Unit 4: Structure of Matter

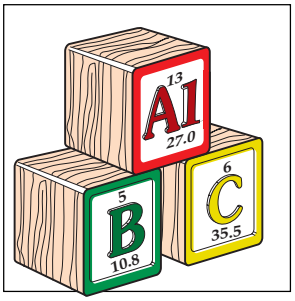
This unit explains the differences among elements, compounds, and mixtures. Students will learn the properties of these substances.

Student Goals

- Define the terms elements, compounds, and mixtures.
- Demonstrate, through laboratory activities, the differences between compounds and mixtures.
- Recognize common elements by their symbols.

Unit Focus

- Know the difference between an element, a molecule, and a compound. (SC.A.2.4.2)



Vocabulary

Use the vocabulary words and definitions below as a reference for this unit.

atom ..... the smallest unit of an element that is still that element; the basic building block of matter

atomic number ..... a number used to identify an element and represent its placement in the periodic table; identifies the number of protons in the nucleus of an atom

chemical change ..... change in which a new substance is produced

chemical properties ..... the qualities of matter that indicate whether it can change from one substance to another

combustion ..... the process of burning a substance

compound ..... a substance formed when two or more elements combine chemically

density ..... the mass per certain volume of a material

element ..... a substance that cannot be broken down into a simpler form by ordinary chemical means

formula ..... the way a chemist tells how two or more elements are combined to make a compound
Example: H_2O is the formula for water

gas ..... the form of matter that has no definite shape or volume

hydrogen (H) ..... the lightest and most abundant of all elements; occurs as a gas when not in other substances

liquid ..... the form of matter that has a definite volume but does not have a definite shape

mass ..... the amount of matter in a substance

matter ..... anything that has both mass and volume

mixtures ..... two or more substances put together; no chemical reaction takes place and they are easily separated

oxygen (O) ..... an element found as a gas when not in other substances; it has an atomic number of eight and is involved in burning and rusting

periodic table ..... a table showing the arrangement of the chemical elements according to their atomic numbers and chemical properties

physical change ..... any change in the form or phase of matter; no new substances are formed

physical properties ..... the qualities of matter that can be observed without changing the matter (color, shape, size, density)

solid ..... the form of matter that has a definite shape and volume

substance ..... any material or matter

symbols ..... the letters used by scientists to represent the names of the elements

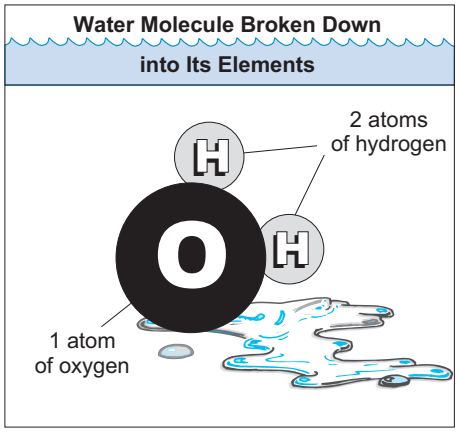
volume ..... the amount of space that matter takes up

Introduction

You may have wondered how two substances with **oxygen** in them (like water and sugar) could be so different. In this unit, we will discuss what properties these **substances** have that make them unique.

Elements

By now we know that **matter** has **mass**, **volume**, and **density**. We also know that *matter* can be a **solid**, **liquid**, or a **gas**. We have also learned some of the **physical** and **chemical properties** of matter. We know that any change in the form or phase of matter is only a **physical change**. We experimented to show that **chemical changes** produce new *substances*.

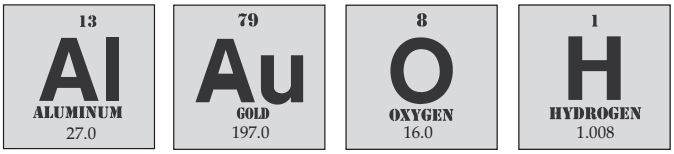


However, what makes up matter? Think about water. Water can be broken down into **hydrogen** and *oxygen*, but the substances of *hydrogen* and oxygen cannot be broken down by chemical means. These substances are called **elements**. *Elements* cannot be broken down by chemical action. All substances are made of elements.

If you look at all the buildings around you, you see that they are different shapes and sizes. But there are also similarities between the buildings. Think of a pyramid and a castle. Both are made of stone blocks, but their blocks have been arranged in very different ways. By doing this, the builders made the structure they wanted.

You can think of elements as building blocks. On Earth, we have discovered about 118 elements. The number of naturally occurring elements totals 92. Some of the elements are human-made and can only be found in very special labs. After these elements are made, they disappear in less than a blink of the eye. These are all the elements that we know exist. Everything is made from these elements.

Some substances are made of only a single element. Aluminum (Al), gold (Au), oxygen (O), and hydrogen (H) are examples of substances with a single element.



examples of substances with a single element

Most elements are *solid* under normal conditions. Few are *liquid*. The mercury (Hg) used in some thermometers is normally liquid.

Many other elements are *gases* under normal conditions. Oxygen (O) and hydrogen (H) are just two of the elements that are gases at room temperature.

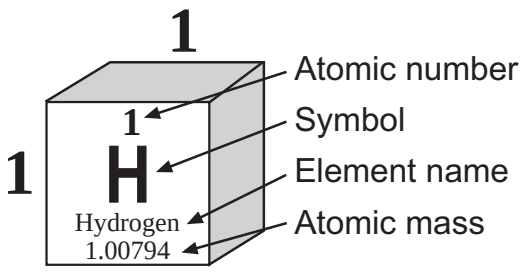
Scientists have a special way of writing the names of elements. They use letters instead of writing the whole word. The letters are called **symbols**. Here are some of the common ones.

Elements	Symbols
Copper	Cu
Aluminum	Al
Iron	Fe
Mercury	Hg
Oxygen	O
Hydrogen	H
Silver	Ag
Gold	Au
Carbon	C

Each of the elements has its own *symbol*. Each element has at least one property that makes it different from another element.

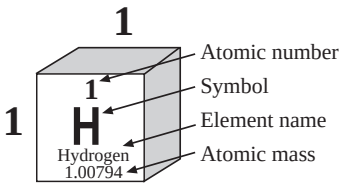
Atomic Number

Scientists decided to make a chart or table based on the **atomic number** of each element. The elements are arranged based on the properties of their **atoms**. An atom is the smallest unit of an element. The chart is called the **periodic table**. The *atomic number* is a number used to identify an element and represent its placement in the *periodic table*. The atomic number identifies the element. Since hydrogen has an atomic number of one (1), it became the first element on the table.



See the periodic table on the following pages. Notice the atomic numbers above each element.

The Periodic



	2		3	4	5	6	7	8	9
2	3 Li Lithium 6.941	4 Be Beryllium 9.01218							
3	11 Na Sodium 22.98977	12 Mg Magnesium 24.305							
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.9380	26 Fe Iron 55.847	27 Co Cobalt 58.9332
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.94	43 Tc Technetium 97.9072*	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055
6	55 Cs Cesium 132.9054	56 Ba Barium 137.33	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22
7	87 Fr Francium 223.0197*	88 Ra Radium 226.0254	103 Lr Lawrencium 260.1054*	104 Rf Rutherfordium 261*	105 Ha Hahnium 262*	106 Sg Seaborgium 263*	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)

Metallic Properties ↓

Transition Elements

Metallic Properties →

Rare Earth Elements

Lanthanoid Series	57 La Lanthanum 138.9055	58 Ce Cerium 140.12	59 Pr Praseodymium	60 Nd Neodymium 144.24	61 Pm Promethium 144.9128*	62 Sm Samarium 150.36
Actinoid Series	89 Ac Actinium 227.0278*	90 Th Thorium 232.0381	91 Pa Protactinium 231.0359*	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642*

** Mass of isotope with longest half-life, that is, the most stable isotope of the element*

Table

Noble Gases

10	11	12	13	14	15	16	17	18
			5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998403	2 He Helium 4.002602
			13 Al Aluminum 26.98154	14 Si Silicon 28.0855	15 P Phosphorus 30.97376	16 S Sulfur 32.06	17 Cl Chlorine 35.453	10 Ne Neon 20.179
28 Ni Nickel 58.69	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.59	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.710	51 Sb Antimony 121.75	52 Te Tellurium 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29
89 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium 208.9824*	85 At Astatine 209.98712*	86 Rn Radon 222.017*
110§ Uun Ununilium 269*	111§ Uuu Unununium 272*	112§ Uub Ununbium 277*	113§	114§	115§	116§	117§	118§

Nonmetallic Properties

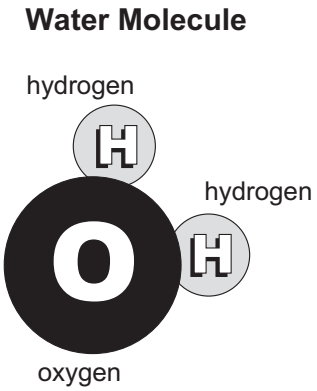
Metallic Properties

63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.9254	66 Dy Dysprosium 162.50	67 Ho Holmium 164.9304	68 Er Erbium 167.26	69 Tm Thulium 168.9342	70 Yb Ytterbium 173.04
95 Am Americium 243.0614*	96 Cm Curium 247.0703*	97 Bk Berkelium 247.0703*	98 Cf Californium 251.0796*	99 Es Einsteinium 252.0828*	100 Fm Fermium 257.0951*	101 Md Mendelevium 258.986*	102 No Nobelium 259.1009*

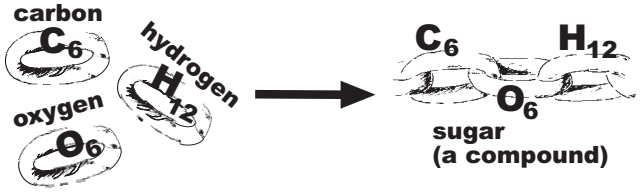
§ *Synthesized elements that are highly unstable. Research on these is continuing and may change what we know about them.*

Compounds

Many substances are made from more than one element. Elements can unite with each other. These united elements form new substances that are very difficult to separate. The new substances are called **compounds**. A *compound* has *chemical* and *physical properties* that are uniquely its own. It may look totally different from the elements that formed it. As you have seen, the atoms of two elements, hydrogen (H) and oxygen (O), combine to form water.



Sugar is a compound formed by atoms of carbon (C), hydrogen (H), and oxygen (O). Sugar and water do not look like the elements that formed them.



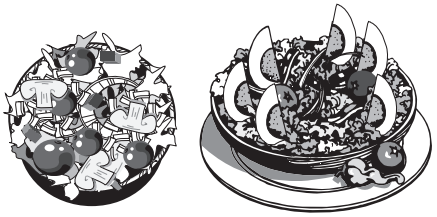
When compounds are formed, the elements always combine in the same proportions. A **formula** tells how elements combine to form compounds. The *formula* for water is H_2O. Compounds always have formulas.

Mixtures

When two elements or compounds are combined, no new substances are produced. No *chemical change* takes place. These substances are called **mixtures**. *Mixtures* can be separated. Each substance in the mixture keeps its own properties. If you mix iron filings with sand, you could separate them because there has been no chemical reaction. There is no new compound; there is only iron and sand.

If we took hydrogen and **combusted** it, or burned it, with oxygen, water would be formed. Water does not have the same properties as hydrogen and oxygen because it is a different compound. Water is always made from two hydrogen atoms and one oxygen atom. Water cannot be made any other way because it is not a mixture.

On the other hand, a mixture can be made in many different ways. Air is a mixture. The elements in the air are not always the same. Tossed salad is a mixture too; salads do not always have the same ingredients. Mixtures do not have formulas. They are not formed by chemical changes.



A tossed salad is a mixture; salads do not always have the same ingredients.

Summary

Now we know that elements are the simplest forms of substances. Gold (Au) is an element. Compounds are formed when a chemical change takes place between two or more elements. Mixtures are formed when two or more substances are put together. No chemical change takes place. The parts of a mixture can easily be separated.

Practice

Use the list below to write the correct term for each definition on the line provided.

atom	**element**	**mixtures**
atomic number	**formula**	**oxygen (O)**
compound	**hydrogen (H)**	**symbols**

_____ 1. a substance that cannot be broken down into a simpler form by ordinary chemical means

_____ 2. two or more substances put together

_____ 3. the letters used by scientists to represent the names of the elements

_____ 4. a substance formed when two or more elements combine chemically

_____ 5. the way a chemist tells how two or more elements are combined to make a compound

_____ 6. an element found as a gas when not in other substances and involved in burning and rusting

_____ 7. the lightest and most abundant of all elements

_____ 8. a number used to identify an element and represent its placement in the periodic table

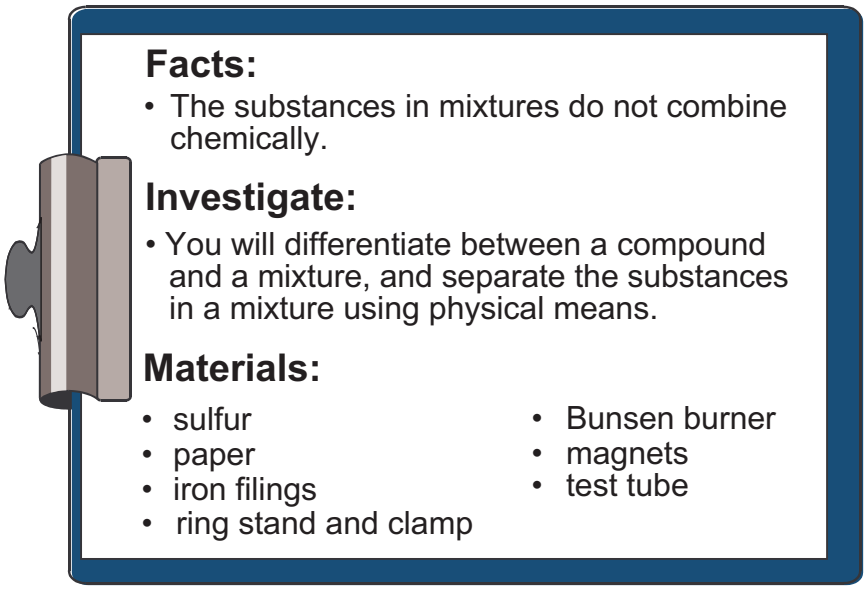
_____ 9. the smallest unit of an element that is still that element

Practice

Use the **periodic table** *on pages 78-79 to identify each of the symbols below. Write the name of the* **element** *and its* **atomic number** *on the line provided.*

1. C _____
2. Au _____
3. Ag _____
4. Hg _____
5. Cu _____
6. Fe _____
7. H _____
8. O _____
9. Al _____

Lab Activity—Part 1: Compounds and Mixtures



Part 1

1. Pour some sulfur onto a sheet of paper.
2. Add some iron filings. Mix the sulfur and the iron filings together.

   a. Did a chemical change take place? _____

   b. Are any new substances formed? _____

   c. Did the iron and the sulfur keep their own properties? _____
3. Move a magnet near the sulfur and the iron filings.

   a. Can you separate the iron from the sulfur? _____

   b. Did the iron and the sulfur form a mixture or a compound?

   _____

Lab Activity—Part 2: Compounds and Mixtures

1. Mix the iron filings and the sulfur on a sheet of paper.
2. Pour the mixture into a test tube.
3. Place the tube in clamp on a ring stand.
4. Heat the tube until it begins to glow.
5. Let the test tube cool.
6. Remove the substance from the test tube.
    a. Can you see the iron? _____
    b. Can you see the sulfur? _____
    c. Could you separate the iron from the sulfur using a magnet?

        _____
    d. Did you make a new substance? _____
    e. Is this new substance a mixture or a compound? _____

        Note: This new substance is called iron sulfide.
    f. What are the two elements that formed the substance?

        _____

Practice

Use the list below to complete the following statements. **One or more terms will be used more than once.**

118	**copper**	**hydrogen**	**mercury**
aluminum	**element**	**laboratories**	**oxygen**
carbon	**elements**	**liquid**	**silver**
chemical	**gold**		

1. An _____ is a substance that cannot be broken down into a simpler form and from which other substances may be made.

2. There are about _____ different kinds of elements.

3. All substances are made from _____ .

4. _____ is an example of a solid element.

5. Mercury is an element that is normally in a _____ form or state.

6. _____ changes produce new substances.

7. Some elements are only found in _____ .

8. **Au** is the symbol for _____ .

9. **Cu** is the symbol for _____ .

10. **C** is the symbol for _____ .

11. **Al** is the symbol for _____ .

12. **Ag** is the symbol for _____ .

13. **O** is the symbol for _____ .

14. **H** is the symbol for _____ .

15. **Hg** is the symbol for _____ .

Classify each of the following as an **element** *or a* **compound**.

16. carbon monoxide, CO _____

17. cobalt, Co _____

18. table sugar, $C_{12}H_{22}O_{11}$ _____

19. gold, Au _____

Practice

Write **True** *if the statement is correct. Write* **False** *if the statement is* not *correct.*

_____ 1. Two or more elements combine chemically to form a substance.

_____ 2. Sugar is a mixture, not an element.

_____ 3. Compounds are very easy to separate.

_____ 4. Hydrogen and oxygen combine to form water.

_____ 5. Compounds have the same properties as the elements from which they are formed.

_____ 6. A compound is formed when two or more substances are put together and no chemical change takes place.

_____ 7. All mixtures have formulas.

_____ 8. Mixtures can easily be separated.

_____ 9. Oxygen is a compound.

_____ 10. Air is a mixture.