

What is Matter?

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CONCEPT

1

What is Matter?

Lesson Objectives

The student will:

- define matter and explain how it is composed of building blocks known as atoms.
- explain the differences between substances and mixtures.
- classify mixtures as homogeneous or heterogeneous.
- identify the chemical symbols of common elements.
- explain the difference between an element and a compound by their symbols or formulas.
- demonstrate the proper use of parentheses and subscripts in writing chemical formulas.
- determine the number of atoms and name of each element in a compound.

Vocabulary

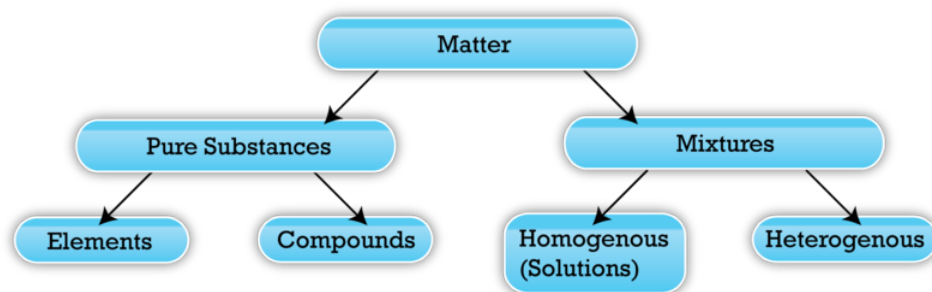
- atom
- compound
- element
- heterogeneous mixture
- homogeneous mixture
- law of constant composition
- matter
- molecule

Introduction

Matter is anything that has mass and volume. The entire universe is composed of matter, which is in turn composed of atoms. An **atom** is the basic building block of all matter. All matter in the universe, from a teaspoon of salt to the Pacific Ocean, has mass and occupies space. The salt and ocean, however, have very different properties and behaviors. Since everything in the universe is composed of matter, there are clearly many types of matter. In this lesson, you will learn about how scientists classify the different types of matter.

Categories of Matter

Matter can be classified into two broad categories: mixtures and pure substances, as illustrated below.



Mixtures are physical combinations of two or more substances. The term “physical combination” refers to mixing together different substances that do not chemically react with each other. The physical appearance of the substances may change, but the atoms in the substances do not.

In comparison, a pure substance is a form of matter that has a constant composition and constant properties throughout the sample. Elements and compounds are both example of pure substances.

Mixtures: Homogeneous and Heterogeneous

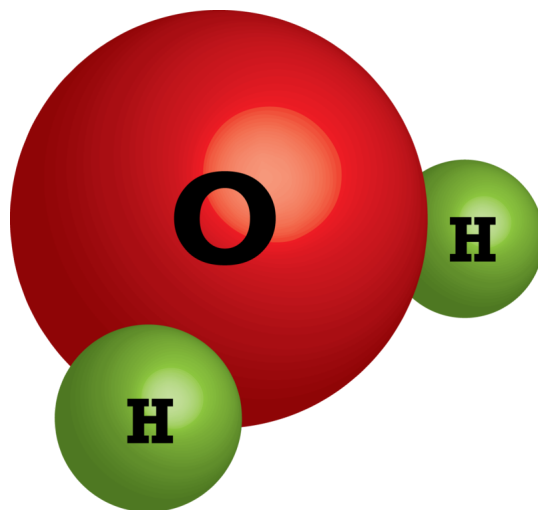
One example of a mixture is sand and gravel stirred together. In this case, you can see that there are two different substances present, each with the same properties that it had before it was mixed. When substances do not mix thoroughly and evenly (like sand and gravel), the mixture is said to be heterogeneous. A **heterogeneous mixture** consists of visibly different substances.

Another example of a mixture is salt dissolved in water. In this case, you cannot see the different substances, but you can test the solution to show that each substance (salt and water) has the same chemical properties it had before being mixed. When substances mix thoroughly and evenly (like salt in water), the mixture is said to be homogeneous. **Homogeneous mixtures** are often referred to as solutions. Solutions often may appear to be one pure substance, but some simple tests can show that the solutions are indeed mixtures.

Pure Substances: Elements and Compounds

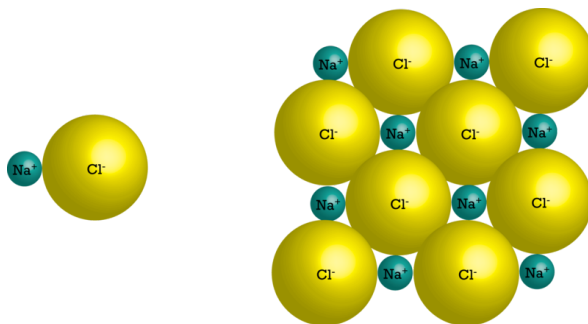
Elements are the simplest substances. An **element** is a substance that is made up of only one type of atom. It doesn't matter if the atoms are in groups, as in P_4 or S_8 , or isolated, as in Na. As long as there is only one kind of atom, the substance is an element. Elements cannot be chemically broken down into anything smaller and still retain the properties of the element. For example, an atom of iron can be smashed into electrons, protons, and neutrons, but those pieces would not have the properties of iron.

Atoms from two or more elements can chemically combine to form a new substance. **Compounds** are substances that are made up of more than one type of atom. In other words, compounds are chemical combinations of elements. These combinations form new substances with completely different properties than the atoms from which they were formed.



The image above is a model of water. Water is a compound consisting of one atom of oxygen and two atoms of hydrogen. Hydrogen is an explosive gas, and oxygen is a gaseous substance that supports combustion. Yet, when these two elements are chemically combined to form water, the product neither burns nor supports combustion. In fact, water is used to put out fires.

A **molecule** is the smallest particle of a compound. If you break up the molecule, you no longer have the properties of the compound. Molecules, like atoms, are too small to be seen. Even with the most powerful microscopes, we have only seen the very largest of molecules.



The illustration above shows a single unit of the compound called sodium chloride on the left. This single unit is made up of one sodium ion and one chloride ion. Sodium is a very reactive metal that explodes in water and burns in air, while chlorine is a very deadly, poisonous gas. When these two are combined, we get table salt (sodium chloride). When sodium chloride is in solid form, many units join together, as illustrated above on the right.

Elements: Names and Symbols

Everything, from ants to galaxies, is composed of atoms. So far, scientists have discovered or created 118 different types of atoms. Scientists have given a name to each different type of element and organized them into a chart called the periodic table. As you can see in the table below, each square contains one of the elements.

1										18							
1A										8A							
1 H 1.01	2 He 4.00											13 Al 27.0	14 Si 28.1	15 P 30.1	16 S 32.1	17 Cl 35.5	18 Ar 39.9
3 Li 6.94	4 Be 9.01											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3	3 B 10.8	4 C 12.0	5 N 14.0	6 O 16.0	7 F 19.0	8 Ne 20.2	9 Na 23.0	10 Mg 24.3	11 Al 27.0	12 Si 28.1	13 P 30.1	14 S 32.1	15 Cl 35.5	16 Ar 39.9		
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.6	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc [98]	44 Ru 101	45 Rh 103	46 Pd 106	47 Ag 108	48 Cd 112	49 In 115	50 Sn 119	51 Sb 122	52 Te 128	53 I 127	54 Xe 133
55 Cs 133	56 Ba 137	57 La 139	72 Hf 178	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 Tl 204	82 Pb 207	83 Bi 209	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra 226	89 Ac 227	104 Rf [261]	105 Db [262]													
58 Ce 140	59 Pr 141	60 Nd 144	61 Pm [145]	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175				
90 Th 232	91 Pa 231	92 U 238	93 Np 237	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [260]				

Each element not only has its own name, it also has its own symbol. Scientists use abbreviations called chemical symbols to represent the elements. Many of these symbols are the first one or two letters of the modern name of the element. The first letter of a chemical symbol must always be a capital letter, and the second letter, when there is a second letter, must always be a lowercase letter. **Table 1.1** shows some examples of elements and their symbols.

TABLE 1.1: Examples of Elements

Element	Symbol
Hydrogen	H
Oxygen	O
Carbon	C
Calcium	Ca
Aluminum	Al

As seen in **Table 1.2**, the symbols for some of the elements consist of the first letter of the name and another letter (not the second letter) that comes later in the name.

TABLE 1.2: More Examples of Elements

Element	Symbol
Zinc	Zn
Magnesium	Mg
Chlorine	Cl
Arsenic	As
Zirconium	Zr

For other elements, the symbols were already used for other elements. When trying to decide on a symbol for silver, for example, the symbol S was already used for sulfur, and the symbol Si was already used for silicon. Since silver has been known to man for over a thousand years, it had a Latin name from ancient times. The old Latin name for silver was *argentum*, so it was decided that the symbol for silver would be Ag. There are a number of symbols chosen in this same manner, as seen in **Table 1.3**.

TABLE 1.3: Examples of Elements Whose Symbol Comes from Latin

Element	Ancient Name	Symbol
Silver	<i>Argentum</i>	Ag
Potassium	<i>Kalium</i>	K
Sodium	<i>Natrium</i>	Na
Gold	<i>Aurum</i>	Au
Lead	<i>Plumbum</i>	Pb
Copper	<i>Cuprum</i>	Cu
Iron	<i>Ferrum</i>	Fe

Compounds: Chemical Formulas

The chemical symbols are not only used to represent the elements, they are also used to write chemical formulas for the millions of different compounds. For a given chemical compound, the **law of constant composition** states that the ratio by mass of the elements in the compound is always the same, regardless of the source of the compound. The law of constant composition can be used to distinguish between compounds and mixtures. Compounds have a constant composition, and mixtures do not. Pure water is always 88.8% oxygen and 11.2% hydrogen by weight, regardless of the source of the water. Brass is an example of a mixture. Brass consists of two elements, copper and zinc, but it can contain as little as 10% or as much as 45% zinc.

The formula for a compound uses the symbols to indicate the type of atoms involved and uses subscripts to indicate the number of each atom in the formula. For example, aluminum combines with oxygen to form the compound aluminum oxide. Forming aluminum oxide requires two atoms of aluminum and three atoms of oxygen. Therefore, we write the formula for aluminum oxide as Al_2O_3 . The symbol Al tells us that the compound contains aluminum, and the subscript 2 tells us that there are two atoms of aluminum in each molecule. The O tells us that the compound contains oxygen, and the subscript 3 tells us that there are three atoms of oxygen in each molecule. It was decided by chemists that when the subscript for an element is 1, no subscript needs to be used. Thus the chemical formula MgCl_2 tells us that one molecule of this substance contains one atom of magnesium and two atoms of chlorine. The formula for sodium chloride is NaCl , which indicates that the compound contains one atom each of sodium and chlorine. The formula for sodium carbonate, Na_2CO_3 , indicates that there are two atoms of sodium, one atom of carbon, and three atoms of oxygen. In formulas that contain parentheses, the subscript outside of the parentheses applies to everything inside. For example, the subscript 2 in $\text{Ca}(\text{OH})_2$, the subscript 2 applies to the (OH). Therefore, this molecule of calcium hydroxide contains one atom of calcium, two atoms of oxygen, and two atoms of hydrogen.

Lesson Summary

- All matter has mass and occupies space.
- Matter can be classified into two broad categories: pure substances and mixtures.
- A pure substance is a form of matter that has constant composition and constant properties throughout the sample.
- Mixtures are physical combinations of two or more substances.
- Elements and compounds are both example of pure substances.
- Compounds are substances that are made up of more than one type of atom.

- Elements are the simplest substances made up of only one type of atom.
- The elements are organized into a chart called the periodic table.
- Scientists use abbreviations called chemical symbols to represent the elements.
- The first letter of a chemical symbol is capitalized, and the second letter is not.

Further Reading / Supplemental Links

You may listen to Tom Lehrer's humorous song "The Elements" with animation at this website.

- <http://www.privatehand.com/flash/elements.html>

This website provides a review about matter and the categories of matter.

- <http://www.thetech.org/exhibits/online/topics/50a.html>

Review Questions

1. Pure substances contain only one type of
 - a. atoms only.
 - b. molecules only.
 - c. atoms or molecules.
 - d. mixture.
2. What type of mixture produces the same properties for every sample of the mixture?
 - a. heterogeneous
 - b. homogeneous
 - c. mechanical
 - d. environmental
3. Which of the following is a heterogeneous mixture?
 - a. pure gold
 - b. distilled water
 - c. helium
 - d. milk
4. Which of the following is *not* a heterogeneous mixture?
 - a. concrete
 - b. pizza
 - c. sugar water
 - d. soup
5. If you can easily see the different parts that make up a mixture, you know that it is a _____ mixture.
 - a. homogeneous
 - b. heterogeneous
 - c. biodegradable
 - d. plasma
6. What do we call a material that is composed of two or more pure substances?
 - a. a compound

- b. an element
 - c. a mixture
 - d. a heterogeneous mixture
7. Identify the following mixtures as homogeneous or heterogeneous.
- a. brass
 - b. sugar dissolved in water
 - c. vegetable soup
8. Identify which of the following pure substances are elements and which are compounds.
- a. table salt
 - b. oxygen
 - c. water
9. A pure substance composed of two or more elements chemically combined is a
- a. homogeneous mixture.
 - b. compound.
 - c. element.
 - d. heterogeneous mixture.
10. The smallest piece of a compound that still has all the properties of the compound is a(n)
- a. atom.
 - b. formula.
 - c. mixture.
 - d. molecule.
11. Identify the elements involved in the compound H_2SO_4 .
12. How many phosphorus atoms are present in one molecule of H_3PO_4 ?