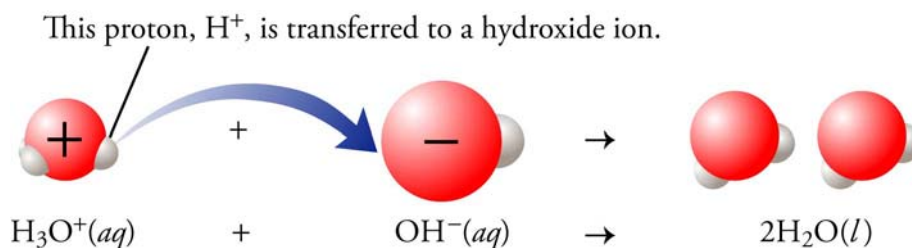


## Chapter 8

# Acids, Bases, and Acid-Base Reactions

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◆ Review Skills

8.1 Strong and Weak Acids and Bases

- Acid Review
- Bases

*Internet: Strong and Weak Bases*

*Internet: Identification of Strong and Weak Acids and Bases*

***Special Topic 8.1: Chemistry and Your Sense of Taste***

8.2 pH and Acidic and Basic Solutions

8.3 Arrhenius Acid-Base Reactions

- Reactions of Aqueous Strong Arrhenius Acids and Aqueous Strong Arrhenius Bases
- Writing Equations for Reactions Between Acids and Bases

*Internet: Acid-Base Reaction Animation*

- Reactions of Arrhenius Acids and Ionic Compounds That Contain Carbonate or Hydrogen Carbonate

***Special Topic 8.2: Precipitation, Acid-Base Reactions, and Tooth Decay***

***Special Topic 8.3: Saving Valuable Books***

***Special Topic 8.4: Be Careful with Bleach***

8.4 Brønsted-Lowry Acids and Bases

◆ Chapter Glossary

*Internet: Glossary Quiz*

◆ Chapter Objectives

Review Questions

Key Ideas

Chapter Problems

## Section Goals and Introductions

---

### Section 8.1 Strong and Weak Acids and Bases

#### Goals

- To review some of the information about acids described in Section 6.3.
- To describe bases and to make the distinction between strong and weak bases.
- To show how you can recognize strong and weak bases.
- To show the changes that take place on the particle level when bases dissolve in water.

This section begins with a review of acids, followed by the following for bases: (1) it states the Arrhenius definition of base, (2) it provides you with the information necessary to identify strong and weak bases, and (3) it describes the changes that take place when one weak base (ammonia) dissolves in water (Figure 8.2). Sample Study Sheet 8.1 summarizes the steps for identification of strong and weak acids and bases. Visit our Web site for more information about strong and weak bases and the identification of strong and weak acids and bases.

*Internet: Strong and Weak Bases*

*Internet: Identification of Strong and Weak Acids and Bases*

### Section 8.2 pH and Acidic and Basic Solutions

*Goal: To explain the pH scale used to describe acidic and basic solutions.*

This section provides an introduction to the pH scale used to describe acidic and basic solutions. Figure 8.4 contains the most important information.

### Section 8.3 Arrhenius Acid-Base Reactions

#### Goals

- To describe acid-base reactions, with an emphasis on developing the ability to visualize the changes that take place on the particle level.
- To show how you can predict whether two reactants will react in an acid-base reaction.
- To show how to write equations for acid-base reactions.

This section does for acid-base reactions what Section 7.3 does for precipitation reactions. It might help to consider the similarities and differences between these two types of chemical changes. Be sure that you can visualize the changes that take place at the particle level for both types of chemical reactions. Pay special attention to Figures 8.5, 8.6, and 8.8. Visit our Web site to see an animation showing an acid-base reaction.

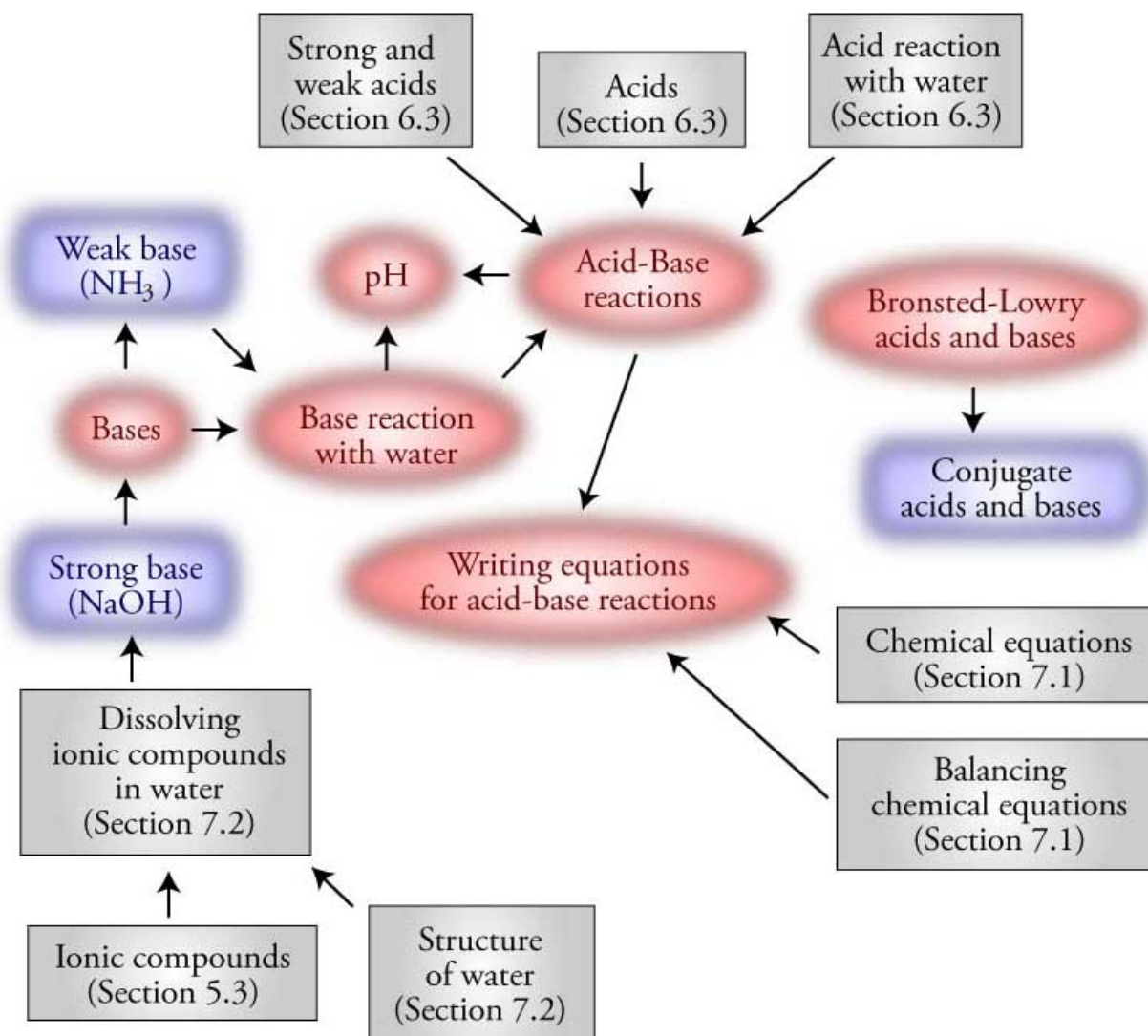
*Internet: Acid-Base Reaction Animation*

### Section 8.4 Brønsted-Lowry Acids and Bases

*Goal: To describe a second set of definitions for acid, base, and acid-base reactions, called the Brønsted-Lowry definitions.*

Although the Arrhenius definitions of acid, base, and acid-base reactions provided in Sections 8.1 and 8.3 are very important, especially to the beginning chemistry student, chemists have found it useful to extend these definitions to include new substances as acids and bases that would not be classified as such according to the Arrhenius definitions. The new definitions, called the Brønsted-Lowry definitions, are described in this section.

## Chapter 8 Map

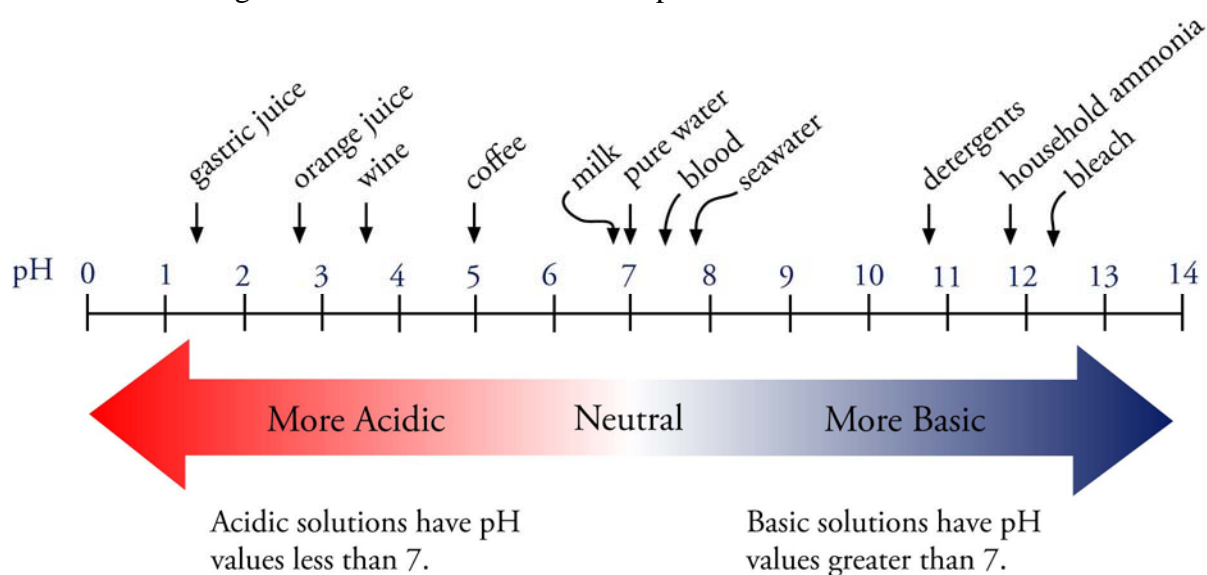


## Chapter Checklist

- Read the Review Skills section. If there is any skill mentioned that you have not yet mastered, review the material on that topic before reading this chapter.
- Read the chapter quickly before the lecture that describes it.
- Attend class meetings, take notes, and participate in class discussions.
- Work the Chapter Exercises, perhaps using the Chapter Examples as guides.
- Study the Chapter Glossary and test yourself on our Web site:  
*Internet: Glossary Quiz*
- Study all of the Chapter Objectives. You might want to write a description of how you will meet each objective. (Although it is best to master all of the objectives, the following

objectives are especially important because they pertain to skills that you will need while studying other chapters of this text: 5, 6, 7, 8, 11, and 18.)

- Reread *Sample Study Sheet 8.1: Identification of Strong and Weak Acids and Bases* and decide whether you will use it or some variation on it to complete the task it describes.
- Memorize the following. Be sure to check with your instructor to determine how much you are expected to know of the following.
  - The significance of the numbers in the pH scale



- To get a review of the most important topics in the chapter, fill in the blanks in the Key Ideas section.
- Work all of the selected problems at the end of the chapter, and check your answers with the solutions provided in this chapter of the study guide.
- Ask for help if you need it.

## Web Resources

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*Internet: Strong and Weak Bases*

*Internet: Identification of*

*Internet: Strong and Weak Acids and Bases*

*Internet: Acid-Base Reaction Animation*

*Internet: Glossary Quiz*

## Exercises Key

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**Exercise 8.1 - Identification of Acids and Bases:** Identify each of the following as an Arrhenius strong acid, an Arrhenius weak acid, an Arrhenius strong base, or an Arrhenius weak base. (06/5)

- |                      |                    |                            |                  |
|----------------------|--------------------|----------------------------|------------------|
| a. $\text{HNO}_3$    | <b>strong acid</b> | c. $\text{K}_2\text{CO}_3$ | <b>weak base</b> |
| b. lithium hydroxide | <b>strong base</b> | d. hydrofluoric acid       | <b>weak acid</b> |

**Exercise 8.2 - Neutralization Reactions:** Write the complete equation for the neutralization reactions that take place when the following water solutions are mixed. (If an acid has more than one acidic hydrogen, assume that there is enough base to remove all of them. Assume that there is enough acid to neutralize all of the basic hydroxide ions.) (*Obj 11*)

- $\text{HCl}(aq) + \text{NaOH}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{NaCl}(aq)$
- $\text{HF}(aq) + \text{LiOH}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{LiF}(aq)$
- $\text{H}_3\text{PO}_4(aq) + 3\text{LiOH}(aq) \rightarrow 3\text{H}_2\text{O}(l) + \text{Li}_3\text{PO}_4(aq)$
- $\text{Fe}(\text{OH})_3(s) + 3\text{HNO}_3(aq) \rightarrow \text{Fe}(\text{NO}_3)_3(aq) + 3\text{H}_2\text{O}(l)$

**Exercise 8.3 - Neutralization Reactions with Compounds Containing Carbonate:** Write the complete equation for the neutralization reaction that takes place when water solutions of sodium carbonate,  $\text{Na}_2\text{CO}_3$ , and hydrobromic acid,  $\text{HBr}$ , are mixed. (*Obj 11*)



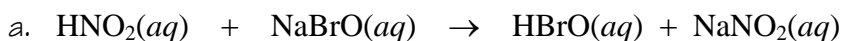
**Exercise 8.4 - Conjugate Acids:** Write the formula for the conjugate acid of (a)  $\text{NO}_2^-$ , (b)  $\text{HCO}_3^-$ , (c)  $\text{H}_2\text{O}$ , and (d)  $\text{PO}_4^{3-}$ . (*Obj 14*)

- $\text{HNO}_2$
- $\text{H}_2\text{CO}_3$
- $\text{H}_3\text{O}^+$
- $\text{HPO}_4^{2-}$

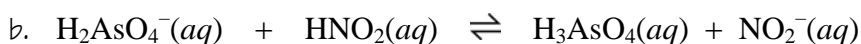
**Exercise 8.5 - Conjugate Bases:** Write the formula for the conjugate base of (a)  $\text{H}_2\text{C}_2\text{O}_4$ , (b)  $\text{HBrO}_4$ , (c)  $\text{NH}_3$ , and (d)  $\text{H}_2\text{PO}_4^-$ . (*Obj 15*)

- $\text{HC}_2\text{O}_4^-$
- $\text{BrO}_4^-$
- $\text{NH}_2^-$
- $\text{HPO}_4^{2-}$

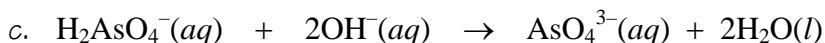
**Exercise 8.6 - Brønsted-Lowry Acids and Bases:** Identify the Brønsted-Lowry acid and base in each of the following equations. (*Obj 18*)



**B/L acid**            **B/L base**



**B/L base**            **B/L acid**



**B/L acid**            **B/L base**

## Review Questions Key

1. Define the following terms.

- aqueous

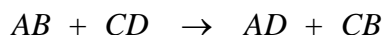
*Water solutions are called aqueous solutions.*

- spectator ion

*Ions that are important for delivering other ions into solution to react, but do not actively participate in the reaction themselves are called spectator ions.*

- double-displacement reaction

*A chemical reaction that has the following form is called a double-displacement reaction.*



d. net ionic equation

*A net ionic equation is a chemical equation for which the spectator ions have been eliminated, leaving only the substances actively involved in the reaction.*

- Write the name of the polyatomic ions represented by the formulas  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$ .
  - $\text{CO}_3^{2-}$  **carbonate**
  - $\text{HCO}_3^-$  **hydrogen carbonate**
- Write the formulas for the polyatomic ions dihydrogen phosphate ion and acetate ion.
  - dihydrogen phosphate ion  **$\text{H}_2\text{PO}_4^-$**
  - acetate ion  **$\text{C}_2\text{H}_3\text{O}_2^-$**
- Which of the following formulas represent an ionic compound?
  - $\text{MgCl}_2$  **ionic**
  - $\text{PCl}_3$  **not ionic**
  - $\text{KHSO}_4$  **ionic**
  - $\text{Na}_2\text{SO}_4$  **ionic**
  - $\text{H}_2\text{SO}_3$  **not ionic**
- Write the names that correspond to the formulas  $\text{KBr}$ ,  $\text{Cu}(\text{NO}_3)_2$ , and  $(\text{NH}_4)_2\text{HPO}_4$ .
  - $\text{KBr}$  **potassium bromide**
  - $\text{Cu}(\text{NO}_3)_2$  **copper(II) nitrate**
  - $(\text{NH}_4)_2\text{HPO}_4$  **ammonium hydrogen phosphate**
- Write the formulas that correspond to the names nickel(II) hydroxide, ammonium chloride, and calcium hydrogen carbonate.
  - nickel(II) hydroxide  **$\text{Ni}(\text{OH})_2$**
  - ammonium chloride  **$\text{NH}_4\text{Cl}$**
  - calcium hydrogen carbonate  **$\text{Ca}(\text{HCO}_3)_2$**
- Predict whether each of the following is soluble or insoluble in water.
  - iron(III) hydroxide **insoluble**
  - barium sulfate **insoluble**
  - aluminum nitrate **soluble**
  - copper(II) chloride **soluble**
- Describe how the strong monoprotic acid hydrochloric acid,  $\text{HCl}$  acts when it is added to water, including a description of the nature of the particles in solution before and after the reaction with water. If there is a reversible reaction with water, describe the forward and the reverse reactions.

*When  $\text{HCl}$  molecules dissolve in water, each  $\text{HCl}$  molecule donates a proton,  $\text{H}^+$ , to water forming a hydronium ion,  $\text{H}_3\text{O}^+$ , and a chloride ion,  $\text{Cl}^-$ . This reaction goes to completion, and the solution of the  $\text{HCl}$  contains essentially no uncharged acid molecules. Once the chloride ion and the hydronium ion are formed, the negatively charged oxygen atoms of the water molecules surround the hydronium ion and the positively charged hydrogen atoms of the water molecules surround the chloride ion. Figure 6.2 shows you how you can picture this solution.*

- Describe how the weak monoprotic acid acetic acid,  $\text{HC}_2\text{H}_3\text{O}_2$ , acts when it is added to water, including a description of the nature of the particles in solution before and after the reaction with water. If there is a reversible reaction with water, describe the forward and the reverse reactions.

*When an acetic acid molecule,  $\text{HC}_2\text{H}_3\text{O}_2$ , collides with an  $\text{H}_2\text{O}$  molecule, an  $\text{H}^+$  can be transferred to the water to form a hydronium ion,  $\text{H}_3\text{O}^+$ , and an acetate ion,  $\text{C}_2\text{H}_3\text{O}_2^-$ . The  $\text{C}_2\text{H}_3\text{O}_2^-$  ions formed in solution reverse the change by reacting with the hydronium ions and pulling  $\text{H}^+$  ions back to reform  $\text{HC}_2\text{H}_3\text{O}_2$  and  $\text{H}_2\text{O}$ . The forward and reverse reactions take place constantly, and soon after the addition of  $\text{HC}_2\text{H}_3\text{O}_2$  to water, they proceed at an equal rate. There is no net change in the amounts of the  $\text{HC}_2\text{H}_3\text{O}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{C}_2\text{H}_3\text{O}_2^-$ , or  $\text{H}_3\text{O}^+$  in the solution. See Figure 6.6.*

10. Describe the process by which the ionic compound sodium hydroxide dissolves in water.  
*When solid sodium hydroxide, NaOH, is added to water, all of the sodium ions, Na<sup>+</sup>, and hydroxide ions, OH<sup>-</sup>, at the surface of the solid can be viewed as shifting back and forth between moving out into the water and returning to the solid surface. Sometimes when an ion moves out into the water, a water molecule collides with it, helping to break the ionic bond, and pushing it out into the solution. Water molecules move into the gap between the ion in solution and the solid and shield the ion from the attraction to the solid. The ions are kept stable and held in solution by attractions between them and the polar water molecules. The negatively charged oxygen ends of water molecules surround the sodium ions, and the positively charged hydrogen ends of water molecules surround the hydroxide ions. (See Figures 7.7 and 7.8 with OH<sup>-</sup> in the place of Cl<sup>-</sup>.)*
11. Write the complete equation for the precipitation reaction that takes place when water solutions of zinc chloride and sodium phosphate are mixed.
- $$3\text{ZnCl}_2(\text{aq}) + 2\text{Na}_3\text{PO}_4(\text{aq}) \rightarrow \text{Zn}_3(\text{PO}_4)_2(\text{s}) + 6\text{NaCl}(\text{aq})$$

## Key Ideas Answers

12. According to the modern version of the Arrhenius theory of acids and bases, a base is a substance that produces **hydroxide ions, OH<sup>-</sup>**, when it is added to water.
14. Compounds that contain hydroxide ions are often called **hydroxides**.
16. A weak base is a base that produces **fewer** hydroxide ions in water solution than there are particles of base dissolved.
18. Basic solutions have pH values **greater than 7**, and the more basic the solution is, the **higher** its pH.
20. When an Arrhenius acid is combined with an Arrhenius base, we say that they **neutralize** each other.
22. Most Arrhenius neutralization reactions, such as the reaction between nitric acid and sodium hydroxide, are **double-displacement** reactions.
24. A Brønsted-Lowry acid is a proton (H<sup>+</sup>) **donor**, a Brønsted-Lowry base is a proton **acceptor**, and a Brønsted-Lowry acid-base reaction is a proton **transfer**.
26. The conjugate base of a molecule or ion is the molecule or ion that forms when one H<sup>+</sup> ion is **removed**.
28. The **Brønsted-Lowry** system is often used to describe specific acid-base reactions, but the **Arrhenius** system is used to describe whether isolated substances are acids, bases, or neither.

## Problems Key

### Section 8.1 Strong and Weak Arrhenius Bases

30. Classify each of the following substances as a weak acid, strong acid, weak base, or strong base in the Arrhenius acid-base sense. (*Obj 5*)
- |                                   |                    |                    |                    |
|-----------------------------------|--------------------|--------------------|--------------------|
| a. H <sub>2</sub> CO <sub>3</sub> | <b>weak acid</b>   | e. NH <sub>3</sub> | <b>weak base</b>   |
| b. cesium hydroxide               | <b>strong base</b> | f. chlorous acid   | <b>weak acid</b>   |
| c. HF(aq)                         | <b>weak acid</b>   | g. HCl(aq)         | <b>strong acid</b> |
| d. sodium carbonate               | <b>weak base</b>   | h. benzoic acid    | <b>weak acid</b>   |

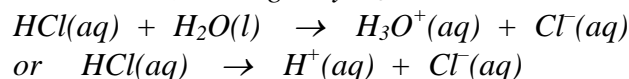
### Section 8.2 pH and Acidic and Basic Solutions

32. Classify each of the following solutions as acidic, basic, or neutral. (*Obj 6*)
- |                                       |  |
|---------------------------------------|--|
| a. tomato juice with a pH of 4.53     | pH < 7, so <b>acidic</b>   |
| b. milk of magnesia with a pH of 10.4 | pH > 7, so <b>basic</b>  |
| c. urine with a pH of 6.8             | pH about 7, so <b>essentially neutral (or more specifically, very slightly acidic)</b> |
34. Which is more acidic, carbonated water with a pH of 3.95 or milk with a pH of 6.3? (*Obj 7*)
- The lower the pH is, the more acidic the solution. **Carbonated water** is more acidic than milk.*
36. Identify each of the following characteristics as associated with acids or bases.
- |                                 |             |
|---------------------------------|-------------|
| a. tastes sour                  | <b>acid</b> |
| b. turns litmus red             | <b>acid</b> |
| c. reacts with HNO <sub>3</sub> | <b>base</b> |

### Section 8.3 Arrhenius Acid-Base Reactions

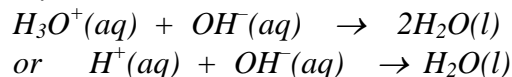
38. Describe the process that takes place between the participants in each of the following neutralization reactions, mentioning the nature of the particles in the solution before and after the reaction. The strong acid hydrochloric acid, HCl(aq), and the strong base sodium hydroxide, NaOH(aq), form water and sodium chloride, NaCl(aq). (*Obj 10A*)

*Because hydrochloric acid, HCl(aq), is an acid, it reacts with water to form hydronium ions, H<sub>3</sub>O<sup>+</sup>, and chloride ions, Cl<sup>-</sup>. Because it is a strong acid, the reaction is a completion reaction, leaving only H<sub>3</sub>O<sup>+</sup> and Cl<sup>-</sup> in solution with no HCl remaining.*



*Because NaOH is a water-soluble ionic compound, it separates into sodium ions, Na<sup>+</sup>, and hydroxide ions, OH<sup>-</sup>, when it dissolves in water. Thus, at the instant that the two solutions are mixed, the solution contains water molecules, hydronium ions, H<sub>3</sub>O<sup>+</sup>, chloride ions, Cl<sup>-</sup>, sodium ions, Na<sup>+</sup>, and hydroxide ions, OH<sup>-</sup>.*

*When the hydronium ions collide with the hydroxide ions, they react to form water. If an equivalent amount of acid and base are added together, the H<sub>3</sub>O<sup>+</sup> and the OH<sup>-</sup> will be completely reacted.*



*The sodium ions and chloride ions remain in solution with the water molecules.*

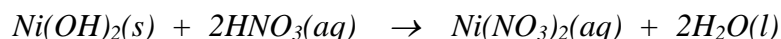


40. Describe the process that takes place between the participants in each of the following neutralization reactions, mentioning the nature of the particles in the solution before and after the reaction. The strong acid nitric acid,  $\text{HNO}_3(\text{aq})$ , and water-insoluble nickel(II) hydroxide,  $\text{Ni}(\text{OH})_2(\text{s})$ , form nickel(II) nitrate,  $\text{Ni}(\text{NO}_3)_2(\text{aq})$ , and water. (Obj 10B)

*A solution with an insoluble ionic compound, such as  $\text{Ni}(\text{OH})_2$ , at the bottom has a constant escape of ions from the solid into the solution balanced by the constant return of ions to the solid due to collisions of ions with the surface of the solid. Thus, even though  $\text{Ni}(\text{OH})_2$  has very low solubility in water, there are always a few  $\text{Ni}^{2+}$  and  $\text{OH}^-$  ions in solution.*

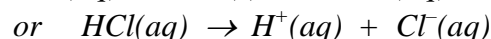
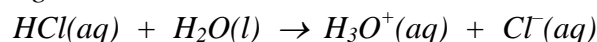
*If a nitric acid solution is added to water with solid  $\text{Ni}(\text{OH})_2$  at the bottom, a neutralization reaction takes place. Because the nitric acid is a strong acid, it is ionized in solution, so the nitric acid solution contains hydronium ions,  $\text{H}_3\text{O}^+$ , and nitrate ions,  $\text{NO}_3^-$ . The hydronium ions will react with the basic hydroxide ions in solution to form water molecules.*

*Because the hydronium ions remove the hydroxide anions from solution, the return of ions to the solid is stopped. The nickel(II) cations cannot return to the solid unless they are accompanied by anions to balance their charge. The escape of ions from the surface of the solid continues. When hydroxide ions escape, they react with the hydronium ions and do not return to the solid. Thus there is a steady movement of ions into solution, and the solid that contains the basic anion dissolves. The complete equation for this reaction is below.*

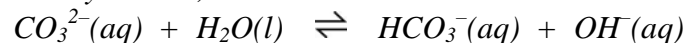


42. Describe the process that takes place between the participants in each of the following neutralization reactions, mentioning the nature of the particles in the solution before and after the reaction. The strong acid hydrochloric acid,  $\text{HCl}(\text{aq})$ , and the weak base potassium carbonate,  $\text{K}_2\text{CO}_3(\text{aq})$ , form water, carbon dioxide,  $\text{CO}_2(\text{g})$ , and potassium chloride,  $\text{KCl}(\text{aq})$ . (Obj 10C)

*Because hydrochloric acid,  $\text{HCl}(\text{aq})$ , is an acid, it reacts with water to form hydronium ions,  $\text{H}_3\text{O}^+$ , and chloride ions,  $\text{Cl}^-$ . Because it is a strong acid, the reaction is a completion reaction, leaving only  $\text{H}_3\text{O}^+$  and  $\text{Cl}^-$  in an  $\text{HCl}(\text{aq})$  solution with no  $\text{HCl}$  remaining.*



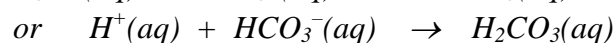
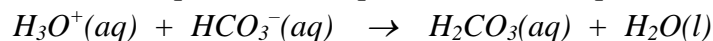
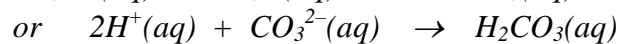
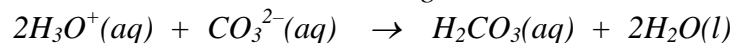
*Because  $\text{K}_2\text{CO}_3$  is a water-soluble ionic compound, it separates into potassium ions,  $\text{K}^+$ , and carbonate ions,  $\text{CO}_3^{2-}$ , when it dissolves in water. The carbonate ions are weakly basic, so they react with water in a reversible reaction to form hydrogen carbonate,  $\text{HCO}_3^-$  and hydroxide,  $\text{OH}^-$ .*



*Thus, at the instant that the two solutions are mixed, the solution contains water molecules, hydronium ions,  $\text{H}_3\text{O}^+$ , chloride ions,  $\text{Cl}^-$ , potassium ions,  $\text{K}^+$ , carbonate ions,  $\text{CO}_3^{2-}$ , hydrogen carbonate ions,  $\text{HCO}_3^-$ , and hydroxide ions,  $\text{OH}^-$ .*

*The hydronium ions react with hydroxide ions, carbonate ions, and hydrogen carbonate ions. When the hydronium ions collide with the hydroxide ions, they react to form water. When the hydronium ions collide with the carbonate ions or hydrogen carbonate ions, they react to form carbonic acid,  $\text{H}_2\text{CO}_3$ . The carbonate with its minus two charge*

requires two  $H^+$  ions to yield a neutral compound, and the hydrogen carbonate requires one  $H^+$  to neutralize its minus one charge.



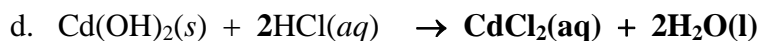
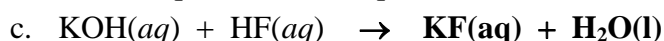
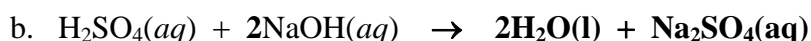
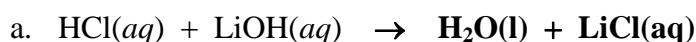
The carbonic acid is unstable in water and decomposes to form carbon dioxide gas and water.



If an equivalent amount of acid and base are added together, the  $H_3O^+$ ,  $OH^-$ ,  $CO_3^{2-}$ , and  $HCO_3^-$ , will be completely reacted.

The potassium ions and chloride ions remain in solution with the water molecules.

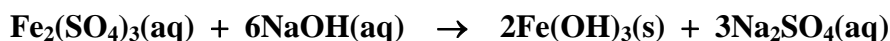
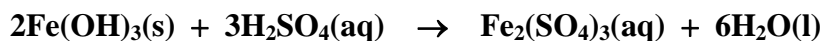
44. Write the complete equation for the neutralization reactions that take place when the following water solutions are mixed. (If an acid has more than one acidic hydrogen, assume that there is enough base to remove all of them. Assume that there is enough acid to neutralize all of the basic hydroxide ions.) (*Obj 11*)



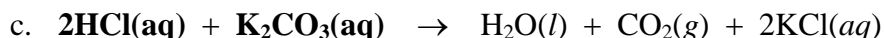
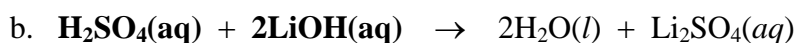
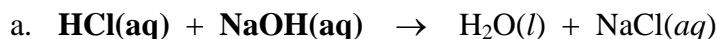
46. Write the complete equation for the reaction between  $HI(aq)$  and water-insoluble solid  $CaCO_3$ . (*Obj 11 & 12*)



48. Iron(III) sulfate is made in industry by the neutralization reaction between solid iron(III) hydroxide and aqueous sulfuric acid. The iron(III) sulfate is then added with sodium hydroxide to municipal water in water treatment plants. These compounds react to form a precipitate that settles to the bottom of the holding tank, taking impurities with it. Write the complete equations for both the neutralization reaction that forms iron(III) sulfate and the precipitation reaction between water solutions of iron(III) sulfate and sodium hydroxide. (*Obj 11*)

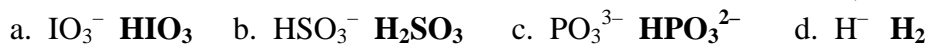


50. Complete the following equations by writing the formulas for the acid and base that could form the given products.

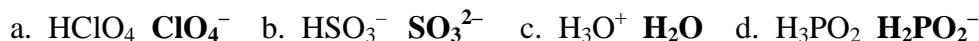


## Section 8.4 Brønsted-Lowry Acids and Bases

53. Write the formula for the conjugate acid of each of the following. (Obj 14)

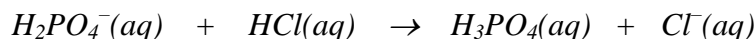


55. Write the formula for the conjugate base of each of the following. (Obj 15)



57. Explain why a substance can be a Brønsted-Lowry acid in one reaction and a Brønsted-Lowry base in a different reaction. Give an example to illustrate your explanation. (Obj 16)

*The same substance can donate an  $\text{H}^+$  in one reaction (and act as a Brønsted-Lowry acid) and accept an  $\text{H}^+$  in another reaction (and act as a Brønsted-Lowry base). For example, consider the following net ionic equations for the reaction of dihydrogen phosphate ion.*

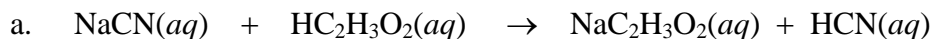


**B/L base**                      **B/L acid**

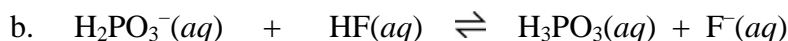


**B/L acid**                      **B/L base**

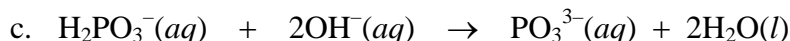
59. For each of the following equations, identify the Brønsted-Lowry acid and base for the forward reaction. (Obj 18)



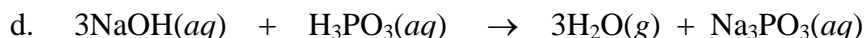
**B/L base**                      **B/L acid**



**B/L base**                      **B/L acid**



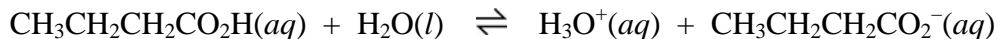
**B/L acid**                      **B/L base**



**B/L base**                      **B/L acid**

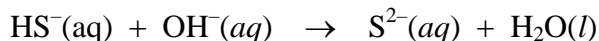
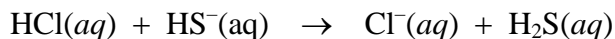
61. Butanoic acid,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ , is a monoprotic weak acid that is responsible for the smell of rancid butter. Write the formula for the conjugate base of this acid. Write the equation for the reaction between this acid and water, and indicate the Brønsted-Lowry acid and base for the forward reaction. (The acidic hydrogen atom is on the right side of the formula.)

**Conjugate base - CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CO<sub>2</sub><sup>-</sup>**



**B/L acid**                      **B/L base**

63. Identify the amphoteric substance in each of the following equations.



**HS<sup>-</sup>(aq)**

