12

BASICS OF CHEMISTRY

LEARNING OBJECTIVES

After completing this chapter, you will be able to:

LO 1
List the difference between organic and inorganic chemistry.

LO 2
Categorize and give examples of different substances for each of the different states of matter: solid, liquid, and gas.

LO 3
Summarize, in your own words, oxidation–reduction (redox) reactions.

LO 4
Define the differences between pure substances and physical mixtures.

LO 5
Evaluate the differences among solutions, suspensions, and emulsions.

LO 6
Explain what pH is and how the pH scale works.

OUTLINE

W hat do you think about when someone mentions the word *chemistry*? Beakers of mixtures bubbling in a lab? Test tubes filled with strange-looking liquids? Petri dishes growing fuzzy things? Most cosmetology services depend on the use of chemicals. So, studying the basics of chemistry means that you will have the knowledge you need to understand the products that you are using in the salon to give your clients the professional services they deserve.

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why study CHEMISTRY?

Cosmetologists should study and have a thorough understanding of chemistry because:

> Without an understanding of basic chemistry, you would not be able to use professional products effectively and safely.

> Every product used in the salon and in cosmetology services contains some type of chemical.

> With an understanding of chemistry, you will be able to troubleshoot and solve common problems you may encounter with chemical services.

After reading the next few sections, you will be able to:

LO1 List the difference between organic and inorganic chemistry.

Recognize How the Science of Chemistry Influences Cosmetology

Chemistry is the science that deals with the composition, structures, and properties of matter and how matter changes under different conditions.

Organic chemistry is the study of substances that contain the element carbon. All living things or things that were once alive, whether they are plants or animals, contain carbon. Organic compounds can contain other elements like nitrogen and oxygen, but it is the bond between carbon and hydrogen that makes it organic. Organic substances that contain both carbon and hydrogen can burn. Although the term *organic* is often used to mean safe or natural because of its association with living things such as foods or food ingredients, not all organic substances are natural, healthy, or safe.

You may be surprised to learn that gasoline, motor oil, plastics, synthetic fabrics, pesticides, and fertilizers are all organic substances.

All hair color products, chemical texturizers, shampoos, conditioners, styling aids, nail enhancements, and skin care products are organic chemicals. So remember, the word *organic*, as applied to chemistry, does not mean natural or healthy; it means that the material contains both carbon and hydrogen from either natural or synthetic sources.

Inorganic chemistry is the study of substances that do not contain the element carbon but may contain the element hydrogen. Most inorganic substances do not burn because they do not contain carbon. Inorganic substances are not, and never were, alive. Metals, minerals, glass, water, and air are inorganic substances. Pure water and oxygen are inorganic, yet they are essential to life. Hydrogen peroxide, hydroxide hair relaxers, titanium dioxide, and zinc oxide in sun protection creams are inorganic substances.

Define Matter

Matter is any substance that occupies space and has mass (weight). All matter has physical and chemical properties and exists in the form of a solid, liquid, or gas. Since matter is made from chemicals, everything made out of matter is a chemical.

Matter has physical properties that we can touch, taste, smell, or see. In fact, everything you can touch and everything you can see—with the exception of light and electricity—is matter. All matter is made up of chemicals. You can see visible light and light that electrical sparks create, but these are not made of matter. Light and electricity are forms of energy and energy is not matter. Everything known to exist in the universe is either made of matter or energy. There are no exceptions to this rule.

Energy does not occupy space or have mass. Energy is discussed further in Chapter 13, Basics of Electricity. This chapter is dedicated to matter.

Elements

An **element** is the simplest form of chemical matter. It cannot be broken down into a simpler substance without a loss of identity. There are 118 known elements today and of these 98 occur naturally and the rest are produced by synthetic methods from nuclear reactions. All matter in the universe is made up of these elements and they have their own distinct physical and chemical

DID YOU KNOW?

Using the word *chemical* to describe something does not mean it is dangerous or harmful. Water and air are 100 percent chemicals. Even your body is completely composed of chemicals.

The vast majority of chemicals you come in contact with every day are safe and harmless. When chemicals do have the potential to cause harm, manufacturers are required to describe that potential harm on the packaging or label. There is no such thing as a chemical-free product, so do not be fooled by misleading marketing claims.

properties. Each element is identified by a letter symbol, such as *O* for oxygen, *C* for carbon, *H* for hydrogen, *N* for nitrogen, and *S* for sulfur. Symbols for all elements can be found in the Periodic Table of Elements in chemistry textbooks or by searching the Internet.

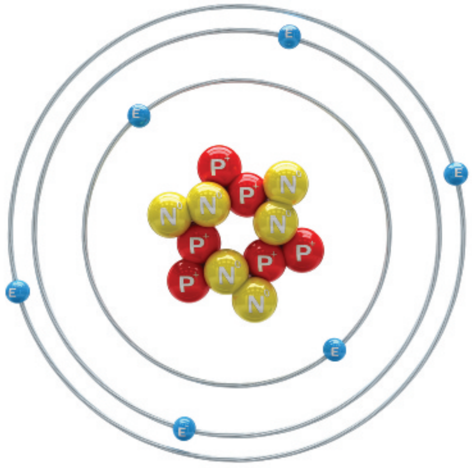

figure 12-1
Atomic structure of carbon with six protons, six neutrons, and six electrons

Atom

An **atom** is the basic unit of matter with a nucleus at the center surrounded by negatively charged **electrons** (E) that move around the nucleus in orbits. The nucleus consists of **protons** (P) (subatomic particles with a positive charge) and **neutrons** (N) (subatomic particles with no charge) and the number of protons determines the element. Atoms cannot be divided into simpler substances by ordinary chemical means. Figure 12-1 shows the atomic structure of carbon with six protons and six neutrons at the nucleus and six electrons in the orbit.

Molecules

Just as words are made by combining letters, molecules are made by combining atoms. A **molecule** (MAHL-uh-kyool) is a chemical combination of two or more atoms in definite (fixed) proportions. For example, water is made from hydrogen atoms and oxygen atoms. Carbon dioxide is made from carbon atoms and oxygen atoms.

Atmospheric oxygen and other chemical substances, such as nitrogen and water vapor, make up the air you breathe. This type of oxygen is called an **elemental molecule** (EL-uh-men-tul MAHL-uh-kyool), a molecule containing two or more atoms of the same element (in this case, oxygen) in definite (fixed) proportions. It is written as O_2. Ozone is another elemental molecule made up of oxygen. Ozone is a major component of smog and can be very dangerous. It contains three atoms of the element oxygen and is written as O_3 (figure 12-2).

Compound molecules (KAHM-pownd MAHL-uh-kyools), also known as *compounds*, are a chemical combination of two or more atoms of different elements in definite (fixed) proportions (figure 12-3). Sodium chloride (NaCl), common table salt, is an example of compound molecules. Each sodium chloride molecule contains one atom of the element sodium (Na) and one atom of the element chlorine (Cl).

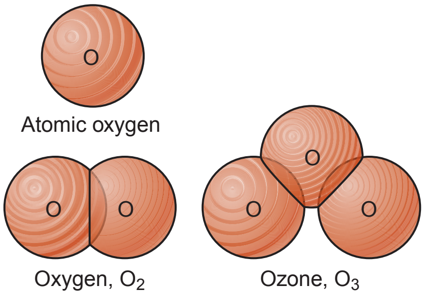

figure 12-2
Elemental molecules contain two or more atoms of the same element in definite (fixed) proportions.

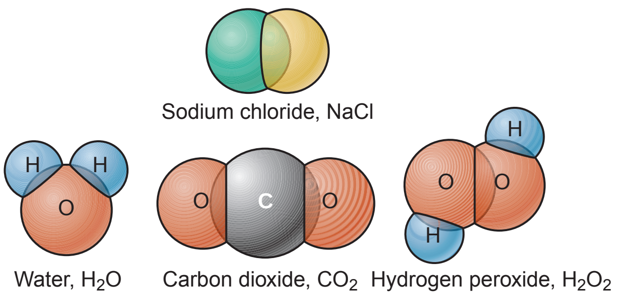

figure 12-3
Compound molecules contain two or more atoms of different elements in definite (fixed) proportions.

After reading the next few sections, you will be able to:

LO2 **Describe and give examples of different substances for each of the different states of matter: solid, liquid, and gas.**

States of Matter

All matter exists in one of three different physical forms:

- Solid
- Liquid
- Gas

These three forms are called the **states of matter**. Matter (**table 12-1**) becomes one of these states, depending on its temperature (**figure 12-4**).

Like many other substances, water (H_2O) can exist in all three states of matter, depending on its temperature. For example, water changes according to how the temperature changes, but it is still water. When water freezes, it turns to ice. When ice melts, it turns back into water. When water boils, it turns to steam. When the steam cools, it turns back into water. The water stays the same chemical, but it becomes a different physical form. When one chemical changes its state of matter, the change is called a physical change. (See Physical and Chemical Changes in this chapter.)

Vapor is a liquid that has evaporated into a gas-like state. Vapors can return to being a liquid when they cool to room temperature, unlike a gas. Steam is an example of a vapor. Vapors are not a unique state of matter; they are liquids that have undergone a physical change.

Physical and Chemical Properties of Matter

Every substance has unique properties that allow us to identify it. The two types of properties are physical and chemical.

Physical properties are characteristics that can be determined without a chemical reaction and that do not involve a chemical change in the substance.

table 12-1

STATES OF MATTER

State	Description	Examples
Solid	Rigid; has a fixed shape and volume.	Brush, roller, wooden nail pusher, ice
Liquid	Definite volume but takes the shape of its container.	Bleach, shampoo, haircolor, water
Gas	No fixed volume or shape; takes the shape and volume of its container. Can never be liquid at normal temperatures or pressures.	Propellant in hairspray, mousse, propane

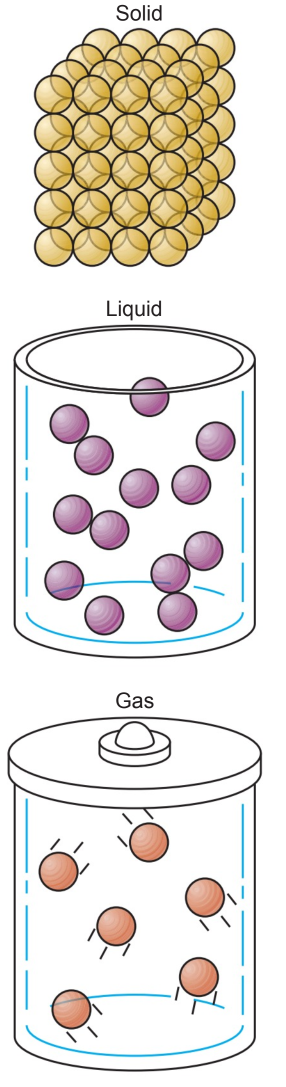

figure 12-4
Solid, liquid, and gas states of matter

Physical properties include color, solubility, odor, density, melting point, boiling point, hardness, and glossiness. (As described above, the state of matter that a substance becomes is an example of a physical property.)

Chemical properties are characteristics that can only be determined by a chemical reaction and a chemical change in the substance. Examples of chemical properties include the ability of iron to rust, wood to burn, or hair to change color through the use of haircolor and hydrogen peroxide.

After reading the next few sections, you will be able to:

LO3 Summarize, in your own words, oxidation–reduction (redox) reactions.

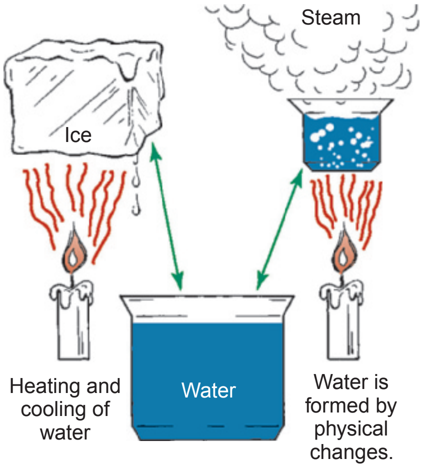

figure 12-5
Physical changes

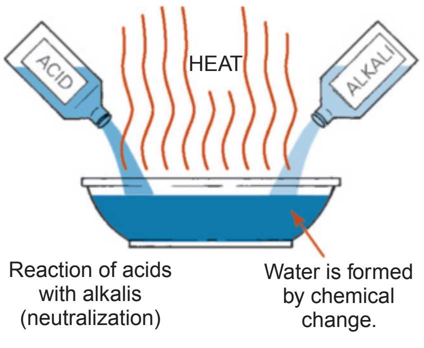

figure 12-6
Chemical changes

Physical and Chemical Changes

Matter can be changed in two different ways. Physical forces cause physical changes and chemical reactions cause chemical changes.

A **physical change** is a change in the form or physical properties of a substance, without a chemical reaction or the creation of a new substance. No chemical reactions are involved in physical change and no new chemicals are formed. Solid ice undergoes a physical change when it melts into water and then converts into steam when heat is applied (figure 12-5). A physical change occurs when nail polish is applied onto nails and the solvent evaporates, forming a layer or film on the nail.

A **chemical change** is a change in the chemical composition or make-up of a substance. This change is caused by chemical reactions that create new chemical substances, usually by combining or subtracting certain elements. Those new substances have different chemical and physical properties (figure 12-6). An example of a chemical change is the **oxidation** (ahk-sih-DAY-shun) of hair color. The term *oxidation* refers to a chemical reaction that combines a substance with oxygen to produce an oxide. Another example is the oxidation of melanin pigments in hair by hydrogen peroxide in lightening processes.

Oxidation–reduction, also known as *redox* (ree-DOCS), is a chemical reaction in which oxidation and reduction take place at the same time. When oxygen is chemically combined with a substance, the substance is oxidized. When oxygen is chemically removed from a substance, the substance is reduced.

? DID YOU KNOW?

Depilatory products are designed to help people to remove unwanted hair. The primary active ingredient in these types of cosmetics is some version of thioglycolic acid. The acid reacts with the cystine amino acids in hair and breaks down the S-S linkages. The hair is reduced to a jelly-like mass that can then be wiped away. This is an example of a chemical reaction.

An **oxidizing agent** is a substance that releases oxygen. Hydrogen peroxide (H_2O_2), which can be thought of as water with an extra atom of oxygen, is an example of an oxidizing agent. A **reducing agent** is a substance that adds hydrogen to a chemical compound or subtracts oxygen from the compound. When hydrogen peroxide is mixed with an oxidation haircolor, oxygen is subtracted from the hydrogen peroxide and the hydrogen peroxide is reduced. At the same time, oxygen is added to the haircolor and the haircolor is oxidized. In this example, haircolor is the reducing agent.

So far, we have considered oxidation only as the addition of oxygen and reduction only as loss of oxygen. Although the first known oxidation reactions involved oxygen, many oxidation reactions do not involve oxygen. Oxidation also results from loss of hydrogen and reduction also results from addition of hydrogen (figure 12-7). Redox reactions are also responsible for the chemical changes created by haircolors, hair lighteners, permanent wave solutions, and thioglycolic acid neutralizers. These chemical services would not be possible without oxidation–reduction (redox) reactions.

OXIDATION	REDUCTION
+ Oxygen	− Oxygen
− Hydrogen	+ Hydrogen

figure 12-7
Chart of oxidation and reduction reactions

Under certain circumstances, chemical reactions can release a significant amount of heat. These types of chemical reactions are called **exothermic reactions** (ek-soh-THUR-mik ree-AK-shunz). In fact, all oxidation reactions are exothermic reactions. An example of an exothermic reaction is a nail product that hardens (polymerizes) to create nail enhancements. Exothermic reactions occur but usually clients cannot feel the heat being released.

Combustion (kum-BUS-chun) is the rapid oxidation of a substance accompanied by the production of heat and light. Lighting a match is an example of rapid oxidation. Oxidation requires the presence of oxygen; this is the reason that there cannot be a fire without air.

After reading the next few sections, you will be able to:

LO4 Explain the differences between pure substances and physical mixtures.

Pure Substances and Physical Mixtures

All matter can be classified as either a pure substance or a physical mixture (blend).

A **pure substance** is a chemical combination of matter in definite (fixed) proportions. Pure substances have unique properties. Aluminum foil is an example of a pure substance. It has only atoms of the element aluminum. Most substances do not exist in a pure state. Air contains many substances, including nitrogen, carbon dioxide, and water vapor. This is an example of a physical mixture. A **physical mixture** is a physical combination of matter in any proportion. The properties of a physical mixture are the combined properties of the substances in the mixture. Salt water is a physical mixture of salt and water in any proportion. The properties of salt water are the properties contained in salt and in water: Salt water is salty and wet. Most of the products cosmetologists and nail technicians use are physical mixtures (figure 12-8).

figure 12-8
Examples of pure substances and physical mixtures

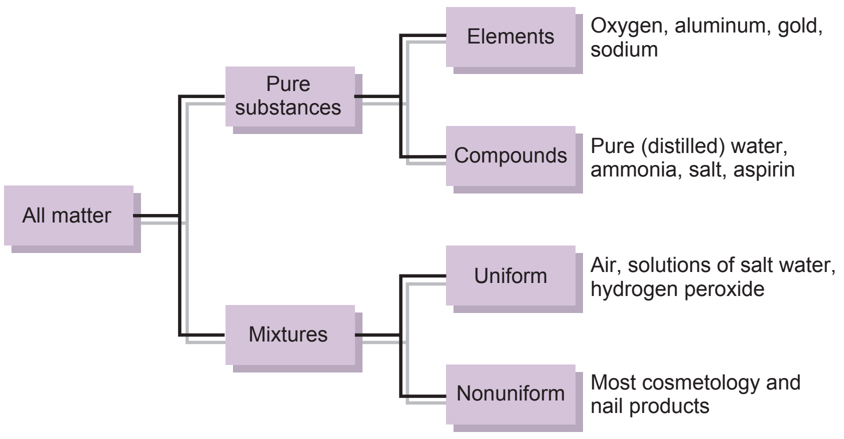

Table 12-2 summarizes the differences between pure substances and physical mixtures.

After reading the next few sections, you will be able to:

LO5 **Explain the differences among solutions, suspensions, and emulsions.**

Solutions, Suspensions, and Emulsions

Solutions, suspensions, and emulsions are all physical mixtures. The differences among solutions, suspensions, and emulsions are determined by the types of substances, the size of the particles, and the solubility of the substances.

- A **solution** is a stable physical mixture of two or more substances in a solvent. The **solute** (SAHL-yoot) is the substance that is dissolved into solution. The **solvent** (SAHL-vent) is the substance that dissolves the solute and makes the solution. For example, when salt is dissolved in water, salt is the solute and water is the solvent. Water is known as a universal solvent because it has the ability to dissolve more substances than any other solvent.

table 12-2

DIFFERENCES BETWEEN PURE SUBSTANCES AND PHYSICAL MIXTURES

Pure Substances	Physical Mixtures
United chemically	United physically
Definite (fixed) proportions	Any proportions
Unique chemical and physical properties	Combined chemical and physical properties
Salt and pure (distilled) water are examples of pure substances.	Salt water is a physical mixture.

ACTIVITY

Pour an ounce of a clear hair styling spay into a cup. Cover it loosely with a paper towel and set it aside for a week. What happens when the liquid evaporates? What does the residue look like? Touch and feel the residue. What is it made from? When styling compounds or polymers are dissolved in alcohol/water mixture, is it a physical or chemical change?

All liquids are either miscible or immiscible. **Miscible** (MIS-uh-bul) liquids are mutually soluble, meaning that they can be mixed together to form clear solutions. Water and alcohol are examples of miscible liquids as in a nail polish remover. When these substances are mixed together, they will stay mixed, forming a solution. Solutions contain small particles that are invisible to the naked eye. Solutions are usually transparent, although they may be colored. They do not separate when left still. Again, salt water is an example of a solution with a solid dissolved in a liquid. Water is the solvent that dissolves the salt (solute) and holds it in solution.

Immiscible (im-IS-uh-bul) liquids are not capable of being mixed together to form stable solutions. Water and oil are examples of immiscible liquids. These substances can be mixed together, but they will separate when left sitting still. When immiscible liquids are combined, they form suspensions.

- **Suspensions** (sus-PEN-shunz) are unstable physical mixtures of undissolved particles in a liquid. Compared with solutions, suspensions contain larger and fewer miscible particles. The particles are generally visible to the naked eye but are not large enough to settle quickly to the bottom. Suspensions are not usually transparent and may be colored. They are unstable and separate over time, which is why some lotions and creams can separate in the bottle and need to be shaken before they are used. Another example of a suspension is the glitter in nail polish that can separate from the polish.

  The suspension will separate when left sitting still and must be shaken before using. Calamine lotion and nail polish are other examples of suspensions.
- An **emulsion** (ee-MUL-shun) is an unstable physical mixture of two or more immiscible substances (substances that normally will not stay blended) plus a special ingredient called an emulsifier. An **emulsifier** (ee-MUL-suh-fy-ur) is an ingredient that brings two normally incompatible materials together and binds them into a uniform and fairly stable blend. Emulsions are considered to be a special type of suspension because they can separate, but the separation usually happens very slowly over a long period of time. An example of an emulsion is hand lotion. A properly formulated emulsion, stored under ideal conditions, can be stable up to three years. Since conditions are rarely ideal, all cosmetic emulsions should be used within one year of purchase. Always refer to the product's instructions and cautions for specific details.

DID YOU KNOW?

Soaps were the first synthetic surfactants. People began making soaps about 4,500 years ago by boiling oil or animal fat with wood ashes. Modern soaps are made from animal fats or vegetable oils. Traditional bar soaps are highly alkaline and combine with the minerals in hard water to form an insoluble film that coats skin and can cause hands to feel dry, itchy, and irritated. Cosmetologists who are performing nail services should be aware that soaps can leave a film on the nail plate, which could contribute to lifting of the nail enhancement. Modern synthetic surfactants have overcome these disadvantages and are superior to soaps; many are milder on the skin than soaps used in the past.

table 12-3

DIFFERENCES AMONG SOLUTIONS, SUSPENSIONS, AND EMULSIONS

Solutions	Suspensions	Emulsions
Miscible	Slightly miscible	Immiscible
No surfactant	No surfactant	Surfactant
Small particles	Larger particles	Largest particles
Stable mixture	Unstable, temporary mixture	Limited stability through an emulsifier
Usually clear	Usually cloudy	Usually a solid color
Solution of nail primer	Nail polish, glitter in nail polish	Shampoos, conditioners, hand lotions

Table 12-3 offers a summary of the differences among solutions, suspensions, and emulsions.

Surfactants (sur-FAK-tants) are substances that allow oil and water to mix, or emulsify. They are one type of emulsifier. The term *surfactant* is a contraction for surface active agents—substances that allow oil and water to mix, or emulsify. A surfactant molecule has two distinct parts (**figure 12-9**): The head of the surfactant molecule is hydrophilic (hy-drah-FIL-ik), capable of combining with or attracting water (water-loving), and the tail is **lipophilic** (ly-puh-FIL-ik), having an affinity for or an attraction to fat and oils (oil-loving). Following the like-dissolves-like rule, the hydrophilic head dissolves in water and the lipophilic tail dissolves in oil. So a surfactant molecule mixes with and dissolves in both oil and water and temporarily joins them together to form an emulsion.

In an **oil-in-water (O/W) emulsion**, oil droplets are emulsified in water. The droplets of oil are surrounded by surfactant molecules with their lipophilic tails pointing in and their hydrophilic heads pointing out. Tiny oil droplets form the internal portion of each O/W emulsion because the oil is completely surrounded by water (**figure 12-10**). Oil-in-water emulsions do not feel as greasy as water-in-oil emulsions because the oil is hidden and water forms the external portion of the emulsion.

In a **water-in-oil (W/O) emulsion**, water droplets are emulsified in oil. The droplets of water are surrounded by surfactants with their hydrophilic heads pointing in and their lipophilic tails pointing out (**figure 12-11**).

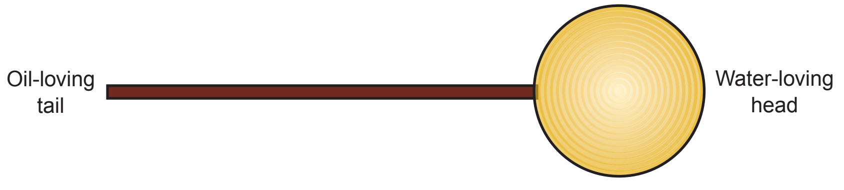

figure 12-9
A surfactant molecule

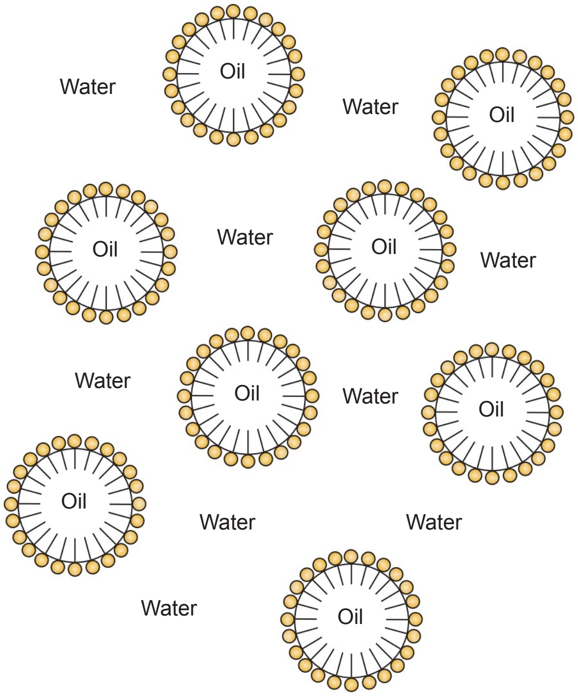

figure 12-10
Oil-in-water emulsions

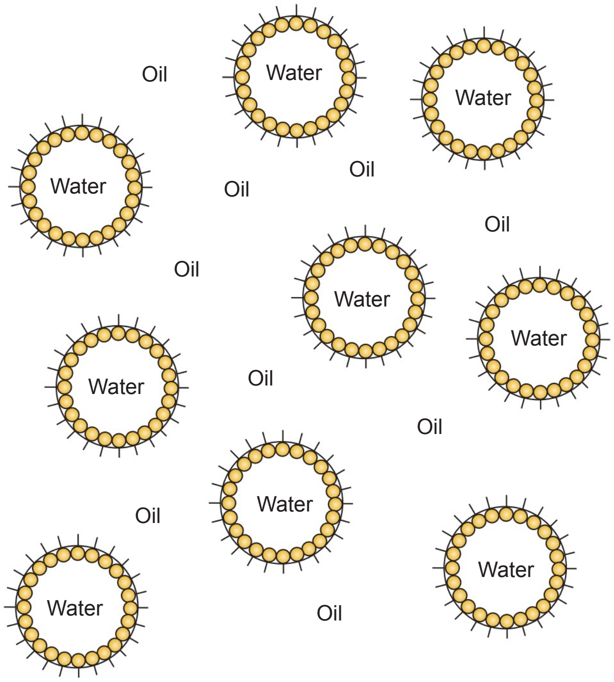

figure 12-11
Water-in-oil emulsions

Tiny droplets of water form the internal portion of a W/O emulsion because the water is completely surrounded by oil. Water-in-oil emulsions feel greasier than oil-in-water emulsions because the water is hidden and oil forms the external portion of the emulsion. Styling creams, cold creams, and foot balms are examples.

Other Physical Mixtures

Ointments, pastes, pomades, and styling waxes are semisolid mixtures made with any combination of petrolatum (petroleum jelly), oil, and wax.

Powders are a physical mixture of one or more types of solids. Off-the-scalp, powdered hair lighteners are physical mixtures. These mixtures may separate during shipping and storage and should be thoroughly mixed by shaking the container before each use.

ACTIVITY

Have you ever heard the saying "Oil and water don't mix"? Pour some water into a glass and then add a little cooking oil (or other oil). What happens? Stir the water briskly with a spoon and observe for a minute or two. What does the oil do?

Common Chemical Product Ingredients

Cosmetologists use many chemical products when performing client services. Following are some of the most common chemical ingredients used in salon products.

DID YOU KNOW?

Mayonnaise is an example of an oil-in-water emulsion of two immiscible liquids. Although oil and water are immiscible, the egg yolk in mayonnaise emulsifies the oil droplets and distributes them uniformly in the water. Without the egg yolk as an emulsifying agent, the oil and water would separate. Most of the emulsions used in a salon are oil-in-water. Haircolor, shampoos, conditioners, hand lotions, and facial creams are oil-in-water emulsions.

> **DID YOU KNOW?**
> Silicon (Si) is an atom like carbon (C) and oxygen (O) with a metallic appearance and is widely used in the electronics industry. Do not be confused with silicones which are compounds made with silicon and other elements. Silicones are used in a variety of personal care products including hair care, skin care, and nail care products.

- **Volatile alcohols** (VAHL-uh-tul AL-kuh-hawlz) are those that evaporate easily, such as isopropyl alcohol (rubbing alcohol) and ethyl alcohol (hairspray and alcoholic beverages). These chemicals are familiar to most people but there are many other types of alcohols, from free-flowing liquids to hard, waxy solids. Fatty alcohols, such as cetyl alcohol and cetearyl alcohol, are nonvolatile alcohol waxes that are used as skin conditioners.
- **Alkanolamines** (al-kan-oh-LAH-mynz) are alkaline substances used to neutralize acids or raise the pH of many hair products. They are often used in place of ammonia because they produce less odor.
- **Ammonia** (uh-MOH-nee-uh) is a colorless gas with a pungent odor that is composed of hydrogen and nitrogen. It is used to raise the pH in hair products to allow the solution to penetrate the hair shaft. Ammonium hydroxide and ammonium thioglycolate are examples of ammonia compounds that are used to perform chemical services in a salon.
- **Glycerin** (GLIS-ur-in) is a sweet, colorless, oily substance. It is used as a solvent and as a moisturizer in skin and body creams.
- **Silicones** (SIL-ih-kohnz) are a special type of oil used in hair conditioners, water-resistant lubricants for the skin, and nail polish dryers. Silicones are less greasy than other oils and form a breathable film that does not cause comedones (blackheads). Silicones also give skin a silky, smooth feeling and great shine to hair. Certain silicone resins (silicone gums) can withstand high pH environments and can be incorporated into relaxers and permanent wave formulations[i].
- **Volatile organic compounds (VOCs)** are compounds that contain carbon (organic) and evaporate very easily (volatile). For example, a common VOC used in hairspray is SD alcohol (ethyl alcohol). Volatile organic solvents such as ethyl acetate and isopropyl alcohol are used in nail polish, base and top coats, and polish removers.

After reading the next few sections, you will be able to:

LO6 Explain what pH is and how the pH scale works.

Understand Potential Hydrogen (pH) and How It Affects Hair, Skin, and Nails

Although **pH**, the abbreviation used for *potential hydrogen*, is often mentioned when talking about salon products, it is one of the least understood chemical properties. Notice that *pH* is written with a small *p* (which represents a quantity) and a capital *H* (which represents the hydrogen ion). The term *pH* represents the quantity of hydrogen ions. Understanding pH and how it affects the hair, skin, and nails is essential to understanding all salon services. For more information about the pH of products used in salon services, see Chapter 15, Scalp Care, Shampooing, and Conditioning, and Chapter 20, Chemical Texture Services.

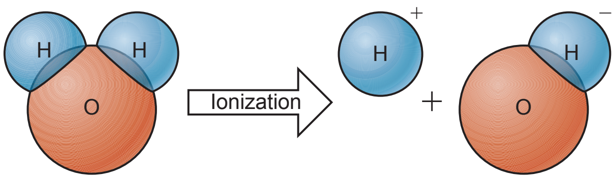

figure 12-12
The ionization of water

Water and pH

Before you can understand pH, you need to learn about ions. An **ion** (EYE-on) is an atom or molecule that carries an electrical charge. **Ionization** (eye-on-ih-ZAY-shun) is the separation of an atom or molecule into positive and negative ions. An ion with a negative electrical charge is an **anion** (AN-eye-on). An ion with a positive electrical charge is a **cation** (KAT-eye-on).

In water, some of the water (H_2O) molecules naturally ionize into hydrogen ions and hydroxide ions. The pH scale measures these ions. The hydrogen ion (H^+) is acidic. The more hydrogen ions there are in a substance, the more acidic it will be. The hydroxide ion (OH-) is alkaline. The more hydroxide ions there are in a substance, the more alkaline it will be. pH is only possible because of this ionization of water. Only products that contain water can have a pH.

In pure (distilled) water, each water molecule that ionizes produces one hydrogen ion and one hydroxide ion (**figure 12-12**). Pure water has a neutral pH because it contains the same number of hydrogen ions as hydroxide ions. It is an equal balance of 50 percent acidic and 50 percent alkaline. The pH of any substance is always a balance of both acidity and alkalinity. As acidity increases, alkalinity decreases. The opposite is also true; as alkalinity increases, acidity decreases. Even the strongest acid also contains some alkalinity.

The pH Scale

A **pH scale** is a measure of the acidity and alkalinity of a substance. It has a range of 0 to 14. A pH of 7 is a neutral solution, a pH below 7 indicates an **acidic solution**, and a pH above 7 indicates an **alkaline solution** (**figure 12-13**). The term **logarithm** (LOG-ah-rhythm) means multiples of 10.

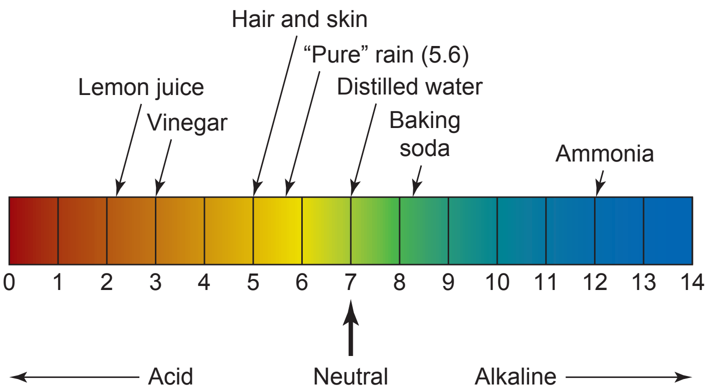

figure 12-13
The pH scale

Since the pH scale is a logarithmic scale, a change of one whole number represents a tenfold change in pH. This means, for example, that a pH of 8 is 10 times more alkaline than a pH of 7. A change of two whole numbers represents a change of 10 times 10, or a 100-fold change. So a pH of 9 is 100 times more alkaline than a pH of 7. Even a small change on the pH scale represents a large change in the pH.

pH is always a balance of both acidity and alkalinity. Pure water has a pH of 7, which is an equal balance of acid and alkaline. Although a pH of 7 is neutral on the pH scale, it is not neutral compared to the hair and skin, which have an average pH of 5. Pure (distilled) water, with a pH of 7, is 100 times more alkaline than a pH of 5, so pure water is 100 times more alkaline than your hair and skin. This difference in pH is the reason pure water can cause the hair to swell as much as 20 percent and the reason that water is drying to the skin.

Acids and Alkalis

All acids owe their chemical reactivity to the hydrogen ion. Acids have a pH below 7.0.

Alpha hydroxy acids (AHAs) (al-FAH HY-drok-see AS-udz), derived from plants (mostly fruit), are examples of acids often used in salons to exfoliate the skin and to help adjust the pH of a lotion, conditioner, or cream. Acids contract and close the hair cuticle. One such acid is **thioglycolic acid** (thy-oh-GLY-kuh-lik AS-ud), a colorless liquid or white crystals with a strong unpleasant odor that is used in permanent waving solutions. **Glycolic acid** is an alpha hydroxy acid used in exfoliation and to lower the pH of products.

All **alkalis** (AL-kuh-lyz), also known as *bases*, owe their chemical reactivity to the hydroxide ion. Alkalis are compounds that react with acids to form salts. Alkalis have a pH above 7.0. They feel slippery and soapy on the skin. Alkalis soften and swell hair, skin, the cuticle on the nail plate, and calloused skin.

Sodium hydroxide, commonly known as lye, is a very strong alkali used in chemical hair relaxers, callous softeners, and drain cleaners. These products must be used according to manufacturers' instructions, and it is very important that you do not let the products touch or sit on the skin as they may cause injury to or a burning sensation on the skin. Sodium hydroxide products may be especially dangerous if they get into the eyes, so always wear safety glasses to avoid eye contact. Consult the product's SDS for more specific information on safe use.

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ACTIVITY

For a product to have a pH, it must contain water. Shampoos, conditioners, haircolor, permanent waves, relaxers, lotions, and creams have a pH. Divide into groups and research these products online to find their pH. If the information is not available online, contact the manufacturers. Make a chart and compare your findings with what your classmates found. How will the pH of these products affect the hair?

Here is a hint to save you some time: Oils, waxes, and nail polish have no pH because they contain no water.

Acid-Alkali Neutralization Reactions

The same reaction that naturally ionizes water into hydrogen ions and hydroxide ions also runs in reverse. When acids and alkalis are mixed together in equal proportions, they neutralize each other to form water (**figure 12-14**). Neutralizing shampoos and normalizing lotions used to neutralize hair relaxers work by creating an acid-alkali neutralization reaction. Liquid soaps are usually slightly acidic and can neutralize alkaline callous softener residues left on the skin after rinsing.

Chemistry Will Help You in the Salon

Whether you are studying the pH of products, redox reactions, suspensions, solutions, or emulsions, there is a lot to learn about how chemistry affects the products you use in the salon. Having a basic understanding of chemistry will help you use professional products effectively and safely in the salon.

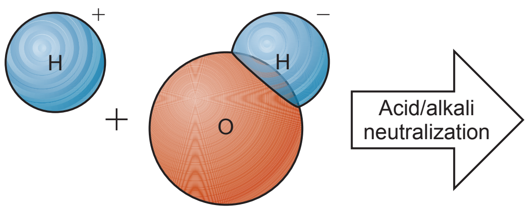

figure 12-14
Acid and alkali neutralization reaction

REVIEW QUESTIONS

1. What is chemistry?
2. Why is a basic understanding of chemistry important to a cosmetologist?
3. What are the differences among between organic and inorganic chemistry?
4. What is matter?
5. What is an element?
6. What are atoms?
7. Explain the difference between elemental molecules and compound molecules. Give examples.
8. Name and describe the three states of matter.
9. What are the physical and chemical properties of matter? Give examples.
10. What is the difference between physical and chemical change? Give examples.
11. Explain oxidation–reduction (redox).
12. Explain pure substances and physical mixtures. Give examples.
13. What are the differences among solutions, suspensions, and emulsions? Give examples.
14. Define pH and the pH scale.

STUDY TOOLS

- **Reinforce what you just learned:** Complete the activities and exercises in your Theory or Practical Workbook, or your Study Guide.
- **Expand your knowledge:** Search for websites about the topics in this chapter and make a list of additional resources.
- **Study and prepare for your quiz:** Take the chapter test in your Exam Review or your Milady U: Online Licensing Prep.
- **Re-Test your knowledge:** Take the Chapter 12 *Quizzes*!
- **Learn even more:** Look up in a dictionary or search the internet for the definitions of any additional terms you want to learn about.

CHAPTER GLOSSARY

acidic solution	p. 265	A solution that has a pH below 7.0 (neutral).
alkaline solution	p. 265	A solution that has a pH above 7.0 (neutral).
alkalis AL-kuh-lyz	p. 266	Also known as *bases*; compounds that react with acids to form salts.
alkanolamines al-kan-oh-LAH-mynz	p. 264	Alkaline substances used to neutralize acids or raise the pH of many hair products.
alpha hydroxy acids al-FAH HY-drok-see AS-udz	p. 266	Abbreviated AHAs; acids derived from plants (mostly fruit) that are often used to exfoliate the skin.
ammonia uh-MOH-nee-uh	p. 264	Colorless gas with a pungent odor that is composed of hydrogen and nitrogen.

anion AN-eye-on	p. 265	An ion with a negative electrical charge.
atoms	p. 256	The smallest chemical components (often called particles) of an element; structures that make up the element and have the same properties of the element.
cation KAT-eye-on	p. 265	An ion with a positive electrical charge.
chemical change	p. 258	A change in the chemical composition or make-up of a substance.
chemical properties	p. 258	Characteristics that can only be determined by a chemical reaction and a chemical change in the substance.
chemistry	p. 254	Science that deals with the composition, structures, and properties of matter and how matter changes under different conditions.
combustion kum-BUS-chun	p. 259	Rapid oxidation of a substance accompanied by the production of heat and light.
compound molecules KAHM-pownd MAHL-uh-kyools	p. 256	Also known as compounds; a chemical combination of two or more atoms of different elements in definite (fixed) proportions.
electrons	p. 256	Subatomic particles with a negative charge.
element	p. 255	The simplest form of chemical matter; an element cannot be broken down into a simpler substance without a loss of identity.
elemental molecule EL-uh-men-tul MAHL-uh-kyool	p. 256	Molecule containing two or more atoms of the same element in definite (fixed) proportions.
emulsifier ee-MUL-suh-fy-ur	p. 261	An ingredient that brings two normally incompatible materials together and binds them into a uniform and fairly stable blend.
emulsion ee-MUL-shun	p. 261	An unstable physical mixture of two or more immiscible substances (substances that normally will not stay blended) plus a special ingredient called an emulsifier.
exothermic reactions ek-soh-THUR-mik ree-AK-shunz	p. 259	Chemical reactions that release a significant amount of heat.
glycerin GLIS-ur-in	p. 264	Sweet, colorless, oily substance used as a solvent and as a moisturizer in skin and body creams.
glycolic acid	p. 266	An alpha hydroxy acid used in exfoliation and to lower the pH of products.
immiscible im-IS-uh-bul	p. 261	Liquids that are not capable of being mixed together to form stable solutions.
inorganic chemistry	p. 255	The study of substances that do not contain the element carbon, but may contain the element hydrogen.
ion EYE-on	p. 265	An atom or molecule that carries an electrical charge.
ionization eye-on-ih-ZAY-shun	p. 265	The separation of an atom or molecule into positive and negative ions.
lipophilic ly-puh-FIL-ik	p. 262	Having an affinity for or an attraction to fat and oils (oil-loving).

logarithm LOG-ah-rhythm	p. 265	Multiples of 10.
matter	p. 255	Any substance that occupies space and has mass (weight).
miscible MIS-uh-bul	p. 261	Liquids that are mutually soluble, meaning that they can be mixed together to form stable solutions.
molecule MAHL-uh-kyool	p. 256	A chemical combination of two or more atoms in definite (fixed) proportions.
neutrons	p. 256	Subatomic particles with no charge.
oil-in-water emulsion	p. 262	Abbreviated O/W emulsion; oil droplets emulsified in water.
organic chemistry	p. 254	The study of substances that contain the element carbon.
oxidation ahk-sih-DAY-shun	p. 258	A chemical reaction that combines a substance with oxygen to produce an oxide.
oxidation–reduction	p. 258	Also known as *redox* (ree-DOCS); a chemical reaction in which the oxidizing agent is reduced (by losing oxygen) and the reducing agent is oxidized (by gaining oxygen).
oxidizing agent	p. 259	Substance that releases oxygen.
pH	p. 264	The abbreviation used for potential hydrogen. pH represents the quantity of hydrogen ions.
pH scale	p. 265	A measure of the acidity and alkalinity of a substance; the pH scale has a range of 0 to 14, with 7 being neutral. A pH below 7 is an acidic solution; a pH above 7 is an alkaline solution.
physical change	p. 258	A change in the form or physical properties of a substance without a chemical reaction or the creation of a new substance.
physical mixture	p. 259	A physical combination of matter in any proportion.
physical properties	p. 257	Characteristics that can be determined without a chemical reaction and that do not cause a chemical change in the substance.
protons	p. 256	Subatomic particles with a positive charge.
pure substance	p. 259	A chemical combination of matter in definite (fixed) proportions.
reducing agent	p. 259	A substance that adds hydrogen to a chemical compound or subtracts oxygen from the compound.
silicones SIL-ih-kohnz	p. 264	Special type of oil used in hair conditioners, water-resistant lubricants for the skin, and nail polish dryers.
solute SAHL-yoot	p. 260	The substance that is dissolved in a solution.
solution	p. 260	A stable physical mixture of two or more substances.
solvent	p. 260	The substance that dissolves the solute and makes a solution.
states of matter	p. 257	The three different physical forms of matter: solid, liquid, and gas.
surfactants sur-FAK-tants	p. 262	A contraction of surface active agents; substances that allow oil and water to mix, or emulsify.
suspensions	p. 261	Unstable physical mixtures of undissolved particles in a liquid.

thioglycolic acid thy-oh-GLY-kuh-lik AS-ud	p. 266	A colorless liquid or white crystals with a strong unpleasant odor that is used in permanent waving solutions
volatile alcohols	p. 264	Alcohols that evaporate easily.
volatile organic compounds	p. 264	Abbreviated VOCs; compounds that contain carbon (organic) and evaporate very easily (volatile).
water-in-oil emulsion	p. 262	Abbreviated W/O emulsion; water droplets emulsified in oil.