ion (OH⁻).
- What does a water molecule that gains a hydrogen ion become?
It becomes a positively charged hydronium ion (H₃O⁺).
- The reaction in which water molecules produce ions is called the
self-ionization of water.
- In water or aqueous solution, hydrogen ions (H⁺) are always joined to
water molecules as hydronium ions (H₃O⁺).
- Is the following sentence true or false? Any aqueous solution in which [H⁺] and [OH⁻] are equal is described as a neutral solution. true

► Ion Product Constant for Water (pages 595–596)

- What is the ion-product constant for water (K_w)? Give the definition, the expression, and the value. The ion-product constant for water is the product of the concentrations of the hydrogen ions and hydroxide ions in water.

$$K_w = [\text{H}^+] \times [\text{OH}^-] = 1.0 \times 10^{-14}$$

CHAPTER 19, Acids, Bases, and Salts (continued)

7. A(n) acidic solution is one in which $[H^+]$ is greater than $[OH^-]$.
 A(n) basic solution is one in which $[H^+]$ is less than $[OH^-]$.

8. Match the type of solution with its hydrogen-ion concentration.

- | | |
|------------------|--|
| <u>b</u> acidic | a. less than $1.0 \times 10^{-7} M$ |
| <u>c</u> neutral | b. greater than $1.0 \times 10^{-7} M$ |
| <u>a</u> basic | c. $1.0 \times 10^{-7} M$ |

► **The pH Concept** (pages 596–600)

9. The pH of a solution is the negative logarithm of the hydrogen-ion concentration.

10. Match the type of solution with its pH.

- | | |
|------------------|---------------|
| <u>c</u> acidic | a. $pH > 7.0$ |
| <u>b</u> neutral | b. $pH = 7.0$ |
| <u>a</u> basic | c. $pH < 7.0$ |

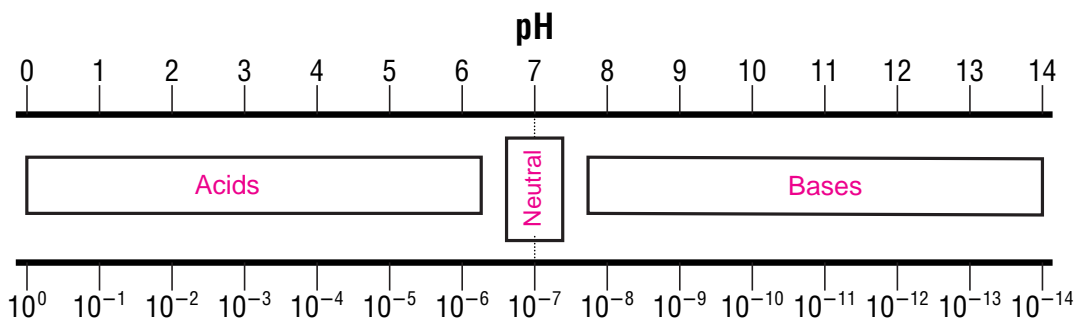
11. Look at Table 19.5 on page 598. What is the approximate $[H^+]$, the $[OH^-]$, and the pH of washing soda? $1 \times 10^{-12} \text{ mol/L}$, $1 \times 10^{-2} \text{ mol/L}$, and 12.0

12. The pOH of a solution is the negative logarithm of the hydroxide-ion concentration.

13. What is the pOH of a neutral solution? 7

14. For pH calculations, in what form should you express the hydrogen-ion concentration? You should express the hydrogen-ion concentration in scientific notation.

15. Look at the pH scale below. Label where you would find acids, bases, and neutral solutions.



16. Is the following sentence true or false? Most pH values are whole numbers.

 false

17. If $[H^+]$ is written in scientific notation but its coefficient is not 1, what do you need to calculate pH? You need either a table of common logarithms or a calculator

 with a log function key.

18. Is the following sentence true or false? You can calculate the hydrogen-ion concentration of a solution if you know the pH. true

► **Measuring pH (pages 600–603)**

19. When do you use indicators and when do you use a pH meter to measure pH?

 You use indicators for preliminary measurements and for small-volume samples. You use a pH meter for precise and continuous measurements.

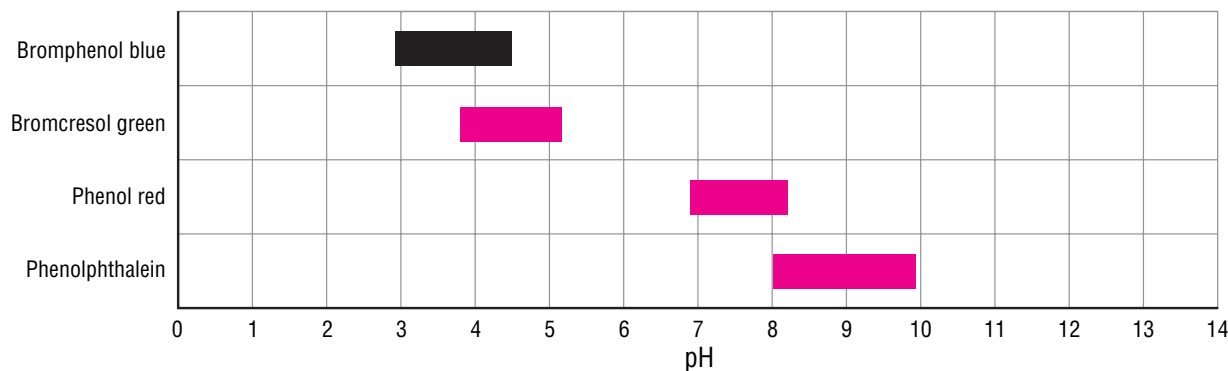
20. Why is an indicator a valuable tool for measuring pH?

 It is a valuable tool for measuring pH because its acid form and base form have different colors in solution.

21. Why do you need many different indicators to span the entire pH spectrum?

 For each indicator, the change from dominating acid form to dominating base form occurs in a narrow range of approximately two pH units.

22. Look at the figure below. Fill in the missing pH color change ranges for the indicators.



23. List three characteristics that limit the usefulness of indicators.

- a. At temperatures other than 25°C, an indicator may change color at a different pH.
- b. Indicator color can be distorted if a solution is not colorless.
- c. Dissolved salts in a solution can affect the dissociation of the indicator.

CHAPTER 19, Acids, Bases, and Salts (*continued*)

24. How accurate are measurements of pH obtained with a pH meter?

to within 0.01 pH unit of the true pH

25. What is the pH of each of the following solutions?

a. water 7

b. vinegar 3

c. milk of magnesia 10.5

26. Is the following sentence true or false? Measurements of pH obtained with a pH meter are typically accurate to within 0.001 pH unit of the true pH.

false

SECTION 19.3 STRENGTHS OF ACIDS AND BASES (pages 605–611)

This section defines strong acids and weak acids, and then explains how to calculate an acid dissociation constant. It describes how acids and bases are arranged by strength according to their dissociation constants (K_a) and (K_b).

► Strong and Weak Acids and Bases (pages 605–609)

1. What factor is used to classify acids as strong or weak?

Acids are classified by the degree to which they ionize in water.

2. Strong acids are completely ionized in aqueous solution; weak acids ionize only slightly in aqueous solution.

3. Look at Table 19.6 on page 605. Which acid is the weakest acid in the table? Which base is the weakest base?

Hypochlorous acid is the weakest acid. Ammonia is the weakest base.

4. What do you use to write the equilibrium-constant expression?

You use a balanced chemical equation.

5. An acid dissociation constant (K_a) is the ratio of the concentration of the

dissociated form of an acid to the concentration of the undissociated form.

6. What is another name for dissociation constants?

Another name is ionization constants.

7. Is the following sentence true or false? The stronger an acid is, the smaller its K_a value. false

8. A diprotic acid has two dissociation constants.

9. Look at Table 19.7 on page 607. What is the second dissociation constant for the triprotic phosphoric acid? $K_a = 6.2 \times 10^{-8}$
10. Weak bases react with water to form the hydroxide ion and the conjugate acid of the base.
11. A base dissociation constant (K_b) is the ratio of the concentration of the conjugate acid times the concentration of the hydroxide ion to the concentration of the conjugate base.
12. What does the magnitude of the base dissociation constant (K_b) indicate?
It indicates the ability of a weak base to compete with the very strong base OH^- for hydrogen ions.
13. The words *concentrated* and *dilute* indicate how much acid or base is dissolved in solution.
14. Is the following sentence true or false? The words strong or weak refer to the extent of ionization or dissociation of an acid or base. true

► **Calculating Dissociation Constants (pages 609–610)**

15. Is the following sentence true or false? You can calculate the acid dissociation constant (K_a) of a weak acid from experimental data. true
16. To measure the equilibrium concentrations of all substances present at equilibrium for a weak acid, what two conditions must you know?
You must know the initial molar concentration of the acid and the pH (or $[\text{H}_3\text{O}^+]$) of the solution at equilibrium.



Reading Skill Practice

By looking carefully at photographs and drawings in textbooks, you can better understand what you have read. Look carefully at Figure 19.16 on page 606. What important idea does this drawing communicate? Do your work on a separate sheet of paper.

The illustration compares the extent of dissociation of strong, weak, and very weak acids.

CHAPTER 19, Acids, Bases, and Salts (continued)

SECTION 19.4 NEUTRALIZATION REACTIONS (pages 612–616)

This section explains how acid–base titration is used to calculate the concentration of an acid or a base. It also explains the concept of equivalence in neutralization reactions.

► **Acid–Base Reactions** (pages 612–613)

1. Is the following sentence true or false? Acids react with compounds containing hydroxide ions to form water and a salt. true

2. What does the reaction of an acid with a base produce?
 It produces water and a salt.

3. In general, reactions in which an acid and a base react in an aqueous solution to produce a salt and water are called neutralization reactions.

4. Look at Table 19.9 on page 613. Circle the letter of the salt that is used for photographic emulsions.

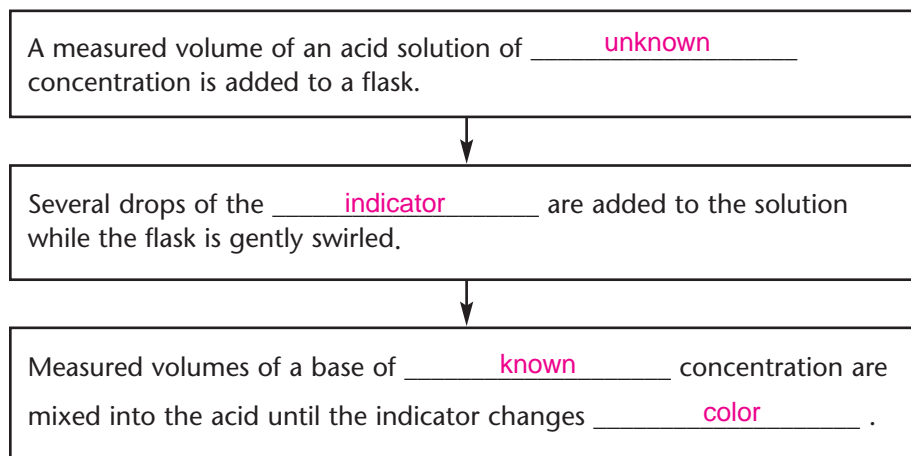
a. calcium chloride	c. silver bromide
b. potassium chloride	d. sodium chloride

5. Salts are compounds consisting of a(n) anion from an acid and a(n) cation from a base.

► **Titration** (pages 613–616)

6. How can you determine the concentration of an acid or base in a solution?
 You can perform a neutralization reaction.

7. Complete the flow chart below showing the steps of a neutralization reaction.



8. The process of adding a known amount of solution of known concentration to determine the concentration of another solution is called titration.
9. What is the solution of known concentration called?
It is called the standard solution.

SECTION 19.5 SALTS IN SOLUTION (pages 618–622)

This section demonstrates with equations how buffers resist changes in pH. It also explains how to calculate the solubility product constant of a slightly soluble salt.

► Salt Hydrolysis (pages 618–620)

1. What is salt hydrolysis? Salt hydrolysis occurs when the cations or anions of a dissociated salt remove hydrogen ions from or donate hydrogen ions to water.
2. Complete this table of the rules for hydrolysis of a salt.

Reactants	Products
<u>Strong</u> acid + <u>Strong</u> base	Neutral solution
Strong acid + Weak base	<u>Acidic</u> solution
<u>Weak</u> acid + <u>Strong</u> base	Basic solution

► Buffers (pages 620–622)

3. What are buffers? Buffers are solutions in which the pH remains relatively constant when small amounts of acid or base are added.
4. A buffer is a solution of a weak acid and one of its salts, or a solution of a weak base and one of its salts.
5. Is the following sentence true or false? The buffer capacity is the amount of acid or base that can be added to a buffer solution before a significant change in pH occurs. true

CHAPTER 19, Acids, Bases, and Salts (continued)

GUIDED PRACTICE PROBLEMS

EXTRA PRACTICE PROBLEM (similar to Practice Problem 13, page 600)

13. Find the value of $[\text{OH}^-]$ for a solution with a pH of 8.00.

If $\text{pH} = 8.00$, $\text{pOH} = 6.00$ because $\text{pH} + \text{pOH} = 14$.

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

$$6.00 = -\log [\text{OH}^-]$$

$$-6.00 = \log [\text{OH}^-]$$

$$10^{-6.00} = 10^{\log [\text{OH}^-]}$$

$$[\text{OH}^-] = 10^{-6}$$

GUIDED PRACTICE PROBLEM 16b (page 601)

16b. Calculate the pH of this solution: $[\text{H}^+] = 8.3 \times 10^{-10} \text{ M}$.

Step 1. Identify the known and unknown values.

Known

$$[\text{H}^+] = 8.3 \times 10^{-10} \text{ M}$$

Unknown

$$\text{pH} = ?$$

Step 2. Substitute values into the pH equation.

$$\begin{aligned} \text{pH} &= -\log [\text{H}^+] \\ &= -\log (8.3 \times 10^{-10}) \end{aligned}$$

Step 3. The logarithm of a product equals the sum of the logs of its factors.

$$= -(\log 8.3 + \log 10^{-10})$$

Step 4. Evaluate $\log 8.3$ by using a calculator. Evaluate $\log 10^{-10}$ by using the definition of logarithm.

$$= -(0.919 + -10)$$

Step 5. Add and simplify. Write your answer with two significant figures to the right of the decimal point.

$$= -(-9.081) = 9.08$$

GUIDED PRACTICE PROBLEM 22 (page 610)

22. For a solution of methanoic acid exactly 0.1 M, $[H^+] = 4.2 \times 10^{-3}M$. Calculate the K_a of methanoic acid.

Analyze

Step 1. What is known about the acid?

It is a 0.1 M solution, $[H^+] = 4.2 \times 10^{-3}M$, and the equation for dissociation is



Step 2. What is the unknown? K_a

Step 3. What is the expression for the K_a of methanoic acid?

$$K_a = \frac{[HCOO^-] \times [H^+]}{[HCOOH]}$$

Solve

Step 4. What expression can you write to find the equilibrium concentration of HCOOH?

$$0.1000 - 4.2 \times 10^{-3} = 0.0958$$

Step 5. Substitute values into the formula for K_a and solve.

$$\begin{aligned} K_a &= \frac{(4.2 \times 10^{-3}) \times (4.2 \times 10^{-3})}{0.0958} = \frac{1.764 \times 10^{-5}}{0.0958} \\ &= 184.1 \times 10^{-6} = 1.8 \times 10^{-4} \end{aligned}$$

Analyze

Step 6. Look at Table 19.7 on page 607. Explain why your answer is reasonable.

The value for K_a is the same as the one given in the table.

