chapter 1

Classifying

The Composition of Matter

INTRODUCTION

The early stages of scientific research involve making observations and gathering information. However, merely collecting facts is not enough. The scientist needs to arrange and classify the facts and to find relationships among them.

The word *classification* comes from the word *class*—meaning a group of things that all have one important element in common. Scientists group related information into an array. Chemists, for example, cannot study every element, but can make generalizations by arranging all the elements into groups with related properties. Thus, if iodine is identified as belonging to the same group as chlorine and bromine, its properties can be predicted. Similarly, since there are several million kinds of plants and animals on earth, it is clearly impossible to study each one. However, by classifying an animal as a member of a particular group, or species, a biologist can predict its characteristics. Classification is thus very basic to scientific thought and expression.

Short Reading

Read the following passage and find out how matter may be classified.

The Nature of Matter

Everything around us consists of matter: this book, your body, the air you breathe, and the water you drink. Matter is anything that has weight or mass and takes up space.

All matter may be classified as either solid, liquid, or gas. Solids are firm and have a definite form. Rubber, wood, glass, iron, cotton, and sand are all classified as solids. A considerable force would be needed to change the shape or volume of an iron bar, for example, because the atoms or molecules of a solid are densely packed and have very little freedom of movement.

Solids may be further divided into two classes: crystalline and amorphous. Rocks, wood, paper, and cotton are crystalline solids. Crystalline solids are made up of atoms arranged in a definite pattern. When these solids are heated, the change to a liquid, known as melting, is sharp and clear. Amorphous substances include rubber, glass, and sulfur. In these substances, the pattern of the atoms is not orderly, and when heated, they gradually soften.

Liquids, on the other hand, are not rigid. If water, milk, or oil is poured on a table, it will flow all over the surface. The atoms or molecules of liquids attract each other and thereby enable liquids to flow. But these atoms are loosely structured and do not keep their shape. Therefore a liquid will take the shape of any container in which it is poured. However, liquids have a definite volume; a quart of milk cannot fit in a pint container.

Gases, such as air, oxygen, and carbon dioxide, have no fixed shape or volume of their own. They diffuse or spread out to fill any container. If water is put into a tire, it will run to the bottom; if air is put into a tire, it fills the whole space inside the tire. The atoms or molecules of gases are widely spaced and move very rapidly. They either compress or expand to adapt to any area.

Everything we know is made of matter in solid, liquid or gaseous form. Later in this chapter, we will discuss other ways matter may be classified.

USING ENGLISH TO CLASSIFY

A classification includes:

1. a general class,
2. a specific item or items, and
3. a basis for classification, which is frequently *not* stated because it is understood or explained elsewhere.

Consider this sample sentence:

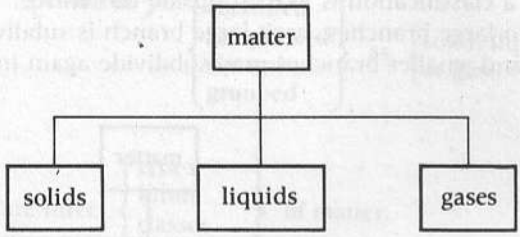
All matter may be classified as either solid, liquid, or gas.

The general class is *matter*. The specific items are *solid, liquid,* and *gas*. The basis for classification is the physical state of matter, which is not mentioned in the sentence.

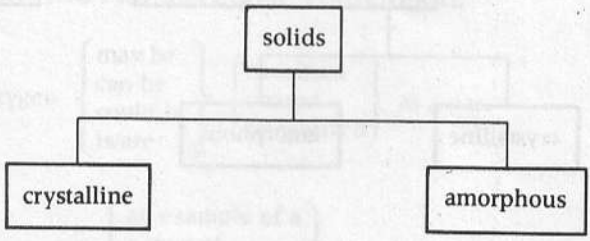
But there is more than one way matter may be classified. For example, it may be classified on the basis of its chemical composition as either living or nonliving. For this reason, classification sentences frequently contain modals of possibility, such as *can, could,* or *may*.

CLASSIFYING FROM GENERAL TO SPECIFIC

All matter may be classified as either solid, liquid, or gas.
(Note that all matter is included in these three subdivisions.

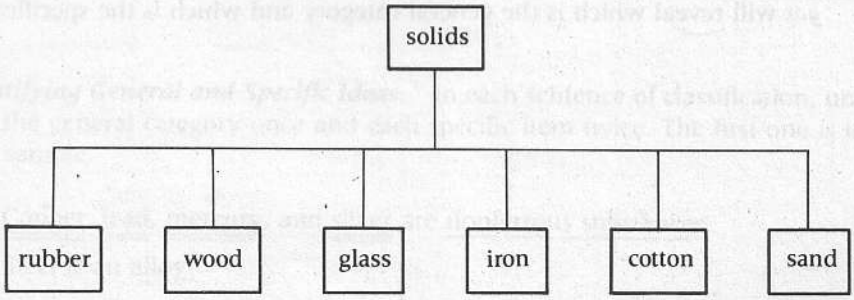


Solids may be further divided into two classes: crystalline and amorphous.

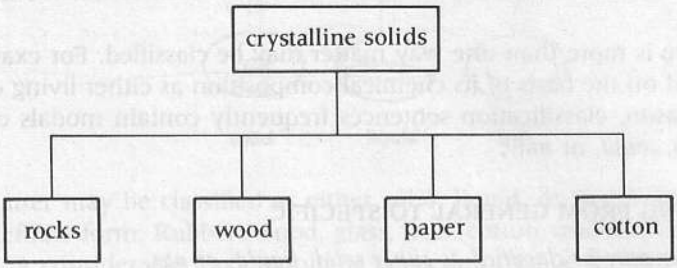


CLASSIFYING FROM SPECIFIC TO GENERAL

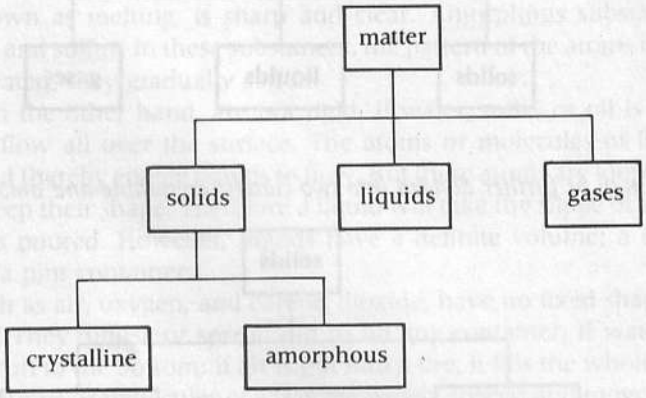
Rubber, wood, glass, iron, cotton, and sand are all classified as solids.
(When classifying from specific to general, the specific items do not necessarily cover all the subdivisions of the general category; that is, there are obviously other solids that are not included here.)



Rocks, wood, paper, and cotton are crystalline solids.



(Note that a classification is like an upside-down tree. The trunk of a tree is divided into large branches, each large branch is subdivided into smaller branches, and smaller branches may subdivide again into even smaller branches.)



NOTES

1. The passive form is used frequently in sentences of classification and in all scientific writing because the emphasis in science is usually on the action, not on the person performing the action.
2. The present simple tense is the most commonly used tense in scientific writing because it expresses universals. (For example, *Water freezes at 0° C.*)
3. In a sentence like, *Oxygen is a gas*, only the meanings of the words *oxygen* and *gas* will reveal which is the general category and which is the specific item.

Sentence Patterns

CLASSIFYING FROM GENERAL TO SPECIFIC

Matter { is/are / may be / can be / could be } { classified / grouped / divided / arranged / categorized } into { divisions. / groups. / types. / classes. / categories. / classifications. }

{ classified / categorized / classed / grouped } as { solid, liquid, / or gas. }

There are three { types / kinds / classes / categories } of matter.

CLASSIFYING FROM SPECIFIC TO GENERAL

Oxygen { may be / can be / could be / is/are } { classified / classed / categorized } as a gas.

Oxygen is { an example of a / a type of / a kind of / a form of / a } gas.

Note: These sentence patterns are only samples, not *a comprehensive list of all possible patterns.*

Identifying General and Specific Ideas. In each sentence of classification, underline the general category once and each specific item twice. The first one is done as a sample.

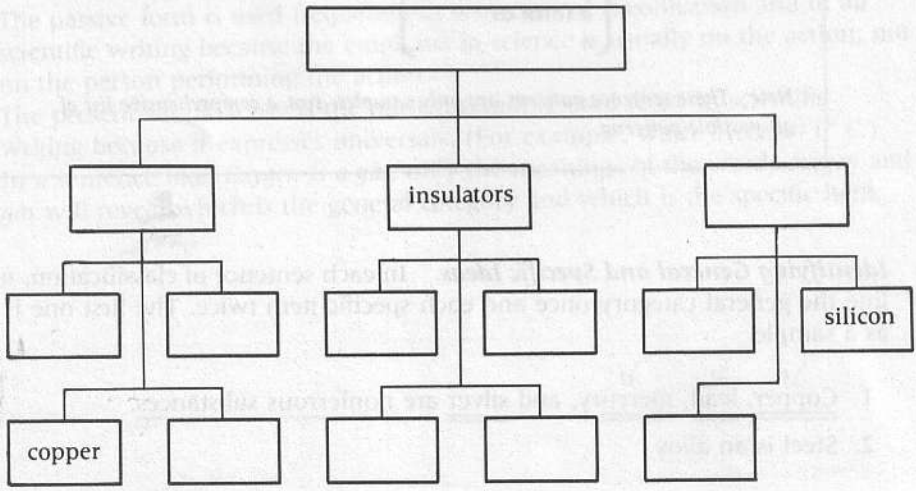
1. Copper, lead, mercury, and silver are nonferrous substances.
2. Steel is an alloy.

3. Five important classes of compounds are acids, bases, salts, metallic oxides, and nonmetallic oxides.
4. A deer is a mammal.
5. Carbon exists in three forms: graphite, diamond, and amorphous.
6. Rocks are grouped into three categories: igneous, metamorphic, and sedimentary.
7. Coffee, tea, and paint are colloids.
8. Coal, wood, and oil may be classified as fuels.
9. Salts are inorganic compounds.
10. The two kinds of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

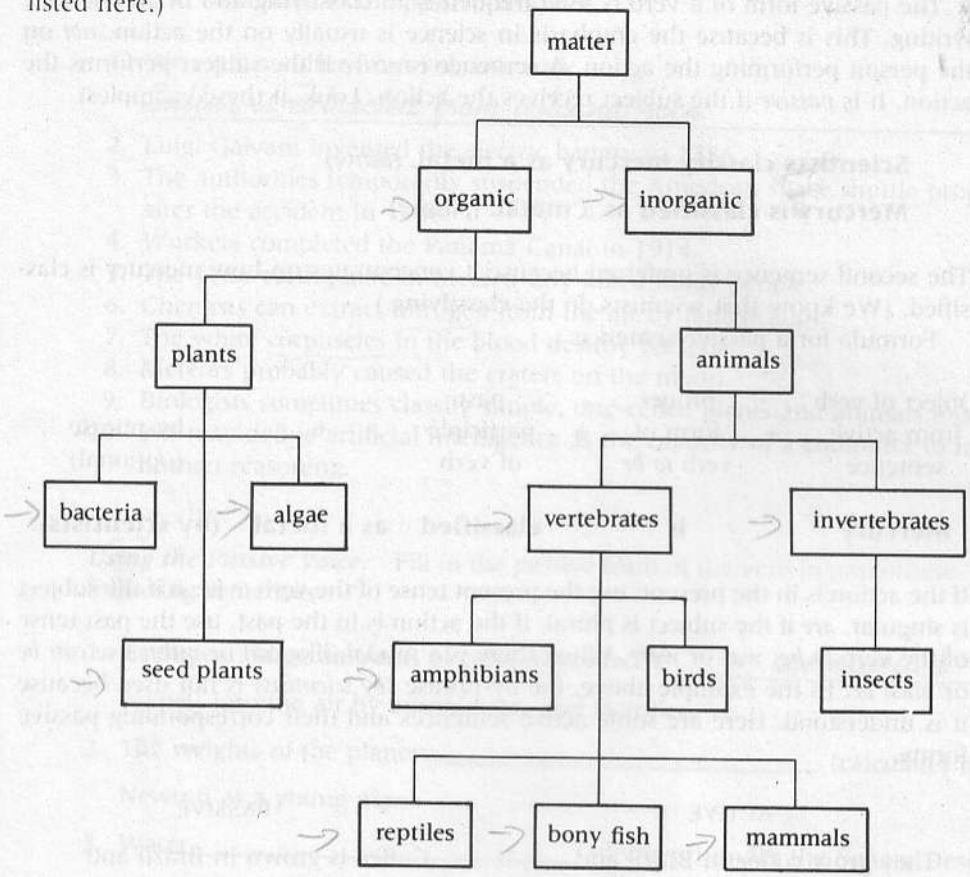
Transferring Information. Read the following paragraph and find another way that matter may be classified. Then use the information in the passage to complete the chart.

ELECTRICAL CONDUCTIVITY

Matter is frequently classified according to its electrical conductivity as a conductor, nonconductor, or semiconductor. Conductors have many electrons that are free to move and are useful in carrying, or conducting, electric current. All metals, particularly silver, copper, gold, and aluminum, are good conductors. Substances with few free electrons are called nonconductors, or insulators, because they do not carry electric charge and can be used to prevent electricity from flowing where it is not wanted. Air, wood, glass, and plastic are insulators. A few substances, like carbon, silicon, and germanium, do not fall into either of these categories. They are classed as semiconductors and are used in such electronic devices as transistor radios.



Completing Sentences. Complete the following sentences. Use the sentence patterns on p. 7 to help you. (Note that not all categories of plants and animals are listed here.)



1. There are two _____ *categories* _____ of animals: vertebrates and invertebrates.
2. Organic matter can be _____ into two _____ : plants and animals.
3. Algae are a _____ of plant.
4. Insects can be _____ as invertebrates.
5. Matter may be _____ into two _____ : organic and inorganic.
6. Reptiles and amphibians are _____ as vertebrates.
7. Bacteria can be _____ as plants.
8. Invertebrates are a _____ of animal.

The Passive Voice

The passive form of a verb is used frequently in classifying and in all scientific writing. This is because the emphasis in science is usually on the action, *not* on the person performing the action. A sentence is *active* if the subject performs the action. It is *passive* if the subject receives the action. Look at these examples:

Scientists classify mercury as a metal. *(active)*

Mercury is classified as a metal. *(passive)*

The second sentence is preferred because it concentrates on how mercury is classified. (We know that scientists do the classifying.)

Formula for a passive sentence:

Object of verb from active sentence	+	proper form of verb *to be*	+	past participle of verb	+	by-phrase (optional)
Mercury		**is**		**classified**	**as a metal**	**(by scientists).**

If the action is in the present, use the present tense of the verb *to be*: *is* if the subject is singular, *are* if the subject is plural. If the action is in the past, use the past tense of the verb *to be*: *was* or *were*. When there is a modal, like *can* or *must*, use *can be* or *must be*. In the example above, the by-phrase (*by scientists*) is not used because it is understood. Here are some active sentences and their corresponding passive forms.

ACTIVE	PASSIVE
They grow coffee in Brazil and Columbia.	Coffee is grown in Brazil and Columbia.
We use lasers in place of needles in compact disc recordings.	Lasers are used in place of needles in compact disc recordings.
They discovered diamonds in South Africa in the nineteenth century.	Diamonds were discovered in South Africa in the nineteenth century.
James Watson and Francis Crick formulated the theory of the double helix.	The theory of the double helix was formulated by James Watson and Francis Crick.
Penicillin can cure pneumonia.	Pneumonia can be cured by penicillin.

Changing Active Voice to Passive Voice. Change each of the following active sentences to the passive form. Be careful to choose the correct tense (present or

past) and the correct number (singular or plural) for the verb *to be*. Include a by-phrase when you think the original subject (that is, the subject of the active sentence) is important to the passive sentence.

1. We extract sulfur from volcanic rock.
   Sulfur is extracted from volcanic rock.
2. Luigi Galvani invented the electric battery in 1786.
3. The authorities temporarily suspended the American space shuttle program after the accident in 1986.
4. Workers completed the Panama Canal in 1914.
5. The 1986 earthquake in Mexico City killed many people.
6. Chemists can extract nitrogen from the air by liquefication.
7. The white corpuscles in the blood destroy bacteria.
8. Meteors probably caused the craters on the moon.
9. Biologists sometimes classify simple, one-celled plants and animals together.
10. We may define artificial intelligence as the capacity of a computer to imitate human reasoning.

Using the Passive Voice. Fill in the passive form of the verb in parentheses in the following sentences.

1. Each year, large amounts of carbon monoxide *are expelled* (expel) into the air by automobiles and factories.
2. The weights of the planets _____ (calculate) by Newton as a young man.
3. Water _____ (discover) under the Sahara Desert.
4. Coal _____ (produce) by plant matter of prehistoric times.
5. Soap _____ (manufacture) by boiling vegetable or animal fat with sodium or potassium hydroxide.
6. The hydrogen bomb _____ (call) a thermonuclear bomb because extremely high temperatures _____ (need) to start the fusion process.
7. Human speech _____ (control) by a part of the brain called the cerebrum.
8. The concept of relativity _____ (propose) by Albert Einstein in 1905.

READING SKILLS

Vocabulary Building

A good vocabulary will help you with every aspect of communication; it will improve your reading and listening comprehension and will enable you to speak and write better. A good vocabulary will help you succeed in any profession.

When you first study a language, you learn everyday words that are repeated so often that they soon become part of your permanent vocabulary. However, after you have acquired a basic vocabulary, there is always a decline in vocabulary growth rate. Reading and speaking the language will increase your fluency but will *not* automatically increase your vocabulary. This is because the words you are learning appear less frequently and are thus more difficult to remember. At this stage of language development, you must make a special effort to acquire new words.

All the words in the vocabulary sections in this book were selected from the readings and lectures because they appear frequently in scientific discourse. There are no rare or specialized words. The word parts are also those found frequently in scientific terminology. In addition, the vocabulary sections contain strategies for continuing to build your vocabulary, that is, for making vocabulary growth a lifetime habit.

Vocabulary in Context. Circle the letter of the answer that best matches the meaning of the italicized word as it is used in each of these sentences.

1. Atoms are *infinitesimal* in size.
   (a.) tiny b. huge
2. Chemists study the composition of natural *substances.*
   a. materials b. machines
3. The whale suddenly *emerged* from the water.
   a. arose b. disappeared
4. All matter is either liquid, solid, or gas, and solids may be *subdivided* into crystalline and amorphous.
   a. built up b. broken down
5. Plastic products are hard to dispose of because they are almost *indestructible.*
   a. unable to be destroyed b. unable to be constructed
6. At one time the atom was thought to be *indivisible.*
   a. unable to be divided b. unable to be seen
7. Einstein's ideas are too *abstract* for many people to understand.
   a. practical b. theoretical

8. The *reaction* of iron and oxygen produces rust.
   a. chemical activity b. separation
9. The airplane had to rely on radar in the *dense* fog.
   a. thick b. thin
10. The moon *revolves* around the earth.
    a. stretches b. circles
11. The mosquitoes showed their *attraction to* the light.
    a. dislike for b. liking for
12. Some scientists suspect that the planet Uranus once *collided* with another object in space.
    a. crashed b. orbited

Finding Main Ideas

Scientific writing consists mainly of concepts and material that supports those concepts. The concept is usually stated in a *topic sentence*, which acts as an umbrella to cover all the information in the paragraph. The rest of the paragraph contains supporting material—that is, information that explains, clarifies, or proves what is stated in the topic sentence.

The topic sentence is frequently but not always the first sentence of the paragraph. Sometimes it is the second sentence, appearing after an introduction or transition. At other times it is the last sentence, with other sentences leading up to it. Only rarely does it appear in the middle of the paragraph. All the sentences in the paragraph should relate to the topic sentence. (Occasionally a paragraph has no topic sentence because it contains support material for an earlier paragraph or acts as a transition between other paragraphs.)

In the following passage, put square brackets [] around the topic sentence of each paragraph.

Reading

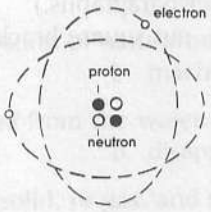
The Infinitesimal Atom

There are over four million substances known to man. [Yet it is one of the amazing facts of science that all these substances are made up of only about 100 different varieties of matter, which are called elements.] Oxygen, hydrogen, gold, aluminum, sulfur, carbon, and chlorine are all examples of elements that combine in different ways to make the more than four million substances. Elements are made of particles called molecules, too tiny to be seen even with a powerful microscope. Molecules are made of even smaller particles called atoms. All the world is made of atoms.

The concept of atoms first emerged in ancient Greece. In 400 B.C. the philosopher Democritus theorized that matter could be divided into smaller and smaller particles until a point was reached beyond which no further subdivision was possible. These indestructible particles were called *atomos*, a Greek word meaning indivisible. We know today that atoms are so small that it would take more than a million of them to equal the thickness of this sheet of paper. Democritus' theory, however, was not universally accepted in the ancient world, for many believed in Aristotle's theory that matter is composed of four elements: earth, fire, air, and water.

During the Middle Ages in Europe, the concept of atoms was considered too abstract and was accordingly rejected. Finally, in 1804 the Englishman John Dalton formulated an atomic theory based on his experimentation. He claimed that all matter is made of atoms; that all atoms of a single element have the same shape, size, weight, and behavior; and that atoms of each element are different from those of any other element. He said that atoms are not created or destroyed but rather form new combinations in chemical reactions.

Dalton thought that atoms were solid, but today atoms are believed to consist mainly of space, with a dense nucleus at the center. The size of the nucleus inside an atom is comparable to the size of an ant on a football field. Each nucleus contains protons, which have a positive electric charge, and neutrons, which have no charge. The nucleus is surrounded by electrons, which have a negative electric charge. The number of protons equals the number of electrons in each atom, and therefore the entire atom has no charge. In 1913, the Danish physicist Niels Bohr proposed a model of the atom in which the electrons revolved around the nucleus like the planets revolve around the sun. Today the movement of electrons is thought to be more like bees hovering around a hive. The force of attraction between the positive protons in the nucleus and the negative electrons whirling around keeps the electrons in their paths.



helium atom

What is it that makes iron hard, oxygen a gas, and mercury a liquid? The properties of an element are determined by the number of electrons in an atom, which is called the atomic number. All atoms of the same element are alike. If you've seen one atom of oxygen, you've seen them all. Hydrogen, the lightest element, has one electron and one proton. In fact, the hydrogen atom, the most common atom in the universe, is the basis on which our entire universe was formed. Oxygen has eight protons and eight electrons. Uranium, one of the heaviest elements, has 92 protons and 92 electrons.

All the world is made of atoms: Everything we see and know of is made of the billions and billions of these infinitesimal specks of matter. All life exists because atoms are continually moving, combining, separating, colliding, giving off energy, and absorbing energy.

Understanding the Reading. Each of the following statements is inconsistent with the information in the previous passage. Test your reading comprehension by finding and correcting each error.

1. Molecules are even smaller than atoms.
   Atoms are even smaller than molecules.
2. The concept of the atom did not exist before 1804.
3. In ancient Greece, everyone believed Aristotle's theory that matter is composed of four elements: earth, fire, air, and water.
4. During the Middle Ages, the atomic theory was widely accepted.
5. John Dalton theorized that atoms are composed of electrons, protons, and neutrons.
6. The size of a nucleus inside an atom is equal to the size of an ant.
7. Atoms are densely packed with protons, neutrons, and electrons.
8. Neutrons have a negative electric charge.
9. Each atom is neutral because the number of its protons equals the number of its neutrons.
10. Niels Bohr proposed a model of the atom with the electrons revolving around the planets.
11. Electrons are kept in their paths by the force of gravity.
12. The atomic number of an element is the total of the number of electrons and the number of protons.
13. All the atoms of a single element are different.
14. Atoms of hydrogen are identical to atoms of oxygen.
15. The oxygen atom is the most common atom in the universe.

LISTENING SKILLS

Vocabulary in Context. Circle the letter of the answer that best matches the meaning of the italicized word as it is used in each of these sentences.

1. Water *decomposes* into hydrogen and oxygen.
   (a.) separates b. evaporates
2. Diamonds are expensive partly because they are so *rare*.
   a. scarce b. abundant

3. The device was driven by *mechanical* energy.
   a. machine b. electrical
4. Although hydrogen and oxygen have some similarities, each has characteristics that are *distinct*.
   a. similar b. different
5. Sodium and chlorine are the *constituents* of salt.
   a. components b. characteristics
6. Oxygen is a very *active* element that combines readily with other elements.
   a. stable b. unstable
7. Some mushrooms are safe to eat, and others are *poisonous*.
   a. delicious b. deadly
8. It was important to keep the temperature *constant* throughout the experiment.
   a. unchanging b. changing
9. The outcome of an experiment is affected by *variables*.
   a. substances b. changing factors
10. Besides nitrogen and oxygen, there is a small *proportion* of other gases in the air.
    a. quality b. quantity
11. The noble gases are a group of gases with *homogeneous* properties.
    a. similar b. different
12. A mosquito is *categorized* as an insect.
    a. classified b. described
13. A flower can only *retain* its beauty for a short time.
    a. keep b. lose

Note-Taking

Many people like to take a camera when they make a trip partly because they know that they will remember the people and places they have recorded on film and forget much of the rest. The notes you take during a lecture are like the photographs you take on a trip. What you record, you will retain; most of the rest, you will forget. Without notes, in a short while you will undoubtedly forget most of the material presented in a lecture, even when the subject matter is interesting to you. Just as with pictures, your goal is to record as many important points as clearly and specifically as possible. Note-taking will *not* interfere with your listening. On the contrary, it will help you to focus on what is being said and avoid letting your mind wander. The succeeding chapters contain suggestions for good note-taking.

Take notes as you listen to the lecture "The Chemistry of Matter," and then use your notes to complete the next exercise.

Using Your Notes to Classify. Use the information from the lecture to classify each of these statements as describing an element (*E*), mixture (*M*), or compound (*C*).

M 1. Its constituents may be present in any proportion.

_____ 2. Its constituents cannot be separated by mechanical means.

_____ 3. Alcohol is an example of one.

_____ 4. It cannot be broken down into simpler substances by ordinary chemical means.

_____ 5. There is more than one type of atom within each molecule.

_____ 6. It retains the properties of its constituents.

_____ 7. Milk is an example of one.

_____ 8. Carbon is an example of one.

_____ 9. The law of definite composition applies.

_____ 10. There are only about 92 found in nature.

_____ 11. Its characteristics are different from those of its constituents.

_____ 12. They are frequently categorized as metals and nonmetals.

DISCUSSION POINTS

1. How might you classify the students in this class or school?
2. What are some ways you could classify foods? fabrics? cars? schools? films? cities? academic subjects? animals? jobs? the people of a town or country? music?
3. A nutritionist might be interested in classifying foods according to calories, sodium content, cholesterol content, sugar content, vitamin content, and the like. This information would be needed to prescribe a diet for a specific person. What types of classification might interest a biologist? a chemist? a meteorologist? a psychologist? a police detective? a football player?

WRITING SKILLS

Topic Sentences

In English, written material is organized into paragraphs. Each paragraph expresses a complete thought. This central thought or idea is summarized in the topic sentence, which should cover everything that is in the paragraph and *only* what is in the paragraph.