Chapter 8

General Chemistry

Key Terms

Atoms
Chemical change
Chemical compounds
Chemistry
Compound molecules
Organic chemistry
Elemental molecules
Elements
Emulsions
Immiscible
Inorganic chemistry
Matter
Miscible
Mixtures
Molecules
Physical change
Pure substance
Solute
Solutions
Solvent
Suspensions
States of matter

Learning Objectives

After completing this chapter, you should be able to:

- Describe the classification and structure of matter.
- Understand the difference among solutions, suspensions, and emulsions.
- Explain how a physical change differs from a chemical change.
- List the properties of matter.

INTRODUCTION

Scientists refer to chemistry as the "Central Science" because it is essential to the study of all other sciences. Although you may not think so, chemistry is just as essential to hairstyling. None of the services performed in today's salon would be possible without chemistry.

Wet sets, thermal styling, permanent waving, and chemical hair relaxing rely on breaking and reforming the hair's side bonds with heat and chemicals (Chapter 13, Permanent Waving). All haircoloring services rely on chemicals. Chemical reactions develop the dye in oxidation haircolors and make it possible to lighten natural hair color (Chapter 12, Haircoloring). Maintaining healthy hair, skin, and scalp wouldn't be possible without the chemistry of shampoos and conditioners and there would be far fewer styling options without some type of setting lotion or hairspray (Chapter 10, Shampoos, Conditioners, and Styling Aids).

CHEMISTRY

Chemistry is the science of the structure and properties of matter and the changes it undergoes. There are two main branches of chemistry: organic chemistry and inorganic chemistry.

Organic Chemistry

Organic chemistry is the study of substances that contain the element carbon. All things that are, or ever were, alive contain carbon. You have probably heard the term organic incorrectly used to imply natural. That is a common mistake because of the association between the term organic and living, but organic does not mean natural. The term organic only means that the substance contains the element carbon. Most organic substances will burn. Plants, animals, gasoline, motor oil and plastics are all organic substances.

Inorganic Chemistry

Inorganic chemistry is the study of substances that do not contain carbon. Inorganic substances are not, and never were, alive. Inorganic substances will not burn. Metals, minerals, and ammonia are inorganic substances. The water we drink and the air we breathe are also inorganic. Inorganic does not mean unnatural or unhealthy.

MATTER

Matter is anything that has volume (occupies space) and mass (weight). Anything that you can see, touch, taste, and smell is matter. Although we can see visible light, color, and electric sparks, they are all forms of energy. Energy is not matter because it doesn't occupy space or have mass.

Elements

Elements are substances that cannot be separated into simpler substances by chemical means. There are 109 different elements known today and each has its own distinctive physical and chemical properties (Figs. 8-1 and 8-2). About 90 of the 109 elements occur naturally. The remaining elements have only been produced by artificial means. All the matter in the universe is made from these one hundred and nine different elements.

Atoms

Atoms are the basic building blocks of all matter. All matter is composed of atoms. An atom is the smallest particle of an element that retains the properties of that element. Atoms are the smallest units of matter and cannot be divided into simpler substances by chemical means. The word atom is derived from the Greek word *atomos*, which means indivisible.

Atoms are the structural units of the elements that makeup matter. The atoms of each element are different in structure from the atoms of all other elements. The structural differences of the 109 different atoms account for the 109 different elements and their properties.

Atoms can be compared to the letters of the alphabet (e.g., A, B, C, D). Each of the 26 letters in the English alphabet has a different structure that makes

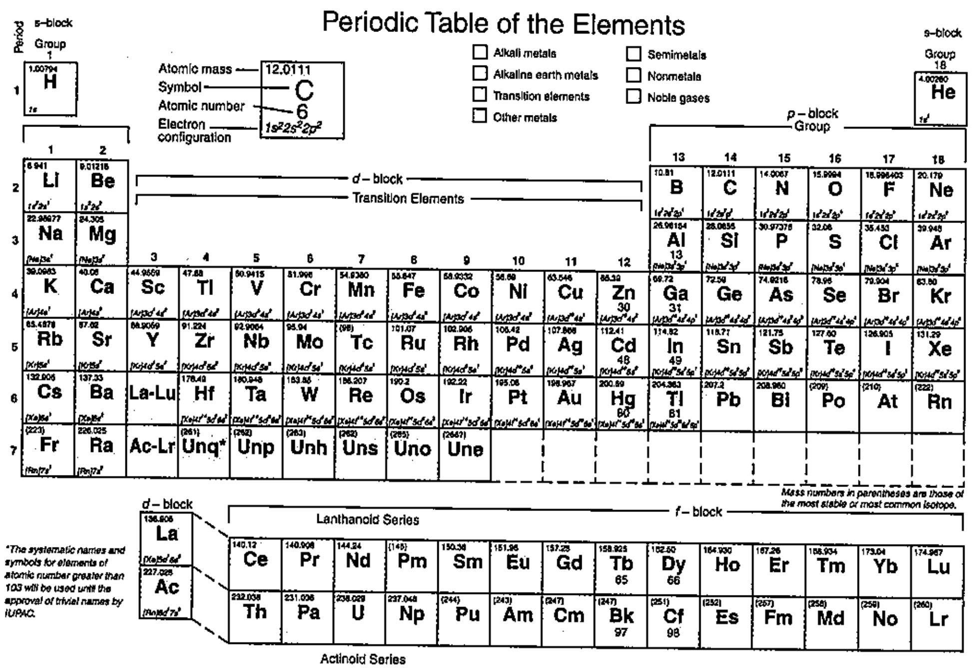


Figure 8-1 *Periodic table of the 109 known elements.*

Element	Symbol	Number	Element	Symbol	Number
Hydrogen	H	1	Barium	Ba	56
Helium	He	2	Lanthanum	La	57
Lithium	Li	3	Cerium	Ce	58
Beryllium	Be	4	Praseodymium	Pr	59
Boron	B	5	Neodymium	Nd	60
Carbon	C	6	Promethium	Pm	61
Nitrogen	N	7	Samarium	Sm	62
Oxygen	O	8	Europium	Eu	63
Fluoride	F	9	Gadolinium	Gd	64
Neon	Ne	10	Terbium	Tb	65
Sodium	Na	11	Dysprosium	Dy	66
Magnesium	Mg	12	Holmium	Ho	67
Aluminum	Al	13	Erbium	Er	68
Silicon	Si	14	Thulium	Tm	69
Phosphorus	P	15	Ytterbium	Yb	70
Sulfur	S	16	Lutetium	Lu	71
Chlorine	Cl	17	Hafnium	Hf	72
Argon	Ar	18	Tantalum	Ta	73
Potassium	K	19	Tungsten	W	74
Calcium	Ca	20	Thenium	Re	75
Scandium	Sc	21	Osmium	Os	76
Titanium	Ti	22	Irdium	Ir	77
Vanadium	V	23	Platinum	Pt	78
Chromium	Cr	24	Gold	Au	79
Manganese	Mn	25	Mercury	Hg	80
Iron	Fe	26	Thallium	Tl	81
Cabalt	Co	27	Lead	Pb	82
Nickel	Ni	28	Bismuth	Bi	83
Copper	Cu	29	Polonium	Po	84
Zinc	Zn	30	Astatine	At	85
Gallium	Ga	31	Radon	Rn	86
Germanium	Ge	32	Francium	Fr	87
Arsenic	As	33	Radium	Ra	88
Selenium	Se	34	Actinium	Ac	89
Bromine	Br	35	Thorium	Th	90
Krypton	Kr	36	Protactinium	Pa	91
Rubidium	Rb	37	Uranium	U	92
Strontium	Sr	38	Neptunium	Np	93
Yttrium	Y	39	Plutonium	Pu	94
Zirconium	Zr	40	Americium	Am	95
Niobium	Nb	41	Curium	Cm	96
Molybdenum	Mo	42	Berkelium	Bk	97
Technetium	Tc	43	Californium	Cf	98
Ruthenium	Ru	44	Eisteinium	Es	99
Rhodium	Rh	45	Fermium	Fm	100
Palladium	Pd	46	Mendelevium	Md	101
Silver	Ag	47	Nobelium	No	102
Cadmium	Cd	48	Lawrencium	Lr	103
Indium	In	49	Rutherfordium	Db	104
Tin	Sn	50	Dubnium	Db	105
Anitomy	Sb	51	Seaborgium	Sg	106
Tellurium	Te	52	Bohrium	Bh	107
Iodine	I	53	Hassium	Hn	108
Xenon	Xe	54	Meitnerium	Mt	109
Cesium	Cs	55			

Figure 8-2 *List of elements by atomic number.*

that letter different and identifies it. All the words in the English language are a combination of two or more of those 26 letters. All of the great works of American literature were written using only 26 different letters.

MOLECULES

Just as words are made by combining letters, molecules are made by combining atoms. Molecules are combinations of two or more atoms that are joined together chemically. The two types of molecules are: elemental molecules and compound molecules.

Elemental Molecules

Elemental molecules are chemical combinations of two or more atoms of the same element. When all the atoms that form a molecule are the same, the molecule is still an element and it is called an elemental molecule. The oxygen in the air that we breathe is the elemental molecule O_2, and the ozone in the atmosphere, that protects us from ultraviolet radiation, is the elemental molecule O_3. If molecules were like words in the English language, elemental molecules would look like this: AA, BBB, or CCCC.

Compound Molecules

Compound molecules are chemical combinations of two or more atoms of different elements. When two or more of the atoms that make a molecule are different, the molecule is a compound and called a compound molecule. Sodium chloride (NaCl), or common table salt, is a compound molecule that is a chemical combination of one atom of sodium (Na) and one atom of chlorine (Cl). If molecules were like words in the English language, compound molecules would look like this: AB, BAB, or CACC.

THE STATES OF MATTER

All matter exists in one of three different forms: solid, liquid, or gas. These three different physical forms are called the **states of matter**. The form in which matter appears is dependent on temperature.

Like most other substances, water (H_2O) can exist in all three states of matter, depending on its temperature. Ice turns to water as it melts and water turns to steam as it boils. The form of the water is different because of a change of state, but it is still water (H_2O). It is not a different chemical. It is the same chemical in a different form (Figs. 8-3 and 8-4).

Solids have a definite volume (size) and a definite shape. Ice is an example of a solid. Ice has a definite size and shape. Ice is solid water (H_2O) at a temperature of less than 32°F/0°C.

Liquids have a definite volume but not a definite shape. Water is an example of a liquid. Water has a definite size but does not have a definite shape. Water is liquid water (H_2O) at a temperature above 32°F/0°C and below 212°F/100°C.

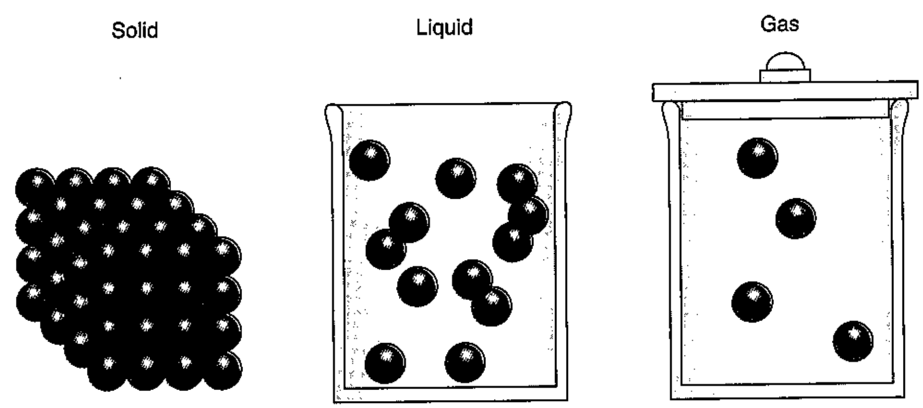


Figure 8-3 *The three states of matter, solid, liquid and gas.*
(Reprinted with permission of PADI Americas)

Gases don't have a definite volume or a definite shape. Steam is an example of a gas. Steam doesn't have a definite size or a definite shape. Steam is gaseous water (H_2O) at a temperature at or above 212°F/100°C.

PHYSICAL AND CHEMICAL PROPERTIES

Every substance has a unique set of properties that allow us to identify it. These properties of matter can be grouped into physical properties and chemical properties.

Physical Properties

Physical properties are those characteristics that can be determined without a chemical reaction and without a chemical change in the identity of the substance. Physical properties include color, odor, weight, density, melting point, boiling point, and hardness. The color and weight of an object can be observed without a chemical reaction or a chemical change in the identity of the substance.

Chemical Properties

Chemical properties are those characteristics that can only be determined with a chemical reaction and will cause a chemical change in the identity of the substance. Chemical properties include the ability of iron to rust and wood to burn. In both of these examples, oxidation is the chemical reaction that creates a chemical change in the identity of the substance. The iron is chemically changed to

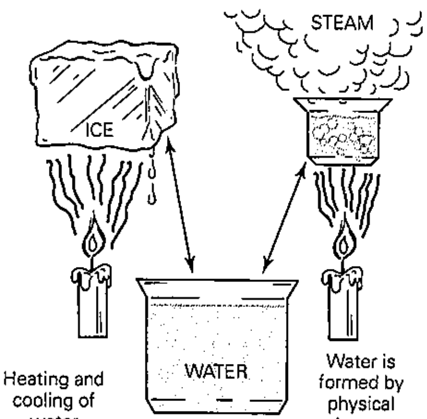
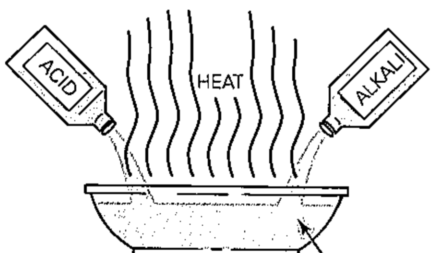
Types	Examples	Definition	Use in Cosmetology
PHYSICAL	 Heating and cooling of water Water is formed by physical changes.	Changes of a substance in form from solid-liquid-gas state. No new substance is formed. Action is easily reversible. Rate of change is simply controlled.	Setting, finger waving, etc. Hair is softened by setting agents – then hardened into waves by drying.
CHEMICAL	 Reaction of acids with alkalis (neutralization) Water is formed by chemical change.	Permanent changes with formation of new substances. Action is NOT easily reversible. Rate of change must be controlled by: a. Temperature b. Concentration c. Time d. pH of solution in contact with the hair	COLD WAVING Keratin in cortex is chemically changed by waving solutions. Waves made permanent by reaction of neutralizers on changed keratin. BLEACHING Bleaches react with hair pigments to reduce color. TINTING Reaction of developer with tint bases forms tint pigments.

Figure 8-4 *Physical and chemical changes. Acid-alkali neutralization.*

rust and the wood is chemically changed to charcoal. The rust and charcoal are the products of the chemical reaction. They are different chemicals with different properties.

PHYSICAL AND CHEMICAL CHANGES

Matter can be changed in two ways. Physical forces create physical changes and chemical reactions create chemical changes (Fig. 8-4).

Physical Change

A **physical change** is a change in the form, or the physical properties, of a substance. A physical change is the result of physical forces. A physical change does not involve a chemical reaction and no new chemicals are formed. A change of state is an example of a physical change. Solid ice undergoes a physical change when it melts to liquid water. This is a physical change because ice and water are the same chemical (H_2O). There is no chemical reaction and no new chemicals are formed.

Temporary haircolor is an example of a physical change. Temporary haircolor changes the appearance of the hair by physically adding color molecules to the surface of the hair. Although the hair appears to be a different color, there is no change in the chemical structure of the hair. There is no chemical reaction and no new chemicals are formed.

Chemical Change

A **chemical change** is a change in the chemical properties of a substance. A chemical change is the result of a chemical reaction. The products created by a chemical reaction are new chemicals. Oxidation is an example of a chemical reaction that causes a chemical change. Iron undergoes a chemical reaction and a chemical change when it rusts. The iron changes chemically, combining with oxygen from the air, to produce a new substance called rust. This is a chemical change because iron and rust are not the same chemical. This is a chemical reaction and a new chemical is formed.

Permanent hair color is an example of a chemical change. Permanent haircolor changes the chemical structure of the color by chemically developing the dye and chemically adding color to the internal structure of the hair. The hair is a different color because of changes in the chemical structure of both the dye and the hair. This is a chemical reaction and new chemicals are formed.

PURE SUBSTANCES, COMPOUNDS, AND MIXTURES

All matter can be classified into one of two categories: either a pure chemical substance or a physical mixture (Figs. 8-5 and 8-6).

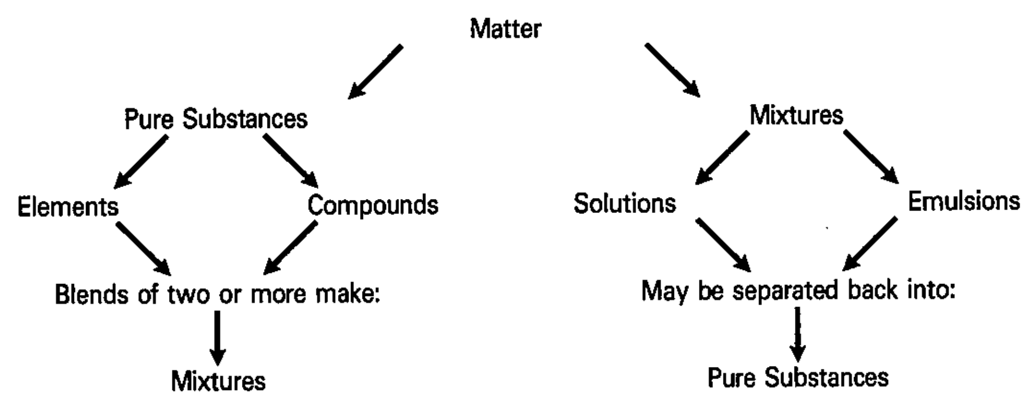


Figure 8-5 *Classification of Matter.*

Pure Substances

A **pure substance** is matter that has a fixed chemical composition, definite proportions, and distinct properties. Elements and chemical compounds are the two types of pure substances. Elemental molecules contain two or more atoms of the same element that are united chemically. Elemental molecules are pure substances. Aluminum foil is an example of a pure substance. Aluminum foil is composed only of atoms of the element aluminum. The properties of aluminum foil are the properties of the element aluminum.

Chemical Compounds

Chemical Compounds are combinations of two or more elements united chemically with a fixed chemical composition, definite proportions, and distinct properties. Chemical compounds are the result of a chemical reaction. The elements that are united in chemical compounds give up their own chemical identity and properties. The properties of chemical compounds are much different than the properties of the elements from which they were made.

Water (H_2O) is a chemical compound. A water molecule is composed of two atoms of the element hydrogen (H) and one atom of the element oxygen (O). These proportions are definite and any other combination is not water. When these two gases are joined together chemically they make the liquid, water. Water is a chemical compound with different properties than the elements oxygen and hydrogen from which it is made. Just like water, all chemical compounds are pure substances.

Mixtures

Mixtures are combinations of two or more substances united physically, without a fixed composition and in any proportions. Mixtures are not the result of a chemical

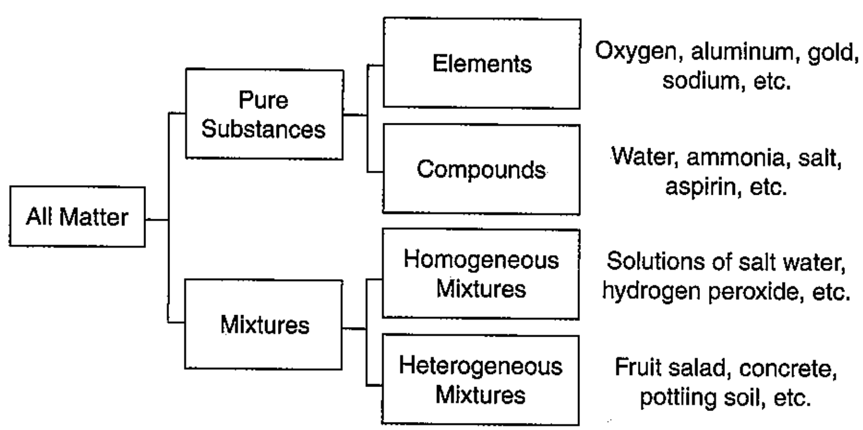


Figure 8-6 *Pure substances and mixtures.*

reaction. In a physical mixture, each substance retains its own identity and its own distinct properties. The properties of mixtures are a combination of the substances from which they are made. Pure air is a mixture of gases, mostly nitrogen and oxygen.

Fruit salad is a physical mixture of different types of fruits. Fruit salad can be made from many different types of fruits, mixed in any proportions. Fruit salad is a physical mixture. A chemical reaction is not involved and no new chemicals are formed. The properties of the fruit salad are the combined properties of the fruits in the mixture. The properties of the individual fruits are not changed; they are just mixed together. Although collectively it's fruit salad, we can still identify each individual type of fruit and physically separate each one (Figs. 8-5 and 8-6).

SOLUTIONS, SUSPENSIONS, AND EMULSIONS

Solutions, suspensions, and emulsions are all mixtures of two or more different substances. The distinction between solutions, suspensions, and emulsions is dependent on the size of the particles and the solubility of the components.

Solutions

Solutions (soh-LOO-shuns) are uniform mixtures of two or more mixable substances. A **solute** (SOL-yoot) is any substance that is dissolved into a solvent to form a solution. A **solvent** (SOL-vent) is any substance that dissolves the solute to form a solution. If a gas or a solid is dissolved in a liquid, the gas or solid is the solute and the liquid is the solvent. When one liquid is dissolved in another liquid, the minor component is usually the solute and the major component is the solvent.

Miscible (MIS-eh-bel) liquids are mutually soluble. Water and alcohol are examples of miscible (mixable) liquids. **Immiscible** liquids are not mutually soluble. Water and oil are examples of immiscible (nonmixable) liquids. You've probably heard the saying, "oil and water don't mix."

Solutions contain particles the size of a small molecule that are invisible to the naked eye. Solutions are usually transparent although they may be colored. Solutions do not separate on standing. Salt water is a solution of a solid dissolved in a liquid. Water is the solvent that dissolves the salt and holds it in solution. Air, salt water, and hydrogen peroxide are examples of solutions.

Suspensions

Suspensions are uniform mixtures of two or more substances. Suspensions differ from solutions due to the size of the particles. Suspensions contain larger particles than solutions. The particles in a suspension are large enough to be visible to the naked eye. Suspensions are not usually transparent and may be colored. Suspensions have a tendency to separate over time.

Oil and vinegar salad dressing is an example of a suspension with oil suspended in vinegar. Salad dressing will separate on standing and should be shaken well before use. Many of the lotions used by hairstylists are suspensions and should be shaken or mixed well before use. Salad dressing, paint, and aerosol hair spray are examples of suspensions.

Emulsions

Emulsions (ee-MUL-shuns) are suspensions (mixtures) of two immiscible liquids held together by an emulsifying agent. The term emulsify means "to form an emulsion," which is a suspension of one liquid dispersed in another. Although emulsions have a tendency to separate over time, a properly formulated emulsion, that is stored correctly, should be stable for at least three years. Without adequate dispersion, emulsions can become unstable and break (separate) into two insoluble layers.

Mayonnaise is 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 disperses them uniformly in the water. Without the egg yolk as an emulsifying agent, the oil and water would separate into two insoluble layers. Mayonnaise should not separate on standing. Many of the lotions and creams used by hairstylists are emulsions. Mayonnaise, cold cream, shampoos, and conditioners are examples of emulsions. Emulsions will be covered in more detail in Chapter 10, Shampoos, Conditioners, and Styling Aids.

Review Questions

1. Define the word chemical.
2. List the three states of matter.
3. What is the difference between an emulsion and a suspension?
4. How do compounds differ from elements? How do atoms differ from molecules?

Discussion Questions

1. Make a list of organic substances that are poisonous.
2. Make a list of inorganic substances that are healthy.
3. An increase in temperature causes ice to melt. What is heat? Why does adding heat make ice melt?